NATURAL GAS MIDSTREAM OPERATIONS

Scott Neil, PE
AGENDA Outline

- The Midstream Business
- Gas Purchase/Process Contracts
- Gathering and Processing ("G&P") Overview
- Gathering Operations and Equipment
- Processing Operations and Equipment
- Emissions
The Midstream Business

- Overview
  - Hydrocarbon value chain
  - Processes
  - Geography

- Business
  - Value to Customer
  - “Must run”
Midstream Natural Gas Industry
Natural Gas Midstream Activities

E & P

NGLS

Fractionation

Transportation

Storage

Marketing

Chemicals, Fuels & Blend Stocks

Gathering

Processing

Provide SERVICES

Residue Gas

Transportation

Storage

Marketing

Utilities, Industrial & Residential
U.S. Gas Processing Basins & Plants

Figure 1. Natural Gas Processing Plants and Production Basins, 2009

Source: U.S. Energy Information Administration, GasTran Natural Gas Transportation Information System.

1 References to operating capacity and number of natural gas processing plants prior to 2009 were estimates compiled by various sources and published by EIA in 2006. For more information, see http://www.eia.gov/pub/oil_gas/natural_gas/feature_articles/2006/ngprocess/ngprocess.pdf
Valued Customer Service

- **Upstream Customers – E&P**
  - Good contract terms – highest possible net backs
  - Timely well connects
  - Reliable operations – high run time efficiency
  - High MMBTU efficiencies
  - Competitive extraction efficiencies
  - Steady operating pressures
  - Desire lower operating pressures
- **Downstream Customers - Markets**
  - Competitive pricing
  - Reliable source of supply
  - Aggregated volumes
  - Spec products
“Must Run” Industry

Processing is required for approximately 75-80% of all wellhead production to meet the downstream pipeline quality specifications

Wellhead
- Methane: 75%
- Ethane: 7%
- Propane: 6%
- Heavier NGLS: 6%
- Carbon Dioxide & Nitrogen: 4%
- Hydrogen Sulfide: 2%

Pipeline Quality
- Methane: 93%
- Ethane: 1%
- Propane: 3%
- Heavier NGLS: 3%
- Carbon Dioxide & Nitrogen: 2%
- Hydrogen Sulfide: 1%
NGL Products

• Raw Mix / Y Grade - Blend of all components
  
  • Ethane (40%)
    ✦ Ethylene - Polyethylene - Flex Plastic
  
  • Propane (28%)
    ✦ Propylene, Polypropylene - Hard Plastic
    ✦ Home Heating, Automotive, Agriculture
  
  • Iso Butane (7%)
    ✦ Refining Component - Octane for Gasoline
  
  • Normal Butane(10%)
    ✦ Chemical Cracking - Propylene, Butylene, Benzene, Toluene
    ✦ Refining Blendstock in Winter - Provides Gasoline Vapor Pressure
  
  • Natural Gasoline (15%)
    ✦ Chemical Cracking, Gasoline Blending, Heavy Crude Blending
Gas Purchase/Process Contracts
Key Points of a Gas Contract

All Contracts try to share risks and rewards

• Risks involved
  • Initial Volume – contract made without production test
  • Total Volume – production declines, future production is a forecast
  • Commodity Prices – now and in future – up, down, never constant
  • Commodity Prices - affecting processing mode
  • Capital to construct new connect
  • Capital recovery for existing infrastructure
  • Operating expenses – Plant and System, always increasing

• Question for Negotiation
  • Who stands the various risks?
  • What is the reward for the risks assumed?
Types of Contracts

**Keep Whole Contract**
Producer is paid the residue price for the gross heating value of the wellhead volume of gas. Processor retains all recovered Residue and NGL but stands all losses/fuel. Assumes NGL is always worth more as a liquid than heating value.

**NGL Contract**
Producer receives the value of the Net Residue (after all fuel and losses) plus a portion of the recovered NGL. Processor retains a share of the recovered NGL but stands no fuel. Processor will always recover the maximum NGL as it is the only commodity they receive payment.

**Percent of Proceeds Contract**
Producer and Processor each get a fixed percentage of Net Residue and NGL sales after all fuel and usage. Percentage is typically the same for residue and NGL, ie 85/85 contract, is 85% of sales to Producer, 15% to Processor. This contract puts both parties at the same processing mode to maximize income.

**Fixed Fee Contract**
Processor get a fixed fee for service. Producer gets all sales value and stands all fuel and use.
Types of Contracts – variations

Gathering Fee plus POP
Processor gets a fee to gather the gas and a small POP percentage. $0.25/mcf with a 90/90 POP (10% of net sales).

POP with a fixed meter fee
Processor gets a meter fee and a smaller POP percentage. $2000/month with a 90/90 POP (10% of net sales).

POP with a volume scale
Processor gets POP percentage that changes with volume.
Volume over 1000 mcfd 90/90 POP
500-1000 mcfd 85/85 POP
100-500 mcfd 80/80 POP
Less than 100 mcfd 60/60 POP

Pressure Based POP
HP Delivery 90/90 POP
LP Delivery 80/80 POP or 90/90 with $0.20/mcf Comp fee
Modes of Processing

Contract Specs
Residue Gas – 950-1100 btu/cf, less than 2% CO2, N2
NGL – less than 0.5% C1 in NGL, no CO2, Water, N2, H2S

DeMethanizing mode
Maximum NGL recovery, typically
Residue gas  964 btu/cft
Ethane  90-95%
Propane  99%
Butane +  100%.

DeEthanizing mode
Minimum ethane recovery to upper end of Residue spec, typically
Residue gas  1086 btu/cft
Ethane  40-50%
Propane  90-95%
Butane +  100%.
# CONTRACT EXAMPLE

## Gas Analysis

<table>
<thead>
<tr>
<th>Component</th>
<th>Mole %</th>
<th>GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td>4.190%</td>
<td></td>
</tr>
<tr>
<td>N2</td>
<td>0.820%</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>72.480%</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>11.040%</td>
<td>2.943</td>
</tr>
<tr>
<td>C3</td>
<td>6.640%</td>
<td>1.820</td>
</tr>
<tr>
<td>IC4</td>
<td>0.740%</td>
<td>0.241</td>
</tr>
<tr>
<td>NC4</td>
<td>1.970%</td>
<td>0.618</td>
</tr>
<tr>
<td>IC5</td>
<td>0.480%</td>
<td>0.175</td>
</tr>
<tr>
<td>NC5</td>
<td>0.540%</td>
<td>0.195</td>
</tr>
<tr>
<td>C6</td>
<td>1.100%</td>
<td>0.450</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.00%</td>
<td>6.440</td>
</tr>
</tbody>
</table>

Inlet Gas BTU  1,276  BTU/CF

## Prices

<table>
<thead>
<tr>
<th>Component</th>
<th>Price</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>$1.63</td>
<td>$13.42</td>
</tr>
<tr>
<td>Ethane</td>
<td>$0.210</td>
<td>$0.525</td>
</tr>
<tr>
<td>Propane</td>
<td>$0.493</td>
<td>$0.986</td>
</tr>
<tr>
<td>1 Butane</td>
<td>$0.582</td>
<td>$1.164</td>
</tr>
<tr>
<td>N Butane</td>
<td>$0.519</td>
<td>$1.038</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>$0.663</td>
<td>$1.326</td>
</tr>
<tr>
<td>T&amp;F</td>
<td>$0.050</td>
<td>$/gal</td>
</tr>
</tbody>
</table>

## Fuel

Field Fuel - compression  6.0% Of wellhead volume
Plant Fuel - processing, compression, etal 2.5% Of Plant Residue volume
# CONTRACT RESULTS

## Ethane Recovery $/mcf

<table>
<thead>
<tr>
<th></th>
<th>Base Prices</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Producer</td>
<td>Processor</td>
<td>Producer</td>
<td>Processor</td>
</tr>
<tr>
<td>Keep Whole</td>
<td>$ 2.080</td>
<td>$ 1.068</td>
<td>$ 17.124</td>
<td>$ (5.520)</td>
</tr>
<tr>
<td>NGL Contract - 30%</td>
<td>$ 2.554</td>
<td>$ 0.594</td>
<td>$ 11.010</td>
<td>$ 0.594</td>
</tr>
<tr>
<td>Percent of Proceeds 85/85</td>
<td>$ 2.676</td>
<td>$ 0.472</td>
<td>$ 9.863</td>
<td>$ 1.741</td>
</tr>
<tr>
<td>Fixed Fee</td>
<td>$ 2.398</td>
<td>$ 0.750</td>
<td>$ 10.854</td>
<td>$ 0.750</td>
</tr>
</tbody>
</table>

## Ethane Rejection $/mcf

<table>
<thead>
<tr>
<th></th>
<th>Base Prices</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Producer</td>
<td>Processor</td>
<td>Producer</td>
<td>Processor</td>
</tr>
<tr>
<td>Keep Whole</td>
<td>$ 2.080</td>
<td>$ 0.968</td>
<td>$ 17.124</td>
<td>$ (4.625)</td>
</tr>
<tr>
<td>NGL Contract - 30%</td>
<td>$ 2.526</td>
<td>$ 0.523</td>
<td>$ 11.977</td>
<td>$ 0.523</td>
</tr>
<tr>
<td>Percent of Proceeds 85/85</td>
<td>$ 2.592</td>
<td>$ 0.457</td>
<td>$ 10.625</td>
<td>$ 1.875</td>
</tr>
<tr>
<td>Fixed Fee</td>
<td>$ 2.299</td>
<td>$ 0.750</td>
<td>$ 11.750</td>
<td>$ 0.750</td>
</tr>
</tbody>
</table>

## Peak NGL Price

<table>
<thead>
<tr>
<th></th>
<th>Producer</th>
<th>Processor</th>
<th>Producer</th>
<th>Processor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep Whole</td>
<td>$ 2.080</td>
<td>$ 3.593</td>
<td>$ 4.322</td>
<td>$ 1.351</td>
</tr>
<tr>
<td>NGL Contract - 30%</td>
<td>$ 4.822</td>
<td>$ 0.851</td>
<td>$ 4.923</td>
<td>$ 0.750</td>
</tr>
<tr>
<td>Percent of Proceeds 85/85</td>
<td>$ 4.539</td>
<td>$ 0.801</td>
<td>$ 4.590</td>
<td>$ 0.750</td>
</tr>
<tr>
<td>Fixed Fee</td>
<td>$ 4.590</td>
<td>$ 0.750</td>
<td>$ 4.590</td>
<td>$ 0.750</td>
</tr>
</tbody>
</table>
Gathering and Processing Overview

• Gathering
  ✦ Measurement
  ✦ Pipelining
  ✦ Compression

• Processing Plant
  ✦ Inlet
  ✦ Treating
  ✦ Distillation
  ✦ Fractionation
Tank Battery \ Measurement Station

Tank Battery
Heater Treater
Flow Computer/Recorder
Radio  Solar Panel
Orifice
VRU
Meter Tube
Producer’s Valve
Gas Measurement

Electronic Flow Computer

Meter Run

Orifice Plate
Gathering & Processing - Connecting a Well

Pipeline Construction

Excavation Equipment

Constructing a new pipe line to a well
Gathering System Map
Gathering Operations and Equipment
Booster Site Inlet Facilities
Separator and Condensate Tank
Typical Compressor/Booster Site
Booster Engine \ Compressor Unit
(High Speed Separable Engine Compressor Package)
Low Speed Integral Compression
Turbine Compression
Gas Operations: Pigging

Pipeline Pig

Pigs / Cleaners
Dirty Pigs
Power Turbine
Processing Operations and Equipment
Gas Processing Facilities

Safe, reliable, and efficient plant operations is key to success

- Processing is necessary to produce a spec residue gas
- Gas is conditioned to remove impurities: H2S, CO2, N2, H2O
- NGL extraction required to reduce BTU content of raw gas
- Y-grade NGL is produced as function of the extraction process
- A series of distillation towers used to fractionate or separate y-grade mixture into purity products
- Final products transported to market by pipeline or truck
Typical Turbo Expander Plant with Fractionator
Inlet Conditioning
(Removal of Free Liquids and Particulates)

- Slug Catchers and Separators to remove free liquids
- Coalescing Filters to remove aerosol liquids
- Particulate Filters to remove fine particulates (typically 1-5 microns)
- Water Wash to remove methanol, soap or other contaminants (Less Common)
Inlet Receiver/Slug Catcher
Amine Treating
(Removal of H2S and CO2)

- Typically Uses Alkonolamines
- Reaction May Be Chemical or Physical
- Reaction is Reversible With Pressure and Temperature
- \( H_2S + \text{Amine} = \text{Amine Sulfide} + H_2O \)
- \( CO_2 + \text{Amine} = \text{Amine Carbamate} + H_2O \)
- Reaction Takes Place in a Contactor
- Regeneration Takes Place in a Stripper or Still
- Acid Gases are Then Routed to a Flare, Vent, Sulfur Recovery Unit or Acid Gas Injection Well
Natural Gas Processing
Inlet Treating Facilities
Amine Contactors
## Natural Gas Processing

### Amine Strength Range

<table>
<thead>
<tr>
<th>Amine</th>
<th>Strength range</th>
<th>Lean loading</th>
<th>Rich loading design</th>
<th>Rich loading operations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MDEA:</strong></td>
<td>40-50 wt%</td>
<td>&lt;0.01 moles of acid gas per mole of amine (m/m)</td>
<td>0.35 – 0.40 m/m</td>
<td>&lt;0.5 m/m</td>
</tr>
<tr>
<td><strong>DEA:</strong></td>
<td>20-35 wt%</td>
<td>&lt;0.01</td>
<td>0.35 – 0.40 m/m</td>
<td>&lt;0.5 m/m</td>
</tr>
<tr>
<td><strong>DGA:</strong></td>
<td>40-50 wt%</td>
<td>up to 0.012</td>
<td>0.35 – 0.40 m/m</td>
<td>&lt;0.5 m/m</td>
</tr>
<tr>
<td><strong>MEA:</strong></td>
<td>&lt;15 wt%</td>
<td>up to 0.012</td>
<td>0.35 – 0.40 m/m</td>
<td>&lt;0.5 m/m</td>
</tr>
</tbody>
</table>
Natural Gas Processing
Amine Contactor

Inlet Exchanger
Amine Contactor
Overhead Scrubber
Amine Flash Tank
Amine Circulation Pumps
Amine Surge Tank
Amine Still Condenser
Amine Still Condenser Pumps
Amine Regeneration Still
Amine Still Reboiler
Amine Still Reflux Accumulator
Lean Amine Coolers
Rich-Lean Amine Exch.
Rich Amine Carbon Filter
Rich Amine Bag Filter
Lean Amine Bag Filter
Amine Booster Pumps
Bubble Cap Trays
Natural Gas Processing
Amine Treating Process

- Gas temperature
- Lean amine temperature
- Design pressure
- Circulation rate
- Inlet gas CO$_2$ and H$_2$S content
- Anti-foam pump
- Differential pressure
- Temperature profile
- Foaming – use anti-foam last!
Natural Gas Processing
Amine Filters and Carbon Bed

- Lean or rich
- Differential pressure
- Review performance with amine lab analysis
- Check amine color and clarity in and out
- Carbon Bed removes hydrocarbon and anti-foam
- Replace every 6 months unless anti-foam is used a lot
Natural Gas Processing
Amine Regeneration

Diagram showing the process flow of Amine Contactors, Flash Tanks, Surges, Circulation Pumps, Inlet Exchangers, and Bag Filters.
Natural Gas Processing
Amine Regeneration System

- Feed temperature
- Overhead temperature 205-220F
- Bottoms/reboiler temperature – rarely changes
- Bottoms/reboiler skimming
- Make-up water pump
- Make-up amine pump – rarely use if system runs correctly
- Reflux condenser temperature
- Reflux accumulator liquid level – skim oil, methanol
- Tower pressure 10-15 psig
Natural Gas Processing
Amine Lean-Rich Exchanger
Natural Gas Processing
Amine Treating Process - Utilities
Natural Gas Processing
Amine Treating Process

• Adjust circulation rate based on:
  • Gas rate
  • CO2 rate
  • Treatment issues
  • Temperature bulge
  • Rich loading

• Keep circulation rate within limits:
  • Environmental air emission permit
  • Equipment limits
Natural Gas Processing
Amine Treating Process - Troubleshooting

- Water make-up, clean, clear and pure
- Amine Strength
- Circulation rate vs gas rate vs acid gas concentration
- Inlet gas conditioning – coalescers, dump valves
- Flash Tank pressure, oil skimmers, dump valves
- Amine filters and Carbon bed - dP
- Rich and lean loading
- Regeneration Still Top Temp  205-220F
- Regeneration Still Pressure 10-15 psig
- Amine Surge tank blanket gas
- System operations – all set point changes are SLOOOOOOW
Natural Gas Processing
Processing Facilities
Dehydration System

- Natural gas must be dry prior to cryogenic process to extract NGL’s – operating at -130F to -160F
- Many use a TriEthylene Glycol system followed by Molecular Sieve Absorbent
- TEG is regenerated using heat similar to an Amine system, Molecular Sieve is regenerated using hot inlet or residue gas
- Regeneration gas is then dehydrated before sales, blended into sales stream or recycled to inlet of plant.
Glycol Dehydrator
Cryo Plant Inlet Dehydration (Mol Sieve)
NGL Extraction
(Cryogenic Turbo Expander)

- Gas is chilled to sub-zero temperatures using Exchangers, Refrigeration, and Expansion
- Non-Methane hydrocarbons are liquified and are separated from Methane
- Liquid Stream passes through a Demethanizer to remove any residual Methane
- Methane is recompressed and sent to Sales
- Liquids are sold to a NGL Pipeline or fractionated into individual products
NGL Extraction
(Cryogenic Turbo Expander)
NGL Extraction
(Cryogenic Turbo Expander)

- Feed gas
- The “split”
- HEX train cooling and the main process chiller
- Cold separator (EFS), expander, and JT valve
- Demethanizer tower/column
- Expander (brake) compressor and residue gas compression to pipeline
- NGL to pipeline
Feed Gas and Split
Cryogenic Plant Feed Gas and Split

- The split is the first gross adjustment.
- Monitor and adjust until cold separator is as cold as it can get.
- Keep temperatures balanced to get cold separator as cold as possible.
HEX and Chiller Train
HEX and Chiller Train

- Brazed aluminum
- Shell and tube
- Plate and frame-stacked, thru bolt
HEX and Chiller Train

- Lowest possible chiller pressure
- Lowest possible 1\textsuperscript{st} stage suction pressure
- Chiller level 1 or 2 inches above top tube layer
- Fully use the installed horsepower
- Keep Condensers clean!
- Seasonal operating variation – needs to be in Plant Economic Model
- Purity of refrigerant

- Do I need a Chiller in my Plant? Depends on inlet gas liquid content
  - Liquid content >2 gpm +/- ? You need a refrigeration system!
- Heavy/wet/rich
- Light/dry/lean
Cold Separator, JT Valve and Expander
Cryogenic Expander
Compressor
Cold Separator

- Refrigeration system
- Inlet gas split
- Other HEX splits (reflux, GSP, etc.)
- Inlet gas temperature (especially non-refrigerated)
- Seasonal
- MDMT limits on separator and piping?
- Some processes designed “warm”
- Liquid feeds to demethanizer tower
- Increased NGL recovery
- Ethane rejection
JT Valve vs Expander

• The JT valve is a bypass valve.
• The JT is normally closed.
• The JT does not provide the high level of refrigeration that the expander does.

• Used for:
  • Start-up/Shutdown
  • Loss of temp control
  • Loss of pressure control
  • Maintenance

• Not used for: Up to us to educate and fight against this
  • Methane control
  • Ethane rejection
  • More capacity
Demethanizer
Demethanizer Pressure

- Increased Pressure Positives
  - Temperature profile
  - Recovery—separation efficiency
  - Reduced CO\textsubscript{2} freezing
  - Residue horsepower

- Decreased Pressure Positives
  - Methane rejection
  - Expander limitations
  - Fuel system pressure
  - Low-pressure residue deliveries
$C_1/C_2$ ratio and Liquid Volume % $C_1$

- Inlet split to bottom reboiler
- Inlet gas temperature
- Trim reboiler
- Effect of refrigeration system
- NGL bottoms product recycle
- Product heater affects
- Stalled reboiler HEX—no circulation
CO$_2$/C$_2$ ratio and Liquid Volume % C$_2$

- Same as methane controls
- Methane is nearly “0” when on CO$_2$ spec
- Warm process and very low ethane recoveries
Ethane Rejection Issues

• Warm up the plant
  • Never use JT
  • Never turn off/down Chiller/Refrigeration system
• Make required changes in flows
• Operate the trim reboiler
• More residue horsepower—increase DC$_1$ pressure to add comp capacity
• Expander off-design performance
• GSP vs. RSV vs. Others – How do we choose?

• Liquid content of the inlet gas
• Market pricing (TF&M)
• Pipeline takeaway
• Horsepower
• CO$_2$ content
• Residue quality specifications
• Capital
• Op Ex
• Flexibility—operating options
• Process Model
Fractionation
(Distillation of NGL’s into Individual Components)

• Products are produced using a Distillation Process
• NGL Products can then be sold into local markets via tank trucks (Propane, Butane, and Natural Gasolines)
• NGL Products may also be sold to pipelines (Ethane, Propane, Butanes and Natural Gasoline)
Fractionation
(Distillation of NGL’s into Individual Components)
Sulfur Recovery Units (SRU) (Claus Units)

- $\text{H}_2\text{S}$ can not be safely emitted in large quantities
- Converts $\text{H}_2\text{S}$ to elemental sulfur
- Reaction occurs in the presence of a catalyst
- SRU Efficiency is a function of age of the unit and design of the unit.
- $\text{H}_2\text{S} + \frac{3}{2} \text{O}_2 + \text{Heat} = \text{SO}_2 + \text{H}_2\text{O}$
- $\text{SO}_2 + 2 \text{H}_2\text{S} + \text{Catalyst} = 3 \text{S} + 2 \text{H}_2\text{O}$
- $\text{H}_2\text{S} + \frac{1}{2} \text{O}_2 = \text{H}_2\text{O} + \text{S}$
Claus Sulfur Recovery Unit
Acid Gas Injection
(Geologic Sequestration of Acid Gases H2S and CO2)

• AGI is an alternative to Claus SRU’s for H₂S
• Acid Gases from amine unit regeneration are compressed and injected into non-producing reservoirs
• Acid Gases are dissolved into water and the resulting solution is pumped into a non-producing reservoir
• Sequesters 100% of the Acid Gases when in operation
  • Always need a back up if compressor is down
  • High reliability Shutdown System
AGI Compressor
AGI Well
Emissions

- Regulatory requirements on amount of emissions
- $\text{H}_2\text{S}$ – poisonous, acid rain
  - From amine treater
- $\text{CO}_2$ – acid rain, greenhouse gas
  - From amine treater, fired equipment
- Methane – greenhouse gas
  - Leaks, open tanks, vents
- Heavy Hydrocarbons (VOC) – ozone precursor
  - Leaks, open tanks, vents, truck hoses
Hydrocarbon Emissions

- Reduce leaks, no open ended pipes
- Annual or Quarterly Test of valves and flanges – repair in 5 days
- No open tanks or vents
  - Compress and reprocess
    - Vapor recovery compressors
    - Vent to Low Pressure gathering system
  - Fired units
    - Flare
    - Thermal Oxidizer