LIQUIDS HANDLING IN NATURAL GAS OPERATIONS

By Jeff C. Stake, Allied Equipment, Inc.
And Peter Smith, Norwood S&S
AGENDA

• Who we are
• Introduction
• Description of Condensate
• Causes of Liquid Fallout
• Seasonal and Operational Volume Change Considerations
• Potential Issues Associated with Inadequate Liquids Handling
• Liquids Handling Design Considerations
  • Front End and Back End
• Value of Condensate
• Potential Current and Future Markets
WHO WE ARE

• Jeff C. Stake
  • Texas Tech University
    • BSCE
  • Hydraulic Design – Kennedy Consulting, Inc.
    • 1 Year
  • Process Chemistry – Nalco Company
    • 6 Years
  • Facilities Design/Sales – Allied Equipment, Inc.
    • 2+ Years

• Peter Smith
  • Texas A&M University
    • BS ChE
  • Distillation Design/Troubleshooting – Norwood S&S
    • 3 Years
COMMON TERMS

- RVP – Reid Vapor Pressure
- TVP – True Vapor Pressure
- BS&W – Basic Sediment and Water
- NGL’s – Natural Gas Liquids
- LNG – Liquified Natural Gas
- LNG – Liquid C1
  - Created Through Liquifaction
- NGL – Liquid C2 – C6
  - Created Through JT, Refrigeration, Cryogenic, etc.
- Condensate – Liquid C4 – C20+
  - Created through liquid fallout after wellhead separation
• RVP – Reid Vapor Pressure – The absolute vapor pressure exerted by a liquid at 100°F as determined by the test method ASTM D-323.

• RVP is the absolute vapor pressure and TVP is the Partial Vapor Pressure.

• RVP to TVP Conversion:

\[ P = \exp \left\{ 0.7553 - \left( \frac{413.0}{T + 459.6} \right) \right\} S^{0.5} \log_{10} (RVP) - \left[ 1.854 - \left( \frac{1.042}{T + 459.6} \right) \right] S^{0.5} \]

\[ + \left( \frac{2.416}{T + 459.6} \right) - 2.013 \log_{10} (RVP) - \left( \frac{8.742}{T + 459.6} \right) + 15.64 \]

Where:
- \( P \) = stock true vapor pressure, in pounds per square inch absolute.
- \( T \) = stock temperature, in degrees Fahrenheit.
- \( RVP \) = Reid vapor pressure, in pounds per square inch.
- \( S \) = slope of the ASTM distillation curve at 10 percent evaporated, in degrees Fahrenheit per percent.
RVP VS. TVP

Figure 7.1-14a. True vapor pressure of refined petroleum stocks with a Reid vapor pressure of 1 to 20 pounds per square inch.
INTRODUCTION

• Natural Gas Liquids in condensate form have been coming in from gathering systems for years and have been handled in different ways.

• Recent developments have elevated our focus on condensates and how they should be handled. Many factors varying from economic to environmental have contributed to this change in prioritization.

• Condensate production has increased as activity in shale plays has increased. This has come at a good time for many natural gas processors due to declined natural gas prices since 2008.
DESCRIPTION OF CONDENSATE

No two condensates are the same
TYPES OF CONDENSATE

• Condensate is a liquid hydrocarbon stream that is sometimes referred to as ultra-light crude oil, due to it being lighter than crude oil but heavier than natural gas liquids, NGLs.
The Energy Information Administration, EIA, describes Lease Condensate as a mixture consisting primarily of hydrocarbons heavier than pentanes that is recovered as a liquid from natural gas in lease separation facilities. This category excludes natural gas plant liquids, such as butane and propane, which are recovered at downstream natural gas processing plants or facilities.
Plant condensate is also known as natural gasoline, pentanes plus or C5+, that remains suspended in natural gas at the wellhead and is removed at a gas processing plant.
CAUSES OF LIQUID FALLOUT

What goes in must come out
TIGHT OIL VS. TIGHT GAS

• Tight Oil – Shale Oil. Typically trapped in relatively impermeable layers such as sandstone or shale layers.

• Tight Gas – Tight Gas is found in impermeable rock layers and impermeable limestone or sandstone typically at depths greater than 10,000 feet below the surface.
U.S. shale gas leads growth in total gas production through 2040 to reach half of U.S. output

Source: EIA, Annual Energy Outlook 2014 Reference case
ASSOCIATED GAS VISUAL
ASSOCIATED GAS VISUAL

Source: New York Times
<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Melting Point (°C)</th>
<th>Boiling Point (°C)</th>
<th>State at 25°C</th>
<th>Boiling Point (°F)</th>
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<tbody>
<tr>
<td>methane</td>
<td>C\textsubscript{2}H\textsubscript{6}</td>
<td>-183</td>
<td>-104</td>
<td>gas</td>
<td>-263.2</td>
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<td>ethane</td>
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<td>-183</td>
<td>-89</td>
<td></td>
<td>-128.2</td>
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<tr>
<td>propane</td>
<td>C\textsubscript{3}H\textsubscript{8}</td>
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<td>-42</td>
<td></td>
<td>-43.6</td>
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<td>butane</td>
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<td>31.1</td>
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<td>pentane</td>
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<td>156.2</td>
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<td>heptane</td>
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<td>98</td>
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<td>208.4</td>
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<td>octane</td>
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<td></td>
<td>257</td>
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<tr>
<td>nonane</td>
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<td>151</td>
<td>liquid</td>
<td>303.8</td>
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<td>decane</td>
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<td>undecane</td>
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<tr>
<td>dodecane</td>
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<tr>
<td>tricosane</td>
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<tr>
<td>tetracosane</td>
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<td>66</td>
<td>450</td>
<td>solid</td>
<td>842</td>
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Source: www.Elmhurst.Edu
PHASE ENVELOPES

Figure 1-1. Typical p-T diagram for a multicomponent system.

Source: Petropedia.blogspot.com
IMPACT OF TEMPERATURE AND PRESSURE

<table>
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<tr>
<th>Total</th>
<th>%</th>
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<tbody>
<tr>
<td>Nitrogen, Diatomic</td>
<td>1.27383</td>
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<tr>
<td>Carbon Dioxide</td>
<td>0.845208</td>
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<tr>
<td>Methane</td>
<td>73.2453</td>
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<tr>
<td>Ethene</td>
<td>12.4866</td>
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<tr>
<td>Propane</td>
<td>9.47178</td>
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<tr>
<td>i-Butane</td>
<td>0.398812</td>
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<tr>
<td>n-Butane</td>
<td>0.99703</td>
</tr>
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<td>i-Pentane</td>
<td>0.249257</td>
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<td>n-Pentane</td>
<td>0.448063</td>
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<tr>
<td>Hexane</td>
<td>0.318468</td>
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</table>

Example Composition

80°F, 40 psig

120°F, 900 psig

80°F, 900 psig
POTENTIAL ISSUES IN PRODUCTION FACILITIES

- Economical Ways of handling high vapor pressure/low volume
  - Small Stabilizer
  - Line Heater
  - Heater Treater

- What to do with initial flash
  - Environmental restrictions do not allow for flash gas to be flared or vented
  - VRU’s are becoming mandatory at production facilities.
POTENTIAL ISSUES IN GATHERING LINES

• Corrosion
• Freezing
• Bacteria

• Potential Remedies
• Pipeline Treating Programs
• Dehydration
• Freeze Conditioning
• Pigging Schedule
• Biocides
PRODUCERS RECENT ISSUES

- Producers have been having to operate small gathering systems due to remote locations, gas lift systems, etc.

- This is requiring them to deal with liquids and low pressure vapors where they haven’t had to in the past.
STATION REFRIGERATION/JT SKIDS

• Fuel Gas Quality

• Associated NGL’s
  • NGL Stabilization

• Liquid/Gas Exchanger

• Liquids can be blended with Crude if specs are met

• Associated Specifications
  • Color
  • TVP
NEW PRODUCTION VS. LEGACY PRODUCTION

• Typically new production contains more “condensate and NGL hydrocarbons

• Existing facilities are not setup to accommodate new liquids handling requirements

• Horizontal and Shale wells tend to have more c4+ in initial vapor stream than traditional vertical wells

Source: www.farmingmagazine.com
SEASONAL AND OPERATIONAL VOLUME CHANGE CONSIDERATIONS

‘Tis the season to be falling
AVERAGE GROUND TEMPERATURES

55°F to 65°F

57°F to 62°F

65°F to 75°F

Source: Builditsolar.com
COMMON TRENDS

• Hexane Seasonal Volumes

Source: RBNEnergy.com
POTENTIAL ISSUES ASSOCIATED WITH INADEQUATE FRONT END LIQUIDS HANDLING

Where did all these liquids come from?
TYPICAL LIQUIDS HANDLING LOCATION

Source: GPSA Databooks
TYPICAL LIQUIDS HANDLING LOCATION CONT’D
ACTIONS AND REACTIONS

• Where do you send it when you are out of storage
• What do you do when it doesn’t meet sales spec?
• What do you do when you are out of storage and you cannot meet spec?
REQUIRED SPECIFICATIONS

- RVP
- BS&W
- Sulfur
- TSS

<table>
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<tr>
<th>Quality</th>
<th>Units</th>
<th>Min</th>
<th>Max</th>
<th>Reference Test Method and Test Frequency</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Density (15 C)</td>
<td>kg/m³</td>
<td>600</td>
<td>799</td>
<td>ASTM 4552 Frequency: AR¹</td>
<td>Industry Equalization and Enbridge Tariff specification. For test results greater than or equal to 600 kg m⁻³, but less than 650 kg m⁻³, perform RVP and Aromatics test to confirm it meets those specifications. If exceed max charge appropriate toll (i.e. Light Petroleum, etc.). Industry Equalization max has been reduced to 799 kg/m³ from 815 kg/m³. Upon violation warning sent to violating shipper. If violation continues in 2nd month stream reclassified and shipper requested to nominate to appropriate stream (i.e. MSW, etc.). Once shipper demonstrates that they are back in spec range they are allowed to nominate to the CRW pool the following month.</td>
</tr>
<tr>
<td>Viscosity (7.5 C)</td>
<td>cSt</td>
<td>2.0</td>
<td></td>
<td>ASTM D445 Frequency: QR*¹</td>
<td>Enbridge Tariff specification. If exceed max charge appropriate toll (i.e. Light Petroleum, etc.). Upon violation increase monitoring for 1 month. If it continues off spec for that month then notify. If continue off spec in the 2nd month you will be reclassified to the appropriate stream (i.e. MSW, etc.) for the 3rd month. In the case of a violation that is corrected in month 2, more frequent monitoring would continue to confirm compliance.</td>
</tr>
<tr>
<td>Sulfur, total</td>
<td>wt%</td>
<td></td>
<td>0.5</td>
<td>ASTM D5845 Frequency: AR²</td>
<td>Industry Equalization specification. Follow similar procedure to Enbridge Book 5 03-03-03-21: Maintaining 0.5% Weight Sulphur Standard but modified for CRW. CRW Procedure to be developed.</td>
</tr>
<tr>
<td>Olefins, total¹</td>
<td>wt%</td>
<td></td>
<td>&lt;1</td>
<td>PONAOK(U) ASTM 6729 (240 cat) Frequency: QR*¹</td>
<td>Enforcement and Consequence: Apply Olefin Decision Tree (all shippers to be advised of location of document once posted)</td>
</tr>
<tr>
<td>Reid Vapour Pressure</td>
<td>kPa</td>
<td>103</td>
<td></td>
<td>ASTM D3253 Frequency: MN¹</td>
<td>Rules and Reps. filed with NBE/FERC specification Enforcement and Consequence: Immediate shut-in¹</td>
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<tr>
<td>BS&amp;W</td>
<td>vol%</td>
<td>0.5</td>
<td></td>
<td>ASTM D95 Frequency: AR²</td>
<td>Rules and Reps. filed with NBE/FERC specification Enforcement and Consequence: Immediate shut-in¹</td>
</tr>
<tr>
<td>Organic Chlorides¹</td>
<td>wppm</td>
<td></td>
<td>&lt;1</td>
<td>ASTM D4529 Frequency: QR*¹</td>
<td>Rules and Reps. filed with NBE/FERC specification Enforcement and Consequence: Immediate shut-in upon identifying violation Request 5 th party Certificate of Analysis prior to subsequent receipt for period of 1 month.</td>
</tr>
</tbody>
</table>

Source: Enbridge
LIQUIDS HANDLING DESIGN CONSIDERATIONS

How big is too big?
WHY IS KNOWING YOUR COMPOSITION IMPORTANT

- V/L Ratio
- Phase Envelope
- Duty Requirement
- Commercial Considerations
- Equipment Sizing
SIZING FOR NORMAL OPERATIONS OR SLUG VOLUMES

• Slug catchers may be either a vessel or constructed of pipe (harp type) and the selection is based on economics. Vessels are typically used in lower pressure services (below 500 psig) and/or when smaller slug sizes are expected (<1,000 bbl).

• In order to avoid thick wall vessels, harp type slug catchers are used for higher pressure and larger slug size applications, since multiple sections of smaller diameter (and thinner-walled) piping are utilized.

Source: GPSA Databooks
TYPES OF SLUGS

- **Terrain slugging** is caused by the elevations in the pipeline, which follows the ground elevation or the sea bed. Liquid can accumulate at a low point of the pipeline until sufficient pressure builds up behind it. Once the liquid is pushed out of the low point, it can form a slug.

- **Hydrodynamic slugging** is caused by gas flowing at a fast rate over a slower flowing liquid phase. The gas will form waves on the liquid surface, which may grow to bridge the whole cross-section of the line. This creates a blockage on the gas flow, which travels as a slug through the line.

- **Riser-based slugging**, also known as **severe slugging**, is associated with the pipeline risers often found in offshore oil production facilities. Liquids accumulate at the bottom of the riser until sufficient pressure is generated behind it to push the liquids over the top of the riser, overcoming the static head. Behind this slug of liquid follows a slug of gas, until sufficient liquids have accumulated at the bottom to form a new liquid slug.

- **Pigging slugs** are caused by pigging operations in the pipeline. The pig is designed to push all or most of the liquids contents of the pipeline to the outlet. This intentionally creates a liquid slug.
SLUG VOLUME PREDICTIONS AND PIGGING SCHEDULE

• Pigging Frequency

• Gas Composition

• Seasonal Fallout Variance

• Processing Capacity

• Producer Facilities Consistency?

• Room for Service Interruption
REQUIRED SEPARATION TECHNOLOGY

• Liquid/Liquid
  • Coalescer
    • What is continuous phase?
  • Separator

• Gas/Liquid
  • 2 Phase or 3 Phase?
    • Retention Time of 1 to 2 minutes is generally adequate for degassing liquids
    • Retention time of 3 to 5 minutes for water/hydrocarbon separation

Source: GPSA Databooks
CONDENSATE STABILIZATION METHOD

- General Theory
  - Tower Type
  - Non Tower Type
- Continuous or Batch Operation
  - Control Scheme
TEMPERATURE/PRESSURE
CONSIDERATIONS

• Higher pressure stabilization can help improve recovery efficiency

• Higher pressure also requires more duty

• Lower Pressures can add additional equipment requirements
  • ie. Condensate Pumps

• If liquid has taken significant pressure drop on its way to stabilizer then low inlet temperatures can be expected
  • Are hydrates a risk?
  • If system is down and full of condensate then thermal relief is to be expected
HEAT MEDIUM/HEAT SOURCE
ADVANTAGES AND DISADVANTAGES

• Direct Fired Reboiler
• Water Bath Reboiler
• Hot Oil Reboiler
• Electric Reboiler
• Steam Reboiler

• Things to consider:
  • Turnup/Turndown
  • Utilities Available
  • Safety
  • Control
  • Consistency
TURNDOWN REQUIRED

- Mass Transfer Equipment
- Duty Control Mechanisms
- Control Valve Sizing
- Where does product go?
  - Pumps Required
  - Pump Turndown?
MASS TRANSFER EQUIPMENT CONSIDERATIONS

General Tower Considerations

• Diameter
• Height
• Mass Transfer Device
• Material of Construction

  • Major Materials
  • Hardware
  • Valve Material
MASS TRANSFER EQUIPMENT CONSIDERATIONS

Stabilizer Specific Considerations

• Fouling
• Flexibility
• Vapor/Liquid Profile
• Flashing Feed

Source: www.sulzer.com
TRAYS VS PACKING

• In general, Trays are preferred in stabilization.

• Wide operation range
• Efficient operation
• Can resist fouling
• Relatively easy maintenance

Norwood S&S Tray preassembled before installation
TRAYS VS PACKING

Packing
• Small diameters
• Increase existing tower capacity

Drawbacks
• Operating window
• Fouling
STABILIZER FEED CONSIDERATIONS

Stabilizer Feed Issues
- Flashing Feeds
- Slug Flow
- Premature Flooding

Feed Designs:
- Chimney Trays
- Reinforced Internals
- Feed Pipe/Baffle

Source: http://www.drbratland.com/
POTENTIAL ISSUES

• Installation problems
• Transportation damage
• Liquid Level Control
• Pressure/Fluid Surges
OVERHEAD VAPOR CONSIDERATIONS

• Where will overhead vapor go?

• What type of facility is this?

• What type of compression is in facility

• Inlet Temps will partially determine outlet vapor temps

• Post cooling liquid fallout

• Is this only feed to compressor or will be blended?

• Liquid Fallout will be too light to go back to condensate

• Product Options
OVERHEAD VAPOR CONSIDERATIONS CONT'D.

- What is in the overhead Vapors?
- What pressure do you need to return vapors to front end?
- VRU considerations

- Typical primary components in Overhead:
  - Methane
  - Ethane
  - Propane
  - Butanes
STORAGE AND QUALITY CONSIDERATIONS

• How will product be loaded/unloaded?

• Is Blanket Gas Required?

• Is VRU Required?

Source: Testex-NDT.com
VALUE OF CONDENSATE

The more the merrier!
PRODUCT CREATION

• Potential Products Into Plant
  • Condensate
  • NGL’s
  • Residue
  • Other Inlets
    • BS&W
• Unstable Condensate May Contain
  • Light hydrocarbons
    • Methane/Ethane/Propane
  • Heavy hydrocarbons (Butane+)
  • BS&W

• Stable Condensate Typically Contains:
  • Butane +

• Stabilizer Outlets Contain:
  • Top –
    • Light hydrocarbons (gas phase)
    • Methane, Ethane, Propane
  • Bottom –
    • Condensate (Butane+)
    • < 12 # vapor pressure, Typically 9.5 psig
PRODUCT CREATION

Source: Hematsaya.blogspot.com
PRICING CONSIDERATIONS

- Hitting standard spec?
- Market selling into?
- Sweet or Sour?
- API Gravity?
POTENTIAL CURRENT AND FUTURE MARKETS

Too light or just right?
DOMESTIC MARKET

Condensate blended with Oil Sand Bitumen to create Dilbit

Source: Muse Stancil
DOMESTIC MARKET

Source: Muse Stancil

Source: EIA
DOMESTIC MARKET

U.S. Gulf Coast Condensate Supply & Disposition

Source: Muse Stancil
EAGLEFORD REFERENCE

Source: RBN Energy
INTERNATIONAL MARKET

39 YEAR OLD BAN ON CRUDE OIL EXPORTS

In June of this year the Obama administration cleared the way for condensate to be exported as long as it fits into a “Product” category.

Source: RBNEnergy.com
INTERNATIONAL MARKET

• In 2010 Enterprise Products entered into a 10 year agreement with Pioneer to transport, market, and process their crude, gas, and liquids production from the Eagleford.

• July 3rd Enterprise Products Sold their first 400 MBbl condensate export cargo to Japanese trader, Mitsui.

distillation

noun

1. the action of purifying a liquid by a process of heating and cooling: “the petroleum distillation process”

2. the extraction of the essential meaning or most important aspects of something: “the film is a distillation of personal experiences”

Source: RBNEnergy.com