Introduction to Natural Gas Processing

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Course Objective

Acquaint the student with the engineering & business fundamentals associated with the natural gas industry

- Develop a basic understanding of the industry “from wellhead to burner tip”
- Develop a basic understanding of gas chemistry and resulting physical properties
- Develop an understanding of the processing steps needed to abide by transportation & usage requirements & specifications
- Use simulation software for natural gas characterization, fractionation, & related operations
  - Aspen Plus / HYSYS / ProMax
Class Topics

Petroleum & natural gas overview
- Sources of natural gas
- Composition of natural gas
- Principal products & markets
- Product specifications
- Combustion characteristics

Gas processing equipment

Overview & usage of simulation programs

Gas processing operations
- Field operations & inlet receiving
- Compression
- Gas treating
- Gas dehydration
- Hydrocarbon recovery
- Nitrogen rejection
- Trace component removal
- Liquids processing
- Acid gas removal & disposal
- Transportation & storage

Liquefied natural gas (LNG)

Capital costs
Course Materials

Textbook

- *Fundamentals of Natural Gas Processing*, 2nd ed
  Arthur Kidnay, William Parrish, Daniel McCartney
  2011

Electronic files on web page
http://inside.mines.edu/~jjechura/GasProcessing/

- Contact information
- Syllabus
- Assignments (printable) & solutions (require password)
- PDF of slides (printable & non-printable)
- Table of pure component properties (spreadsheet)
- VBA code
  - Interpolation & manipulation of distillation curves
- Unit conversion factors
- External links
  - Daily prices for natural gas
  - Web sites for midstream processing companies
- Safety related web sites
Primary References for Class Material

*Fundamentals of Natural Gas Processing, 2nd ed*
Arthur Kidnay, William Parrish, Daniel McCartney
2011

*GPSA Engineering Data Book, 13th & 14th eds.*
2012 & 2016

ASTM standards

Data from the Energy Information Agency (EIS) of the U.S. Department of Energy (DOE)
http://www.eia.gov/naturalgas/
Why are you taking this class?
## Grading Policy

<table>
<thead>
<tr>
<th>Item</th>
<th>Portion of Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Topic</td>
<td>(0 to -10%)</td>
</tr>
<tr>
<td>Homework</td>
<td>30%</td>
</tr>
<tr>
<td>Short Quizzes</td>
<td>30%</td>
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<tr>
<td>Mid-Term Exams</td>
<td>0%</td>
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<tr>
<td>Final Exam</td>
<td>25%</td>
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<tr>
<td>Simulation Project</td>
<td>15%</td>
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Attendance Policy

During the semester attendance is not required. However...

Quizzes are given at the beginning of the class, are unannounced, and no make-up is allowed. However...

If (and only if) you send an email announcing that you will be absent before class starts you will be classified as “excused”.

Homework is due by the stated time whether you attend class or not.

- Homework is to be emailed so that I have a time-stamped record of when it is sent & received.

Attendance is required for the final exam.

- If unavailable for the time for the scheduled time the student is responsible for arranging a time before the rest of the class takes the exam.
Things You Should Already Know

**Unit conversions!**

Change the bases between mass, moles, & “standard” volume

- Standard conditions for ideal gas volumes
- Standard conditions for ideal liquid volumes

How do you do a mass balance?

- Relate “per mass” values for the different constituents
- Relate “per mole” values for the different constituents

How do you do an energy balance?

Make use of values from process simulation software – Aspen Plus, HYSYS, …

Make use of the resources on the class web page!!!

- Table of pure component properties
- Table of unit conversion factors
Concepts We’ll Use in This Class

Mass values are additive

\[ m_{\text{total}} = \sum m_i \]

Ideal liquid volumes are additive at consistent conditions…

\[ V_{\text{total}}^{(0)} = \sum V_i^{(0)} \]

… but densities & corresponding volumes are dependent on temperature & pressure

Calculation of properties based upon their intrinsic basis

- Example – standard liquid density

\[ m_{\text{total}} = \sum m_i \Rightarrow V_{\text{total}}^{(0)} \rho_{\text{total}}^{(0)} = \sum V_i^{(0)} \rho_i^{(0)} \Rightarrow \rho_{\text{total}}^{(0)} = \sum V_i^{(0)} \rho_i^{(0)} \]

Standard & normal conditions for gas & liquid volumes
Standard & Normal Conditions
(Temperature & Pressure)

“Standard conditions” may vary between countries, states within the U.S., & between different organizations

- Standard temperature – 60°F
  - Most other countries use 15°C (59°F)
  - Russia uses 20°C (68°F)
- Standard pressure – 1 atm (14.696 psia)
  - Other typical values are 14.73 psia (ANSI Z132.1) & 14.503 psia

“Normal conditions”

- Almost exclusively used with metric units (e.g., Nm³)
- IUPAC: 0°C & 100 kPa (32°F & 14.50 psia)
- NIST: 0°C & 1 atm (32°F & 14.696 psia)
Other Common Concepts We’ll Use in This Class

Ideal gas volume fractions are the same as molar fractions
- Liquid volume fractions are not the same as molar fractions or mass fractions

Standard gas volumes are not the same as standard liquid volumes
- Standard ideal gas volumes are actually molar amounts

API gravity – defined using standard densities at 60°F

\[ °API = \frac{141.5}{\gamma_o} - 131.5 \quad \Rightarrow \quad \gamma_o = \frac{141.5}{131.5 + °API} \]
Importance of Unit Conversions

Proper unit conversion can help control the precision of your calculated results

- Proper unit conversions cannot make your answer more accurate, but …
- Improper unit conversions can ruin the accuracy of an answer

So, how important is an error in unit conversions?

- On a 20 point problem, how much should be taken off for incorrect unit conversion?
- Does it make a difference if the error causes the crash of a $125 million dollar space craft (e.g., 1999 Mars lander)
- Does it make a difference if the error causes an explosion that kills 50 people?
Safety

Engineering firm has policy that meetings start with a safety topic
- Increases safety awareness
- Improves safety culture

Every student will be responsible for at least 1 safety topic during the semester
- May volunteer ahead of time
- Lack of volunteers, will be called at random
- Will be allowed to “pass” once

Safety culture
March 23, 2005:

BP refinery in Texas City, TX was starting isomerization unit

Sequence of events

- The Raffinate Splitter tower was over-filled completely with liquid
- Liquid in the overhead flowed through PSVs to the nearby blowdown drum
- Blowdown drum overflowed
- Liquid hydrocarbon sprayed throughout the area
Safety Topic – The Safety Culture

The hydrocarbon cloud was ignited by exhaust from an idling truck - the resulting vapor cloud explosion killed 15 and injured 170.
Safety Topic – The Safety Culture

Safety Topic – The Safety Culture

Investigated by BP, the US Chemical Safety Board, & an independent panel headed by James A. Baker III

The US Chemical Safety Board concluded that the primary cause of the accident was a total breakdown in the safety culture at BP:

- In the previous 30 years, the facility had experienced 23 fatalities – three fatalities in 2004 alone
- Management objective was to maintain production with minimum cost expenditure; critical maintenance was never performed
- Operators routinely ignored written operating procedures during startup
- Instruments were repeatedly reported as malfunctioning, and the resulting work orders were cleared without repairing the instruments
- Temporary trailers were erected near the Isomerization unit without any safety review

1 Former White House Chief of Staff, U.S. Secretary of State, U.S. Secretary of Treasury

Safety Topic – The Safety Culture

Legal actions

- September 2005: In a settlement agreement, OSHA fines BP record $21.3 million & charges it with 300 health and safety violations
- October 2007: BP agrees to resolve criminal investigation by pleading guilty to a felony violation of the Clean Air Act – $50 million fine, serve three years' probation, & comply with terms of OSHA settlement
  - Blast victims challenge fine as inadequate
- October 2009: OSHA proposes to fine BP $87 million for the alleged settlement violations
  - July 2010: settled 270 allegations & paid $50.6 million & continued to contest $30.7 million of this fine
- July 2012: $13 million fine to settle 409 allegations
  - Was to resolve final $30 by end of 2012
- Ultimately refinery sold to Marathon Petroleum