Upstream Oil and Gas Emissions Calculations: Storage Tanks

Presented to the 4C Environmental Conference

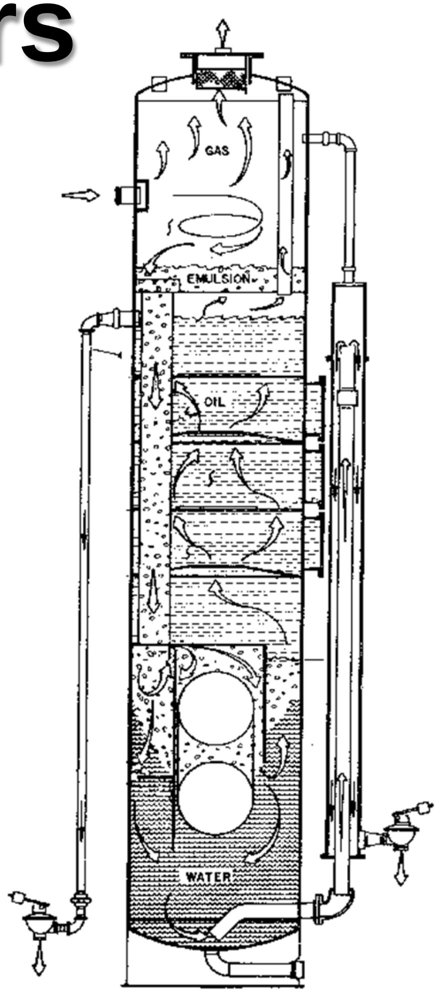
February 20, 2017

Overview

- Briefly review emissions calculations for separators
- Focus on emissions calculations for storage tanks, specifically use of Exploration and Production (E&P) TANK
- Use of sampling data

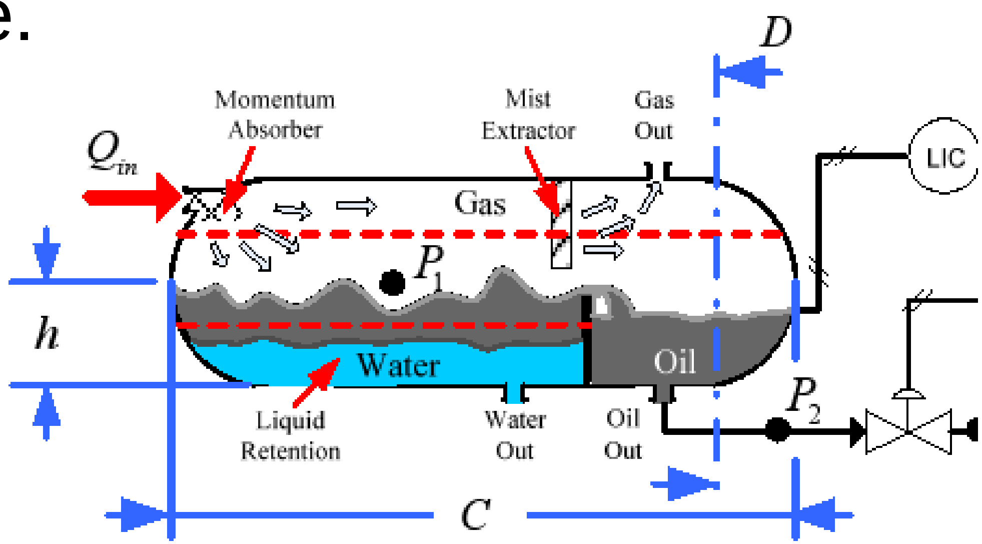
Analyzing Data and Determining Emissions: Separators

- Generally operate above ambient pressure
- May be uncontrolled, typically in oil field
- Flash emissions are a concern if uncontrolled
- Emissions determined using:
  - Process simulator
  - Measurement data (will be discussed in storage tanks portion of presentation)



Analyzing Data and Determining Emissions: Separators (cont.)

- Even if separator is controlled, last stage separator will have direct impact on storage tank emissions.
- Determine whether last stage separator is two-phase or three-phase.
- Obtain actual separator pressure and temperature to use for calculation inputs.



Analyzing Data and Determining Emissions: Separators (cont.)

For process simulator, inputs may include:

- Operating temperatures and pressures of the various process vessels at the facility
- Composition of the inlet gas
- Gas flow rate off the inlet separator
- Composition of the final stabilized oil/condensate product from the stock tanks

- Oil and water production rates to the stock tanks
- API gravity of liquid(s)
- Molecular weights of liquid and/or gas streams

Analyzing Data and Determining Emissions: Storage Tanks

- Three routine emissions modes: flash, working, breathing
- Flash emissions are generally largest emissions
- Emissions determined using:
  - Direct measurement
  - Process simulator models**
  - E&P TANK program
  - Vasquez-Beggs or Rollins, McCain, and Creeger correlations, or software that uses these correlation equations (such as GRI-HAPCalc)**
  - Gas/oil ratio (GOR) method**
  - AP-42 Chapter 7 equations (e.g., TANK ESP, TANKS 4.09d)*

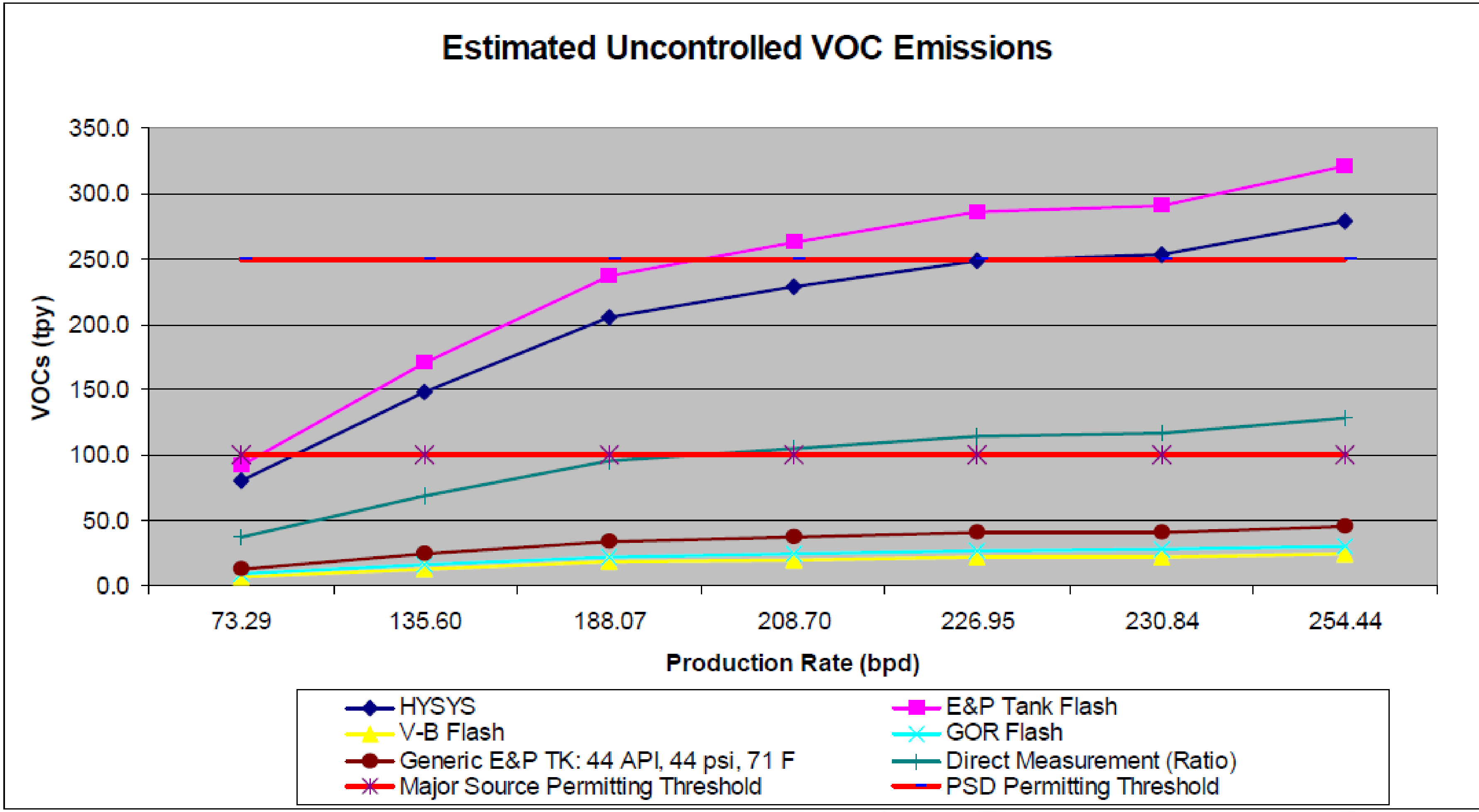
*=method estimates working and breathing loss emissions only

**= method estimates flash emissions only

Table 1: Flash Loss Estimation Methods

No.	Method	Emissions Calculated	Comments
1	Direct measurement of tank emissions	Working, Breathing, Flash	**Sampling and analysis** are expensive, but the results are relatively accurate. **Sampling timing and duration are critical.**
2	Process Simulator computer programs	Flash only	There are several different process simulators (e.g. WinSim, Designer II, HYSIM, HYSIS, VMG, and PROMAX, etc.). The software is expensive, but the results are accurate when based on site-specific **sample and analysis.**
3	E&P Tanks Software, V 2.0, using an option that requires site-specific sampling	Working, Breathing, Flash	A pressurized liquid and/or gas **sample analysis** from a separator will be needed. This choice does not include the Geographical Data base option.
4	Laboratory measurement of the Gas-Oil-Ratio (GOR) from a Pressurized Liquid Sample	Flash only	This is direct laboratory analysis of the flash gas emitted from a pressurized oil/condensate **sample.**
5	Vasquez-Beggs Equation (VBE):	Flash only	A calculation method based on empirical data. The VBE variables must be **supported with a lab sampling analysis** that verifies the API gravity, separator gas gravity, stock tank gas molecular weight, and VOC fraction. If an operating variable used in the VBE calculations falls outside of the parameter limits, the applicant must use another method to calculate flash emissions.
6	E&P Tanks Software, V 2.0, Geographical Database Option **Not allowed for emissions inventory**	Working, Breathing, Flash	Emissions are based on choosing an example case that closely matches operating parameters at the site in question. A justification for using this method must be included if the site is existing. The geographical database is based on 103 sampled sites and is a very poor estimate of emissions from any particular storage tank.
7	Griswold and Ambler GOR Chart Method **Not allowed for emissions inventory**	Flash only	A graph developed by Griswold and Ambler (1978) can be used to approximate total potential vapor emissions from a barrel of oil based on pressure differentials. The curves were constructed using empirical flash data from laboratory studies and field measurements.

Bakken Tank Flash VOC Emission Models and Direct Measurements



Source of data:

1) Comm Engineering, Vent Gas Direct Measurement and Sampling Report for Marathon Oil Company, July 21, 2009 (submitted to EPA July 31, 2009)

2) Marathon Oil Company letter to US EPA, Region 8 dated June 2, 2009

Analyzing Data and Determining Emissions: Storage Tanks (cont.)

Direct measurement

- Two tests: one for flow rate, one for volatile organic compounds (VOC) concentration and speciation
- Should measure flash, working, and breathing losses
- Review test report critically
  - Ensure test period was at least 24 hours to capture full breathing loss cycle.
  - Review liquid levels pre- and post-test. If unchanged, then separator did not dump to tank and the test cannot be used to calculate flash and working loss emissions.
  - Will produce pound/hour or pound (lb)/barrel test result.
  - Pound per barrel is preferred since VOC emissions will increase with increased production.

Analyzing Data and Determining Emissions: Storage Tanks (cont.)

- Example direct measurement calculations: use dimensional analysis to determine emissions.

$$12\ \text{lb}\ \frac{\text{VOC}}{\text{barrel}} \times \frac{28{,}000\ \text{barrel}}{\text{year}} \times \frac{\text{ton}}{2000\ \text{lb}} = 168\ \text{tons VOC per year}$$

- As long as liquid is present in the tank, emissions will be generated.
- If production ceased during the year, but the tank was not emptied, emissions will still need to be estimated.

Analyzing Data and Determining Emissions: Storage Tanks (cont.)

E&P TANK

- Determines flash, working, and breathing losses
- Models separator liquid transfer to tank to calculate flash emissions
- Requires gas and/or liquid sample analysis(es) along with operational data to run model
- Calculates working and breathing losses using either:
  - AP-42, Chapter 7 equations
    - Requires site-specific tank data inputs, typically more accurate
  - RVP option
    - Simulates a distillation column to arrive at sales ‘oil’ RVP

Analyzing Data and Determining Emissions: Storage Tanks (cont.)

- Emissions driven by:
  - Stream composition
  - Separator pressure
  - Sales oil RVP
- First we'll discuss stream composition requirements, which depend upon sampling and related analysis.
- Obtaining an accurate gas or liquid sample analysis is critical: sample must be collected, stored, and analyzed properly.
- Samples are often collected for business purposes, but can be used for regulatory purposes if performed properly.

Analyzing Data and Determining Emissions: Liquid or Gas Analyses

Regulatory and other goals of sampling:

- Determine amount of gas that will be flashed at the storage tank or potentially, the separator
- Can be used to determine GOR which can be used to calculate emissions

Analyzing Data and Determining Emissions: Liquid or Gas Analyses

Regulatory and other goals of sampling, cont.:

- Determine VOC, acid gas, and hazardous air pollutants (HAP) or toxics composition data for gas and/or liquid phase
- Sales gas must meet pipeline specifications for transmission.

Analyzing Data and Determining Emissions: Liquid or Gas Analyses

- Gas composition analyses:
  - Almost all oil/gas process units require extended gas analysis to determine emissions accurately
    - HAPs present in trace amounts will not be detected in sales gas analysis.

Analyzing Data and Determining Emissions: Liquid or Gas Analyses

- Gas composition analysis methods:
  - GPA Standard 2261: Analysis of Natural Gas and Similar Gaseous Mixtures

    Does not provide extended analysis required to obtain HAP speciation.
  - GPA Standard 2286: Analysis of Natural Gas and Similar Gaseous Mixtures by Temperature Programmed Gas Chromatography

    Extended gas analysis, but does not provide nitrogen or carbon dioxide analysis.

Analyzing Data and Determining Emissions: Sample Analysis

Sampling analysis report: critical review

- Provide actual sample report, not Excel spreadsheet
- Review sample lab analysis:
  - Does the report state sample type (liquid, gas, mixture, etc.)?
  - Was the sample taken at that site?
    - If not, does it qualify as a representative sample?
    - Representative sample requirements:
      - Was the sample taken from the same geological formation or reservoir?
      - Is the sample processed and treated in the same manner at the sites in questions?
      - Is the API gravity within three degrees of the actual material?

Analyzing Data and Determining Emissions: Sample Analysis

Sampling analysis report: critical review (cont.)

- Does the report state where at the site the sample was taken?

Important: samples may be required from different locations to accurately determine emissions for different process units.

  - Was the initial opening pressure of the sample at the lab reported?
    - If so, it should be at or above separator pressure.
    - If not, leaks have occurred.

Analyzing Data and Determining Emissions: Sample Analysis

Sampling analysis report: critical review (cont.):

- Does the report state separator pressure and temperature?

If so, does it match operating conditions?

- Labs often perform quality control checks using a bubble point pressure test at the separator temperature.

The bubble point pressure should be comparable with the test separator pressure (within 30 pounds per square inch [psi] absolute).

Analyzing Data and Determining Emissions: Sample Analysis (cont.)

- Gas sample rules of thumb:
  - Low pressure separator gas is not representative of sales gas.
  - The VOC content of sales gas should be ~5 to 25 weight percent.

Analyzing Data and Determining Emissions: Sample Analysis (cont.)

- Liquid sample rules of thumb:
  - The closer to the first stage separator, the lighter it should be.
  - A higher RVP means a higher concentration of lighter hydrocarbons.
  - Separator samples should be near the bubble point.

- Next slides show an example of an extended sample analysis.

Field: Sampled By: J Bosworth

Station Name:		Sample Of:	Natural Gas Spot
Station Number:		Sample Date:	05/23/2013
Station Location:		Sample Conditions:	256 psig, @ 79 °F
Sample Point:	Meter Run	Method:	GPA 2286
Property ID:		Cylinder No:	1959
		Analyzed:	05/24/2013 10:21:41 by LM

Analytical Data

Components	Mol. %	Wt. %	GPM at 14.73 psia
Nitrogen	0.985	1.347	
Carbon Dioxide	0.900	1.934	
Methane	80.400	62.980	
Ethane	11.104	16.303	2.979
Propane	3.809	8.201	1.053
Iso-Butane	0.700	1.987	0.230
n-Butane	1.031	2.926	0.326
Iso-Pentane	0.337	1.187	0.124
n-Pentane	0.294	1.036	0.107
i-Hexanes	0.122	0.507	0.051
n-Hexane	0.073	0.302	0.030
Benzene	0.004	0.013	0.001
Cyclohexane	0.012	0.047	0.004
i-Heptanes	0.069	0.323	0.030
n-Heptane	0.025	0.117	0.011
Toluene	0.009	0.040	0.003
i-Octanes	0.048	0.263	0.024
n-Octane	0.007	0.036	0.003
Ethylbenzene	0.001	0.005	0.000
Xylenes	0.008	0.042	0.003
i-Nonanes	0.043	0.239	0.021
n-Nonane	0.002	0.013	0.001
Decane Plus	0.017	0.152	0.012
	100.000	100.000	5.013

GPM TOTAL C2+ 5.013

Station Name:		Sample Of:	Natural Gas Spot
Station Numbe		Sample Date:	05/23/2013
Station Locatio		Sample Conditions:	256 psig, @ 79 °F
Sample Point:	Meter Run	Method:	GPA 2286
Property ID:		Cylinder No:	1959
		Analyzed:	05/24/2013 10:21:41 by LM

Physical Properties	**Total**	**C10+**
Calculated Molecular Weight	20.48	137.95
GPA 2172-09 Calculation:		
Calculated Gross BTU per ft³ @ 14.73 psia & 60°F		
Real Gas Dry BTU	1216.1	7108.2
Water Sat. Gas Base BTU	1195.5076	6984.5
Relative Density Real Gas	0.7092	4.7626
Compressibility Factor	0.9966	

Analyzing Data and Determining Emissions: Storage Tanks

E&P TANK

- Next driver: separator pressure
  - The higher the separator pressure, the larger the pressure drop the separator liquid experiences when reaching the storage tank. This increases the potential for significant VOC emissions.
- Final driver: sales ‘oil’ RVP
  - The higher the RVP of the final liquid, the more volatile it is, and the higher the VOC emissions.
    - RVP – 2 to 12 (higher RVP for shale wells, typically)
    - API Gravity – 25 to 75 (higher API for shale wells, typically)

Analyzing Data and Determining Emissions: Storage Tanks (cont.)

E&P TANK data inputs:

- Separator: pressure, temperature
- Known separator stream composition data. Options are listed in order of preference (details to follow):
  - Low pressure oil
  - High pressure oil
  - Low pressure gas

Analyzing Data and Determining Emissions: Storage Tanks (cont.)

E&P TANK data inputs:

- Storage tank data only if AP-42 method is chosen for working and breathing losses
  - If RVP distillation method is chosen, tank data cannot be entered.
  - If AP-42 is chosen, ensure the tank location did not default to Homer, Alaska.

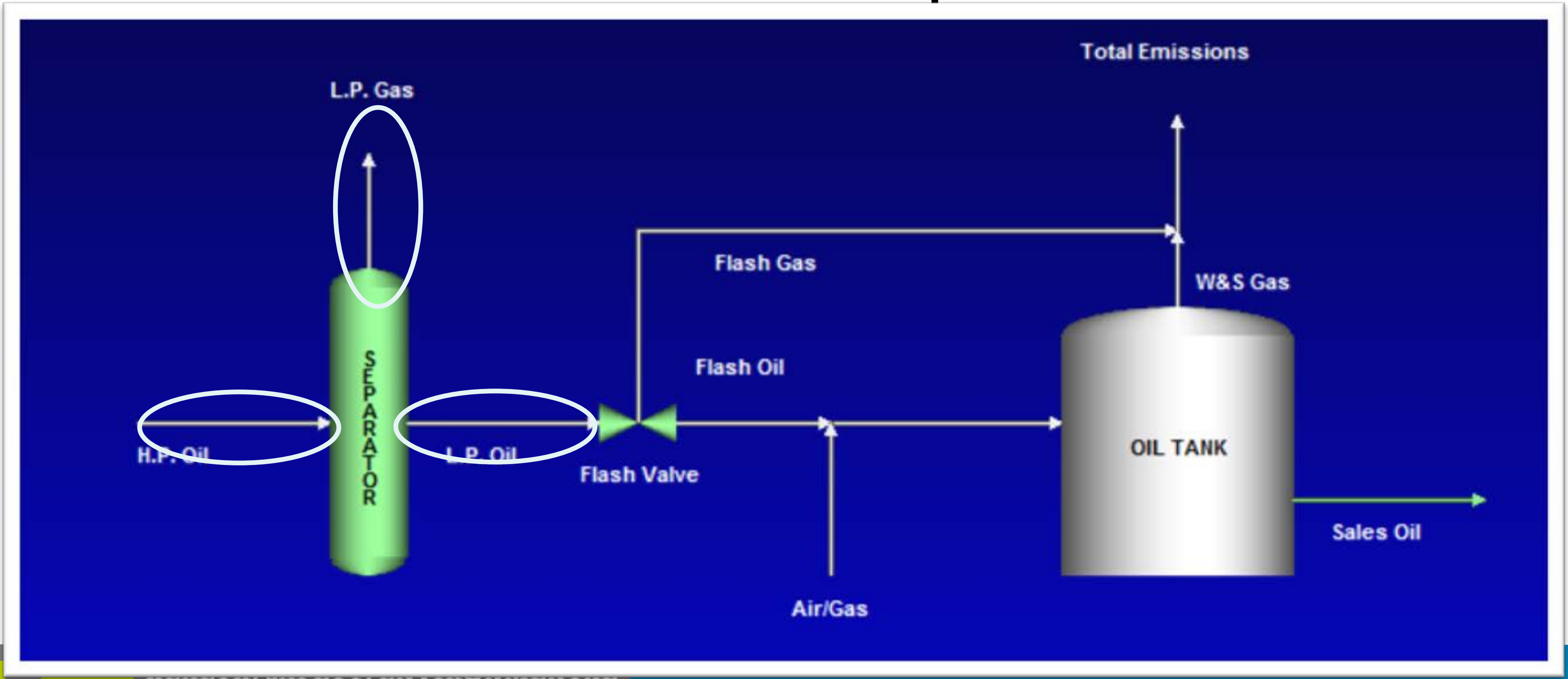
Analyzing Data and Determining Emissions: Storage Tanks (cont.)

E&P TANK data inputs:

- Sales oil data:
  - production rate,
  - days of operation,
  - API gravity,
  - composition data,
  - RVP, and
  - bulk liquid temperature.

Analyzing Data and Determining Emissions: Storage Tanks (cont.)

Ensure the actual sample analysis location matches the E&P TANK reported location:



Analyzing Data and Determining Emissions: Storage Tanks (cont.)

Which separator stream option in E&P TANK should be used?

- Most preferred option is low pressure oil stream
  - Model is dealing with known data, not trying to predict stream composition after flash occurs at separator

Analyzing Data and Determining Emissions: Storage Tanks (cont.)

Which separator stream option in E&P TANK should be used?

- Least preferred option for sweet gas sites is low pressure gas
  - Limited data on liquid inputted into the model, complicating emissions calculations
  - May be useful for sour gas sites, since hydrogen sulfide is more easily measured in the gas phase
  - Requires additional analyses to run model:
    - GOR analysis
    - Liquid sample analysis to obtain API gravity, RVP, and composition data for C7 to C10+ hydrocarbons

Analyzing Data and Determining Emissions: Storage Tanks

Let's analyze case study site values

- Start with gas analysis
- Move to E&P TANK report

Gas Analysis

Conversion of Mole Percent to Weight Percent

Specific Gravity	0.5996
Gross BTU	964

Component	Mole %	MW	Mole % * MW	Weight %
Carbon Dioxide	3.3130	44	1.4577	8.429%
Nitrogen	0.8170	28	0.2288	1.323%
Hydrogen Sulfide	0.0000	34	0.0000	0.000%
Helium	0.0000	4	0.0000	0.000%
Methane	94.3560	16	15.0970	87.298%
Ethane	1.3840	30	0.4152	2.401%
Propane	0.0680	44	0.0299	0.173%
Iso-Butane	0.0040	58	0.0023	0.013%
N-Butane	0.0050	58	0.0029	0.017%
Iso-Pentane	0.0060	72	0.0043	0.025%
N-Pentane	0.0070	72	0.0050	0.029%
Methylcyclopentane	0.0000	86	0.0000	0.000%
n-Hexane	0.0010	86	0.0009	0.005%
Hexane +	0.0000	86	0.0000	0.000%
2,4-Dimethylpentane	0.0000	100	0.0000	0.000%
Methycyclohexane	0.0000	96	0.0000	0.000%
Benzene	0.0010	78	0.0008	0.005%
Cyclohexane	0.0010	84	0.0008	0.005%
n-Heptane	0.0010	100	0.0010	0.006%
Toluene	0.0010	92	0.0009	0.005%
Ethylbenzene	0.0000	106	0.0000	0.000%
Xylenes	0.0030	106	0.0032	0.018%
Octanes+	0.0020	114	0.0023	0.013%
Nonanes+	0.0140	128	0.0179	0.104%
Decanes+	0.0160	142	0.0227	0.131%
Total	100.000			100.000%
Molecular Weight			17.2936	

High CO2 volume % indicates this sample is possibly untreated separator gas stream

These values appear rounded (potentially by Excel). Duplication of 0.001 values appears unusual.

HEXANES		
NMHC	0.5102	2.950%
VOCs (NMNEHC)	0.0950	0.549%
HAPs	0.0057	0.03%
H2S Mole Fraction	0.0000	0.000%
Total HC	15.6072	90.248%
THC:VOC Ratio	0.6087	0.609%

E&P TANK Report

Flowsheet Selection : Oil Tank with Separator
Calculation Method : RVP Distillation
Control Efficiency : 95.0%
Known Separator Stream : Low Pressure Gas
Entering Air Composition : No

****
* Data Input *
****

Separator Pressure : 23.00[psig]
Separator Temperature : 85.00[F]
Molar GOR : 0.0500
Ambient Pressure : 14.70[psia]
Ambient Temperature : 70.00[F]
C10+ SG : 0.8990
C10+ MW : 166.00

These are all default values in E&P TANK, not site-specific values. Emissions inventory (EI) requires site-specific values.

-- Low Pressure Gas --

No.	Component	mol %
1	H2S	0.0000
2	O2	0.0000
3	CO2	4.3680
4	N2	15.7700
5	C1	77.5850
6	C2	1.9790
7	C3	0.1310
8	i-C4	0.0140
9	n-C4	0.0180
10	i-C5	0.0020
11	n-C5	0.0000
12	C6	0.0030
13	C7+	0.0320
14	Benzene	0.0450
15	Toluene	0.0380
16	E-Benzene	0.0030
17	Xylenes	0.0100
18	n-C6	0.0020
19	224Trimethylp	0.0000

Where did these values originate? Need to provide sample analysis.

C7+ Molar Ratio:

C7 :	C8 :	C9 :	C10+
1.0000	1.0000	1.0000	1.0000

These are all default values in E&P TANK, not site-specific values. EI requires a liquid sample analysis.

E&P TANK Report

```
Production Rate               : 50[bbl/day]
Days of Annual Operation      : 365 [days/year]
API Gravity                   : 46.0
Reid Vapor Pressure           : 7.70[psia]
```

These are all default values in E&P TANK (except for the production data), not site-specific values. Reported emissions are potentially inaccurate.

```
******************************************************************************
******
*     Calculation Results
    *
******************************************************************************
******
```

-- Emission Summary

Page 1-- E&P TA

Item	Uncontrolled [ton/yr]	Uncontrolled [lb/hr]	Controlled [ton/yr]	Controlled [lb/hr]
Total HAPs	0.020	0.005	0.001	0.000
Total HC	2.333	0.533	0.117	0.027
VOCs, C2+	0.549	0.125	0.027	0.006
VOCs, C3+	0.399	0.091	0.020	0.005

Uncontrolled Recovery Info.

Vapor	288.3300 x1E-3	[MSCFD]
HC Vapor	249.9200 x1E-3	[MSCFD]
GOR	5.77	[SCF/bbl]

-- Emission Composition

No	Component	Uncontrolled [ton/yr]	Uncontrolled [lb/hr]	Controlled [ton/yr]	Controlled [lb/hr]
1	H2S	0.000	0.000	0.000	0.000
2	O2	0.000	0.000	0.000	0.000
3	CO2	0.411	0.094	0.411	0.094
4	N2	0.256	0.058	0.256	0.058
5	C1	1.783	0.407	0.089	0.020
6	C2	0.151	0.034	0.008	0.002
7	C3	0.016	0.004	0.001	0.000
8	i-C4	0.002	0.000	0.000	0.000
9	n-C4	0.003	0.001	0.000	0.000
10	i-C5	0.000	0.000	0.000	0.000
11	n-C5	0.000	0.000	0.000	0.000
12	C6	0.001	0.000	0.000	0.000
13	C7	0.237	0.054	0.012	0.003
14	C8	0.086	0.020	0.004	0.001
15	C9	0.033	0.008	0.002	0.000
16	C10+	0.001	0.000	0.000	0.000
17	Benzene	0.009	0.002	0.000	0.000
18	Toluene	0.008	0.002	0.000	0.000
19	E-Benzene	0.001	0.000	0.000	0.000
20	Xylenes	0.002	0.000	0.000	0.000
21	n-C6	0.000	0.000	0.000	0.000
22	224Trimethylp	0.000	0.000	0.000	0.000
	Total	3.000	0.685	0.150	0.034

-- Stream Data

No.	Component	MW	LP Oil	Flash Oil	Sale Oil	Flash Gas	W&S Gas

Page 2

Questions?

Danielle Nesvacil
(512) 239-2102
danielle.nesvacil@tceq.texas.gov