VOC EMISSIONS FROM OIL AND CONDENSATE STORAGE TANKS

FINAL REPORT

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Executive Summary

This document reports measurements of speciated volatile organic compound (VOC) emissions from oil and condensate storage tanks at wellhead and gathering site tank batteries in East Texas. The measurements were made by directly monitoring the flow rates of gases escaping from storage tank vents and sampling the vent gases for chemical composition. An emission factor reflecting tank working, breathing, and flashing losses for each tank was calculated by dividing the measured emission rate by the amount of oil or condensate produced during the sampling period. The emission factors are expressed in units of pounds of VOC per barrel of liquid hydrocarbon produced (lb/bbl). Average emission factors for oil and condensate storage tanks were multiplied, respectively, by oil and condensate production totals for East Texas counties, including the Dallas-Fort Worth (DFW), Houston-Galveston-Brazoria (HGB), and Beaumont-Port Arthur (BPA) ozone nonattainment areas, to estimate regional emissions. Options for controlling tank battery vent gas emissions are also presented and discussed.

Emission measurements were made at 11 oil and 22 condensate tank battery sites in the BPA, DFW, and HGB areas during May-July, 2006. The average VOC emission factors for oil and condensate storage tanks were 1.6 ± 99% lb/bbl and 33.3 ± 73% lb/bbl, respectively, where the uncertainties are represented by the 95% confidence intervals of the means (Table ES-1). Variable site characteristics such as separator temperature, separator pressure, and the physicochemical properties of the liquid hydrocarbons, in addition to very low condensate production rates at well sites in Denton and Parker counties are probable leading causes of the uncertainty.

Table ES-1. Average, Standard Deviation, and Range of VOC Vent Gas Emission Factors Measured for Oil and Condensate Storage Tank Batteries

	Emission Factor (lb/bbl)	
	Oil Tanks **Number Sampled =11**	**Condensate Tanks** [a] Number Sampled = 22
Arithmetic Mean	1.6	33.3
Standard Deviation	2.3	53.3
95% Confidence Interval for Mean	0.0 – 3.1	9.1 – 57.7
Minimum	0.0	0.7
Maximum	6.8	215.1
Median	0.8	12.0

[a] Excludes data from one well site that was not representative of normal operating conditions

Table ES-2 gives the total *uncontrolled* VOC emissions estimated for wellhead and gathering site storage tanks in the HGB, DFW, and BPA based on the arithmetic mean emission factors given in Table ES-1 and 2005 daily average oil and condensate production[1]. These estimates assume no vent gas controls at any source; although, it is evident based on screening of candidate host sites that vent gas is recovered at some undetermined number of tank batteries in East Texas. Additional uncertainties in the regional emissions estimates stem from the average emission factor uncertainties, which as noted above are close to a factor of 2, and the small number of test sites relative to the entire population of storage tank batteries in East Texas.

The number and selection of tank batteries that were sampled in this study were limited by budget and schedule constraints in addition to the finite pool of host sites that provided voluntary access. Future studies can reduce average emission factor uncertainty and broaden their applicability by sampling a larger number of tank batteries and by conducting the tests during a wider variety of weather conditions, respectively.

Table ES-2. Estimated VOC Emissions from Oil and Condensate Wellhead and Gathering Site Storage Tanks

Nonattainment Area	Oil (bbl/Year)	Condensate (bbl/Year)	Estimated VOC (Tons per Day)
BPA	2,419,201	3,065,105	145
DFW	102,558	816,724	38
HGB	9,875,858	5,858,404	289
East Texas Attainment Counties [a]	49,939,437	16,171,858	846
East Texas Region Total [a]	62,337,054	25,912,091	1,317

[a] The East Texas Region is defined by all the Texas counties that are traversed by or east of Interstate-35 or Interstate-37, plus Montague, Wise, Parker, Hood, Somervell, and Bosque counties

[1] The 2005 oil and condensate production levels were downloaded during July 2006 from the Texas Railroad Commission Production Data Query System, which is located on the Internet at http://www.rrc.state.tx.us/interactive_data.html.

1.0 Introduction

This document reports measurements of speciated volatile organic compound (VOC) emissions from oil and condensate storage tanks at wellhead and gathering site tank batteries in East Texas. The measurements were made by directly monitoring the flow rates of gases escaping from storage tank vents and sampling the vent gases for chemical composition. An emission factor reflecting tank working, breathing, and flashing losses for each tank was calculated by dividing the measured emission rate by the amount of oil or condensate produced during the sampling period. The emission factors are expressed in units of pounds of VOC per barrel of liquid hydrocarbon produced (lb/bbl). Average emission factors for oil and condensate storage tanks were multiplied, respectively, by oil and condensate production totals for East Texas counties, including the Dallas-Fort Worth (DFW), Houston-Galveston-Brazoria (HGB), and Beaumont-Port Arthur (BPA) ozone nonattainment areas, to estimate regional emissions. Options for controlling tank battery vent gas emissions are also presented and discussed.

The remainder of this section provides the objectives of this study and background information on vent gas emissions from oil and condensate storage tanks. Sections 2 and 3 of this report give the measurement approach and results, respectively. Section 4 describes options for controlling tank battery vent gas emissions. Conclusions and recommendations for future work are provided in Section 5.

1.1 Objectives

The objective of this Texas Environmental Research Consortium (TERC) study is to support the Texas Commission on Environmental Quality (TCEQ) in its efforts to evaluate ozone control strategies for DFW and HGB by conducting three specific tasks:

1) Develop average emission factors, in units of pounds of VOC per barrel of oil or condensate produced (lb/bbl), from direct measurements of vent gas flow rates and chemical composition;
2) Use the average emission factors to estimate regional *uncontrolled* emissions for East Texas ozone nonattainment areas and the East Texas Region as a whole; and
3) Identify and compare options for controlling vent gas emissions.

The emissions estimates produced by this study are intended to improve the quality of region photochemical modeling that TCEQ is performing in support of the ozone State Implementation Plans (SIPs) for the HGB and DFW areas.

1.2 Background

Measurements conducted by the National Oceanic and Atmospheric Administration (NOAA) and other research organizations during the 2000 Texas Air Quality Study (TexAQS 2000) suggested that the levels of volatile organic compounds (VOC) found in ambient air could not all be accounted for based on reported emissions estimates. Following this finding, the Texas Commission on Environmental Quality (TCEQ) began an intensive effort to identify, quantify, and reduce VOC emissions that previously had been underestimated. In 2005, using remote sensing measurement results, TCEQ identified oil and condensate storage tanks as a source category for potentially underestimated emissions (TCEQ, 2005).

Oil and condensate storage tank emissions at wellhead and gathering sites are composed of working losses, breathing losses, and flashing losses. Working losses are vapors that are displaced from a tank during the filling cycle and breathing losses are vapors that are produced in response to diurnal temperature changes. Flashing losses are vapors that are released when a liquid with entrained gases experiences a pressure drop, as during the transfer of liquid hydrocarbons from a wellhead or separator to a storage tank that is vented to the atmosphere.

The U.S. Environmental Protection Agency (EPA) TANKS model (all versions as of September 2006) does not calculate flash emissions; however, several other methods are available for estimating flash emissions from oil and condensate storage tanks. These methods, to name a few, include direct measurement of vent gas flow and chemical composition; process simulator models such as HYSIM®, WINSIM® and PROSIM®; the American Petroleum Association's E&P Tank model; and the Vasquez-Beggs equation. These emissions estimating tools are described elsewhere (TCEQ, 2006; ODEQ, 2004). TCEQ (2006) considers the direct measurement approach to be the most accurate for estimating oil and condensate storage tank emissions at wellhead and gathering sites; however, other, less accurate, approaches appear to be much more commonly used[2].

No reports of oil or condensate storage tank emission factors derived from direct vent gas measurements have been found in the public domain literature; however, Lesair Environmental, Inc. (2003) reported emission factors for 25 condensate storage tank batteries in Colorado based on sampling pressurized liquid from wellhead processing equipment and using the E&P Tank model and PROSIM® (Lesair Environmental, Inc., 2002) to calculate vent gas emissions. An analysis of the data by the Colorado Department of Public Health and Environment (CDPHE) produced average emission factors of 13.7 lb/bbl and 10.0 lb/bbl for different condensate

[2] Costs may run approximately $2000-$3000 for a vent gas 24-hour flow rate measurement and grab sample for chemical composition. Direct measurements over weekly or monthly averaging periods may require installation of dedicated flow monitoring and data acquisition systems.

producing regions (CDPHE, 2006). When applied to condensate production rate estimates, CDPHE estimated a total uncontrolled emission inventory of 134 tons/day for the Denver Early Action Compact Area (CDPHE, 2004), an estimate that is roughly 25% of the total anthropogenic VOC emissions for the area.

2.0 Technical Approach

This section describes the technical approach used to estimate emission factors and regional emissions of speciated VOC from oil and condensate storage tanks at wellhead and gathering sites in East Texas.

2.1 Selection of Sampling Sites

Producers of oil and condensate in the Houston-Galveston-Brazoria (HGB), Dallas-Fort Worth (DFW), and Beaumont-Port Arthur (BPA) ozone nonattainment areas were identified from a directory of entities registered with the Texas Railroad Commission's Oil and Gas Division. The oil and gas directory is available on the Internet at http://www.rrc.state.tx.us/divisions/og/ogdirectory/index.html. Telephone calls, explaining the purpose of this study and requesting permission to sample storage tank vent gas emissions, were placed to the top oil and condensate producers in the HGB, DFW, and BPA (about 40 companies producing greater than 1% of the total oil or condensate in any of the HGB, DFW, or BPA areas). The telephone canvassing yielded invitations from seven companies to perform the emission measurements at one or more wellhead or gathering sites. Reasons given for participating in the study included ground truthing of emissions estimates derived using other methods and evaluation of the economic value of vapor recovery.

Efforts to gain broader participation in the study by other operating companies included a letter sent on TCEQ letterhead and an email message distributed by the Texas Oil & Gas Association (TXOGA) to its Upstream Environmental Committee, each explaining the purpose of the study and requesting voluntary cooperation. Neither of these additional efforts resulted in additional voluntary participation in the study.

Before any sampling was conducted at candidate tank battery sites, field inspections were made to determine the condition of the storage tanks and whether access to suitable sampling ports existed. The storage tank battery sites generally consisted of one or more wellheads, one or more high pressure separators and two or more storage tanks containing either water or liquid hydrocarbon (oil or condensate). A photograph of a typical storage tank battery site is shown in Figure 2-1. Five storage tank batteries out of 39 that we inspected were equipped with vapor recovery units.

Some storage tank batteries in East Texas are configured with gun barrel tanks to separate the fluid produced from a well into oil, gas, and water upstream of the storage tanks. Some lease operators consider the gun barrel to be the only tank having flash emissions while the storage tanks are assumed to have only working and breathing emissions. Only one of the tank batteries that were sampled during this study was configured with a gun barrel tank.

Figure 2-1. Example Storage Tank Battery with Separators

The approximate age of the inspected tank batteries ranged from 2 to more than 50 years. The conditions of the storage tank batteries were found to vary quite a bit, with some older tanks being of bolted construction and the newer tanks being of welded construction. The welded tank batteries generally had piping for vent gas consolidation to a common vent. The storage tank capacities ranged from 300 to 500 barrels except for at one gathering station, which had tank capacities ranging from 5,000 to 10,000 barrels. This gathering station is identified below as Tank Battery #12.

Thirty-three tank batteries met the criteria for sampling vent gas emissions. Four of the older tanks that were inspected were not sampled because they had rusted tops with holes ranging in size from about one-half inch to over one foot diameter. Another two inspected sites did not meet our initial sampling criteria because vent gas was being controlled by vapor recovery units (VRUs). Later, with approval from HARC and TCEQ, we eliminated the condition against sampling tank batteries having vent gas controls as long as the control device could be switched off or bypassed to sample uncontrolled emissions. Indeed, Tank Batteries 3, 5, and 6 had VRUs but were sampled with the VRUs switched off. Several tanks were found during our inspections with hatch covers that were left open allowing vent gas to escape. These tanks were sampled but only after the hatch covers were closed and sealed. Of the 33 tank batteries that were sampled, 27 transferred its liquid product by tanker truck, five by pipeline, and one by barge.

2.2 Measurement Approach

Storage tank emissions were measured by determining vent gas flow rates and sampling the vent gas for chemical composition. Tank batteries having multiple tanks were sampled through common vent gas gathering pipes located at the tops of the tanks (see, for example, Figure 2-2). All vent gas measurements and sampling was conducted at atmospheric pressure. Thief hatches and other potential sources of fugitive emissions were all sealed before making any measurements.

Figure 2-2. Vent Gas Gathering Pipe atop Storage Tanks

Flow rates were measured using a Fox Instruments Model 10A Thermal Mass Flow Meter. This instrument uses a thermal flow sensor, which operates on the principle that fluids absorb heat. A heated sensor placed in the gas stream transfers heat to the gas in proportion to the mass flow rate. Using a bridge circuit, one sensor detects the gas temperature while a second sensor is maintained at a constant temperature above the gas temperature. The temperature difference results in a power demand that equals the gas mass flow rate. The thermal mass flow meter was certified traceable to the National Institute of Standards and Technology (NIST) in September 2005, with an accuracy of ± 0.75% of reading ± 0.5% of full scale. Flow rates were measured over periods of approximately 24 hours. Figure 2-3 shows the Fox flow meter connected to a storage tank vent.

Figure 2-2. Fox Model 10A Flow Meter

Vent gas composition was measured using the Gas Processors Association (GPA) Method 2286-95, titled *"Tentative Method of Extended Analysis for Natural Gas and Similar Mixtures by Temperature Programmed Gas Chromatography"* (GPA, 1995). This analytical method measures the chemical composition of gas mixtures using gas chromatography with flame ionization and thermal conductivity detectors.

The vent gas samples for laboratory compositional analysis were collected in 300 CC evacuated metal bottles. A flexible hose-metal tube combination was connected to one end of the bottle and a hand "squeeze" pump with one way valve was connected to the exit end of the bottle. The flex hose was inserted two feet into the instrumentation tube[3] with flowing vent gas or into the stock tank just above the oil level. The valve on the "oil" side of the bottle was opened. Then the valve on the exit end of the bottle was opened. The hand pump with one way valve was pumped 150 times, both valves on the ends of the sample bottle were then closed, the sample unit was disassembled and the bottle was labeled with an identification tag to indicate the date and location of sample collection. The samples were hand delivered by the COMM Engineering field engineers to FESCO, Ltd. in Lafayette, Louisiana. From there, the samples were transported as registered hazardous cargo to the main FESCO laboratory in Alice, Texas, for analysis.

2.3 Development of Regional Emission Estimates

An emission factor for each tank battery was derived from the field measurement of average vent gas flow rate, the compositional analysis, and measurement of oil or condensate production rate over the period in which the average flow rate was determined. The average emission factors for oil and condensate storage tanks were multiplied, respectively, by 2005 annual oil and condensate production totals for East Texas counties (which were downloaded from the Texas Railroad Commission website during July 2006) and divided by 365 to estimate countywide daily vent gas emissions. The equation used to estimate countywide emissions is:

$$\text{Emissions (ton/day)} = [(EF_o \times P_o) + (EF_c \times P_c)] \div 365$$

Where:

EF_o and EF_c = The arithmetic mean emission factors for oil and condensate tank batteries, respectively in lb/bbl; and

P_o and P_c = The county 2005 total oil and condensate production, respectively, in bbl.

The East Texas region for this study is defined by all the Texas counties that are traversed by or East of Interstate-35 or Interstate-37, including Montague, Wise, Parker, Hood, Somervell, and Bosque counties (Figure 2-4).

[3] The "instrumentation tube" is a two inch diameter four foot long pipe into which all vent gas is routed so that all vent gas will flow across the thermal mass flow meter probe. The instrument probe of the thermal mass flow meter is inserted horizontally at ninety degrees into the two inch "instrumentation tube."

Figure 2-4. The East Texas Study Area (ERG, 2005)

3.0 **Measurement Results**

Table 3-1 gives the API gravities and separator discharge pressures for the 33 tank battery sites that were sampled. API gravities ranged from 19° to 48°, except at the 11 Denton County sites where API gravities ranged from 58° to 61°. Separator discharge pressures ranged from 34 psi to 48 psi except at the 11 Denton County sites and at one gathering station in Galveston County (Tank Battery 32). The Denton County separator discharge pressures were all approximately 200 psi and Tank Battery 32 in Galveston County had a separator discharge pressure of 121 psi. Brief descriptions of each tank battery site are given in Appendix A.

Tables 3-2 and 3-3 summarize the measurement results for oil and condensate tank batteries, respectively, and give the calculated emission factors in units of pounds VOC per barrel of oil/condensate produced. The emission factor for each tank battery was derived using the following equation.

$$EF = (\text{Vent Gas} \times MW \times F) \div (379 \times PR);$$

Where:

EF = the VOC emission factor in lb/bbl;
Vent Gas = vented gas in scf/day;
MW = molecular weight of the vented gas in lb/lb-mole;
F = VOC weight fraction of the vented gas;
PR = oil or condensate production rate in bbl/day; and
379 = volume to mass conversion factor in scf/lb-mole at standard atmospheric pressure and 60°F

For example, Tank Battery No. 1 has:

$$1.59 \text{ lb/bbl} = (4153 \text{ scf/day} \times 44.84 \text{ lb/lb-mol} \times 0.81) \div (379 \text{ scf/lb-mol} \times 250 \text{ bbl/day})$$

Site-specific emission factors for oil storage tank batteries ranged from 0.0 to 6.8 lb/bbl, with an arithmetic mean and 95% confidence interval of 1.6 ± 1.5 lb/bbl. Note that the vent gas from Tank Battery # 8, which had the lowest emission factor, 0.0 lb/bbl, was comprised entirely of methane, ethane, and carbon dioxide (Table 3-4).

Site specific emission factors for condensate storage tank batteries ranged from 0.7 to 1218 lb/bbl; however, the vent gas flow rate at Tank Battery #26, which had the highest emission factor, was measured during non-representative conditions in which approximately 97% of the vented volume was released during the first eight hours of the sampling period. Operating personnel at Tank Battery #26 attributed this anomaly to fracking at an adjacent well. Fracking is a process in which fluids are injected into a well bore under high pressure to force the release of oil or gas from rock formations. Excluding Tank Battery #26, the arithmetic mean emission factor and 95% confidence intervals for condensate storage tank vent gas was 33.3 ± 24.3 lb/bbl.

Table 3-1. API Gravities and Separator Discharge Pressures for Sampled Tank Batteries

Tank Battery	Date Sampled	Liquid Hydrocarbon	County	API Gravity	Separator Discharge Pressure (PSI)
1	05/02/06	Oil	Liberty	19	34
2	05/11/06	Condensate	Montgomery	42	41
3	05/09/06	Condensate	Montgomery	41	38
4	05/10/06	Condensate	Montgomery	40	34
5	05/10/06	Condensate	Montgomery	43	46
6	05/09/06	Condensate	Montgomery	39	33
7	05/16/06	Oil	Waller	20	40
8	05/17/06	Oil	Waller	20	40
9	05/16/06	Oil	Waller	20	40
10	05/17/06	Oil	Waller	20	40
11	06/09/06	Oil	Jefferson	42	36
12	06/09/06	Oil	Jefferson	42	42
13	07/10/06	Condensate	Denton	61	~200
14	07/10/06	Condensate	Denton	59	~200
15	07/11/06	Condensate	Denton	61	~200
16	07/11/06	Condensate	Denton	61	~200
17	07/13/06	Condensate	Denton	58	~200
18	07/13/06	Condensate	Denton	58	~200
19	07/14/06	Condensate	Denton	58	~200
20	07/14/06	Condensate	Denton	59	~200
21	07/19/06	Oil	Montague	47	48
22	07/19/06	Oil	Montague	44	45
23	07/20/06	Condensate	Parker	48	39
24	07/20/06	Condensate	Parker	41	36
25	07/17/06	Condensate	Denton	58	~200
26	07/17/06	Condensate	Denton	58	~200
27	07/18/06	Condensate	Denton	59	~200
28	07/15/06	Condensate	Brazoria	46	38
29	07/26/06	Condensate	Brazoria	42	41
30	07/26/06	Condensate	Brazoria	42	36
31	07/27/06	Oil	Galveston	45	38
32	07/27/06	Condensate	Galveston	48	121
33	07/27/06	Oil	Galveston	43	44

Table 3-2. Vent Gas Flow Rates and Emissions for Oil Storage Tank Batteries

Tank Battery	County	Area	Vent Gas (scf/day) [a]	Mol. Wt. [b]	Total Vent Gas (lb/day) [c]	Wt. % VOC [d]	VOC (lb/day) [e]	Oil Prod (bbl/day) [f]	VOC (lb/bbl) [g]
1	Liberty	HGB	4,153	44.8	491.3	81%	397.9	250	1.59
7	Waller	HGB	977	19.8	51.1	18%	9.4	200	0.05
8	Waller	HGB	48	16.4	2.1	0%	0.0	50	0.00
9	Waller	HGB	18	35.7	1.7	64%	1.1	65	0.02
10	Waller	HGB	89	51.6	12.1	71%	8.6	30	0.29
11	Jefferson	HGB	2,909	22.3	171.1	29%	48.9	250	0.20
12	Jefferson	HGB	2,594	43.9	300.6	73%	220.8	250	0.88
21	Montague	E TX	14,974	43.1	1,700.9	72%	1,219	180	6.77
22	Montague	E TX	6,992	42.7	788.5	43%	335.7	63	5.33
31	Galveston	HGB	2,047	32.1	173.4	57%	99.1	125	0.79
33	Galveston	HGB	6,335	21.5	359.4	22%	79.7	60	1.33
Arithmetic Mean			**3,740**	**34**	**368**	**48%**	**220**	**138**	**1.6**
Standard Deviation			**4,438**	**12**	**504**	**27%**	**359**	**89**	**2.3**
Minimum			**18**	**16**	**2**	**0%**	**0**	**30**	**0.0**
Maximum			**14,974**	**52**	**1,701**	**1**	**1,219**	**250**	**6.8**
Median			**2,594**	**36**	**173**	**57%**	**80**	**125**	**0.8**

[a] Measured vent gas flow rate in scf/day.

[b] Molecular weight of the vent gas sample.

[c] Vent gas emissions converted to units of lb/day.

[d] VOC content of vent gas, as percentage of total weight (excludes methane, ethane, carbon dioxide and nitrogen contents of the vent gas).

[e] Measured VOC emissions expressed in units of lb/day.

[f] An earlier version of this report attributed oil production rate data to the Texas Railroad Commission online interactive database. That was incorrect. Daily average oil production rates rates during the sampling period were obtained from site operating logs.

[g] VOC emission factor in units of lb/bbl.

Table 3-3. Vent Gas Flow Rates and Emissions for Condensate Storage Tank Batteries

Tank Battery	County	Area	Vent Gas (scf/day) [a]	Mol. Wt. [b]	Total Vent Gas (lb/day) [c]	Wt. % VOC [d]	VOC (lb/day) [e]	Cond. Prod (bbl/day) [f]	VOC (lb/bbl) [g]
2	Montgomery	HGB	11,406	27.3	821.3	47%	383.2	105	3.65
3	Montgomery	HGB	12,642	33.4	1,113.8	62%	688.9	87	7.92
4	Montgomery	HGB	1,807	34.3	163.4	57%	93.7	120	0.78
5	Montgomery	HGB	863	42.2	96.2	70%	67.4	100	0.67
6	Montgomery	HGB	6,200	36.4	594.6	65%	384.7	130	2.96
13	Denton	DFW	793	46.4	97.0	81%	78.5	2	39.23
14	Denton	DFW	2,744	30.5	220.7	53%	118.0	4	29.51
15	Denton	DFW	584	47.6	73.4	82%	60.0	5	11.99
16	Denton	DFW	1,084	50.0	143.1	85%	121.2	2	60.58
17	Denton	DFW	4,594	36.6	443.2	65%	290.2	2	145.11
18	Denton	DFW	1,015	38.9	104.2	70%	73.4	10	7.34
19	Denton	DFW	291	44.3	34.0	77%	26.3	2	13.16
20	Denton	DFW	3,113	46.4	380.8	80%	304.3	10	30.43
23	Parker	DFW	1,358	51.9	185.9	81%	150.2	27	5.56
24	Parker	DFW	53	43.0	6.0	70%	4.2	1	4.22
25	Denton	DFW	926	89.0	217.4	99%	215.1	1	215.08
27	Denton	DFW	235	54.0	33.5	86%	28.8	2	14.39
28	Brazoria	HGB	2,846	30.2	226.9	55%	125.2	30	4.17
29	Brazoria	HGB	21,601	43.5	2,476.4	83%	2,055	61	33.68
30	Brazoria	HGB	1,639	34.2	147.9	62%	91.6	15	6.11
32	Galveston	HGB	77,319	50.6	10,312.6	87%	9,016	142	63.49
26	Denton	DFW	9,210	56.2	1,365.7	89%	1,218	1	1217.58
Arithmetic Mean [i]			**7,291**	**43**	**852**	**72%**	**685**	**41**	**33.3**
Standard Deviation [i]			**16,906**	**13**	**2,238**	**13%**	**1,959**	**50**	**53.3**
Minimum [i]			**53**	**27**	**6**	**47%**	**4**	**1**	**0.7**
Maximum [i]			**77,319**	**89**	**10,313**	**99%**	**9,016**	**142**	**215.1**
Median [i]			**1,639**	**43**	**186**	**70%**	**121**	**10**	**12.0**

[a] Measured vent gas flow rate in scf/day.

[b] Molecular weight of the vent gas sample.

[c] Vent gas emissions converted to units of lb/day.

[d] VOC content of vent gas, as percentage of total weight (excludes methane, ethane, carbon dioxide and nitrogen contents of the vent gas).

[e] Measured VOC emissions expressed in units of lb/day.

[f] An earlier version of this report attributed condensate production rate data to the Texas Railroad Commission online interactive database. That was incorrect. Daily average condensate production rates during the sampling period were obtained from site operating logs..

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[g] VOC emission factor in units of lb/bbl.

[i] Excludes Tank Battery 26 (see text on page 3-1 for an explanation)

Table 3-4 gives the speciation profiles in weight percentages based on the extended gas analysis of vent gas samples collected from each oil storage tank battery. Table 3-5 gives the speciation profiles for condensate storage tank samples. Volatile organic compounds (which consisted of the entire gas analysis minus methane, ethane, carbon dioxide, and nitrogen) comprised from 0% to 87% of the vent gas mass from oil tank batteries and from 53% to 99% of the vent gas mass from condensate tank batteries.

Table 3-6 gives the total *uncontrolled* VOC emissions estimated for wellhead and gathering site storage tanks in the HGB, DFW, and BPA based on the arithmetic mean emission factors given in Table ES-1 and 2005 daily average oil and condensate production[4]. The total uncontrolled VOC emissions estimate for HGB is 289 tons per day. The uncontrolled VOC emissions estimates for BPA and DFW are 145 tpd and 38 tpd, respectively; while the uncontrolled emissions estimate for the remainder of the East Texas Region is 846 tpd. These estimates assume no vent gas controls at any source; although, it is evident based on screening of candidate host sites that vent gas is recovered at some undetermined number of tank batteries in East Texas. Additional uncertainties in the regional emissions estimates stem from the average emission factor uncertainties, which as noted above are close to a factor of 2, and the small number of test sites relative to the entire population of storage tank batteries in East Texas. Users of these data should also be mindful that daytime high temperatures ranged from 98 – 107 F at Dallas-Fort Worth Airport during the 9-day period in mid-July, 2006, when condensate storage tanks were sampled in the DFW area. Hence, the average emission factors derived from these data are representative of weather conditions that are favorable for summertime ozone formation and accumulation but perhaps not for estimating annual emissions.

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[4] The 2005 oil and condensate production levels were downloaded during July 2006 from the Texas Railroad Commission Production Data Query System, which is located on the Internet at http://www.rrc.state.tx.us/interactive_data.html.

Table 3-4. Measured Vent Gas Speciation Profiles in Weight Percent for Oil Tank Batteries

	Weight %						
	Site 1	Site 7	Site 8	Site 9	Site 10	Site 31	Site 33
County:	**Liberty**	**Waller**	**Waller**	**Waller**	**Waller**	**Galveston**	**Galveston**
Nitrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon Dioxide	1.56	2.57	2.67	3.66	13.64	2.05	4.46
Methane	9.95	67.81	96.81	25.47	14.19	23.91	58.59
Ethane	7.50	11.23	0.53	6.46	1.38	16.91	14.75
Propane	21.83	14.91	0.00	12.75	1.83	21.82	9.97
Isobutane	9.84	0.51	0.00	5.35	0.65	9.94	3.57
n-butane	14.39	1.20	0.00	8.26	1.49	8.83	3.08
2,2-Dimethylpropane	0.06	0.00	0.00	0.06	0.00	0.16	0.06
Isopentane	7.20	0.05	0.00	4.22	1.53	3.83	1.45
n-pentane	5.54	0.13	0.00	2.59	1.07	2.59	0.88
2,2-Dimethylbutane	0.34	0.04	0.00	1.22	1.31	0.23	0.09
Cyclopentane	0.47	0.01	0.00	0.27	2.76	0.16	0.05
2,3-Dimethylbutane	0.53	0.06	0.00	2.17	0.84	0.29	0.08
2-Methylpentane	2.36	0.01	0.00	1.24	0.00	1.07	0.34
3-Methylpentane	1.27	0.00	0.00	0.96	0.97	0.57	0.17
n-Hexane	2.47	0.01	0.00	0.42	0.08	1.13	0.33
Methylcyclopentane	1.60	0.03	0.00	1.10	0.84	0.55	0.15
Benzene	0.28	0.00	0.00	0.25	0.01	0.29	0.09
Cyclohexane	1.89	0.01	0.00	0.68	0.43	0.78	0.20
2-Methylhexane	0.53	0.01	0.00	0.88	2.07	0.27	0.07
3-Methylhexane	0.50	0.01	0.00	0.32	0.23	0.26	0.07
2,2,4-Trimethylpentane	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other C7's	1.30	0.16	0.00	4.20	9.27	0.59	0.16
n-Heptane	1.09	0.01	0.00	0.09	0.01	0.52	0.13
Methylcyclohexane	2.36	0.01	0.00	0.75	0.53	0.97	0.26
Toluene	0.62	0.01	0.00	0.37	0.18	0.24	0.09
Other C8's	1.78	0.11	0.00	5.45	18.98	0.76	0.22
n-Octane	0.48	0.01	0.00	0.48	1.39	0.23	0.08
Ethylbenzene	0.06	0.02	0.00	0.14	0.33	0.03	0.02
m+p-Xylene	0.28	0.02	0.00	0.56	0.38	0.13	0.08
o-Xylene	0.08	0.03	0.00	0.10	0.35	0.04	0.03
Other C9's	0.91	0.17	0.00	3.70	10.84	0.37	0.16
n-Nonane	0.22	0.01	0.00	0.89	0.51	0.12	0.07
Other C10's	0.51	0.46	0.00	3.16	8.81	0.21	0.16
n-Decane	0.07	0.02	0.00	0.49	0.28	0.05	0.04
Undecanes Plus	0.13	0.39	0.00	1.29	2.83	0.10	0.08
Sum	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Wt% VOC [a]	**80.99%**	**18.39%**	**0.00%**	**64.40%**	**70.80%**	**57.13%**	**22.19%**

[a] Weight % VOC excludes nitrogen, carbon dioxide, methane, and ethane.

Table 3-4. (continued) Measured Vent Gas Speciation Profiles in Weight Percent for Oil Tank Batteries

	Weight %					
	Site 11	Site 12	Site 21	Site 22	Mean	Std. Dev.
County:	Jefferson	Jefferson	Montague	Montague		
Nitrogen	0.00	0.00	0.00	0.00	0.00	0.00
Carbon Dioxide	3.58	3.69	10.58	45.84	8.57	12.93
Methane	59.43	13.96	9.36	8.46	35.27	30.21
Ethane	8.39	8.88	8.39	3.13	7.96	5.12
Propane	5.28	10.66	23.33	9.15	11.96	7.98
Isobutane	3.22	8.21	4.01	2.14	4.31	3.63
n-butane	3.74	8.56	16.42	9.85	6.89	5.46
2,2-Dimethylpropane	0.72	0.60	0.04	0.00	0.15	0.25
Isopentane	2.60	6.71	5.61	3.87	3.37	2.49
n-pentane	1.88	5.02	6.61	5.19	2.86	2.35
2,2-Dimethylbutane	0.46	0.97	0.02	0.02	0.43	0.50
Cyclopentane	0.13	0.28	0.63	0.39	0.47	0.79
2,3-Dimethylbutane	0.52	1.25	0.14	0.07	0.54	0.66
2-Methylpentane	0.84	2.32	1.89	1.26	1.03	0.89
3-Methylpentane	0.45	1.26	1.15	0.72	0.68	0.48
n-Hexane	0.80	2.21	2.75	1.87	1.10	1.05
Methylcyclopentane	0.46	1.30	1.56	0.99	0.78	0.59
Benzene	0.21	0.51	0.08	0.07	0.16	0.16
Cyclohexane	0.59	1.68	0.53	0.38	0.65	0.61
2-Methylhexane	0.22	0.62	0.36	0.22	0.48	0.59
3-Methylhexane	0.22	0.59	0.47	0.30	0.27	0.20
2,2,4-Trimethylpentane	0.00	0.00	0.00	0.00	0.00	0.00
Other C7's	0.71	1.85	1.82	1.13	1.93	2.71
n-Heptane	0.27	0.74	0.92	0.67	0.40	0.40
Methylcyclohexane	0.75	2.18	0.72	0.60	0.83	0.78
Toluene	0.23	0.75	0.11	0.16	0.25	0.24
Other C8's	0.88	2.77	1.30	1.05	3.03	5.52
n-Octane	0.08	0.47	0.33	0.29	0.35	0.39
Ethylbenzene	0.06	0.22	0.04	0.04	0.09	0.10
m+p-Xylene	0.19	1.04	0.05	0.10	0.26	0.31
o-Xylene	0.05	0.36	0.01	0.04	0.10	0.13
Other C9's	0.60	2.38	0.41	0.44	1.82	3.20
n-Nonane	0.08	0.92	0.11	0.22	0.29	0.34
Other C10's	0.88	3.43	0.18	0.55	1.67	2.65
n-Decane	0.20	0.86	0.05	0.46	0.23	0.27
Undecanes Plus	1.32	2.76	0.01	0.38	0.84	1.07
Sum	**100**	**100**	**100**	**100**	**100**	**0**
Wt% VOC [a]	**29%**	**73%**	**72%**	**43%**	**48%**	**27%**

[a] Weight % VOC excludes nitrogen, carbon dioxide, methane, and ethane.

Table 3-5. Measured Vent Gas Speciation Profiles in Weight Percent for Condensate Tank Batteries

	Weight %							
	Site 13	**Site 14**	**Site 15**	**Site 16**	**Site 17**	**Site 18**	**Site 19**	**Site 20**
County:	**Denton**	**Denton**	**Denton**	**Denton**	**Denton**	**Denton**	**Denton**	**Denton**
Nitrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon Dioxide	0.65	2.20	0.82	0.59	1.71	0.85	0.67	0.66
Methane	8.53	31.52	6.52	5.83	23.26	20.24	13.81	7.91
Ethane	9.96	12.80	10.93	8.93	9.54	8.53	8.14	11.51
Propane	17.08	12.08	18.67	16.72	10.21	10.19	9.91	17.20
Isobutane	7.02	4.48	7.84	7.48	3.68	4.54	4.76	7.30
n-butane	15.93	9.14	15.50	16.24	8.30	9.53	11.02	14.69
2,2-Dimethylpropane	0.09	0.00	0.00	0.19	0.00	0.00	0.00	0.08
Isopentane	8.52	5.34	8.60	9.25	5.38	6.26	8.90	8.96
n-pentane	9.33	5.73	9.08	10.02	6.66	7.52	10.22	9.53
2,2-Dimethylbutane	0.27	0.18	0.27	0.30	0.19	0.25	0.38	0.32
Cyclopentane	0.19	0.10	0.15	0.20	0.16	0.15	0.20	0.15
2,3-Dimethylbutane	0.43	0.28	0.45	0.48	0.36	0.43	0.59	0.47
2-Methylpentane	3.77	2.55	4.17	4.31	3.58	4.23	5.29	4.08
3-Methylpentane	1.89	1.28	2.11	2.14	1.84	2.16	2.67	2.01
n-Hexane	4.73	3.15	5.26	5.12	5.22	5.98	6.58	4.72
Methylcyclopentane	0.78	0.46	0.76	0.77	0.86	0.83	0.94	0.63
Benzene	0.19	0.13	0.18	0.20	0.22	0.23	0.25	0.17
Cyclohexane	0.94	0.58	0.83	0.88	1.14	1.16	1.17	0.76
2-Methylhexane	1.11	0.84	1.05	1.16	1.44	1.68	1.65	1.05
3-Methylhexane	1.03	0.79	0.95	1.06	1.41	1.54	1.49	0.93
2,2,4-Trimethylpentane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other C7's	1.29	0.92	1.24	1.30	1.75	1.81	1.79	1.12
n-Heptane	1.82	1.43	1.50	1.84	2.77	2.87	2.66	1.57
Methylcyclohexane	1.28	0.97	0.93	1.23	1.98	1.84	1.79	1.03
Toluene	0.40	0.33	0.25	0.41	0.69	0.65	0.58	0.35
Other C8's	1.60	1.46	1.08	1.77	3.10	3.01	2.51	1.45
n-Octane	0.39	0.38	0.26	0.46	0.93	0.91	0.62	0.38
Ethylbenzene	0.01	0.02	0.01	0.02	0.04	0.03	0.02	0.01
m+p-Xylene	0.12	0.14	0.08	0.17	0.42	0.34	0.22	0.16
o-Xylene	0.02	0.02	0.01	0.02	0.07	0.04	0.03	0.02
Other C9's	0.45	0.46	0.28	0.59	1.43	1.36	0.77	0.50
n-Nonane	0.07	0.08	0.07	0.11	0.38	0.30	0.14	0.10
Other C10's	0.09	0.13	0.11	0.17	0.75	0.41	0.21	0.15
n-Decane	0.01	0.02	0.02	0.02	0.17	0.04	0.02	0.02
Undecanes Plus	0.02	0.04	0.04	0.03	0.38	0.09	0.04	0.03
Sum	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Wt% VOC [a]	**81%**	**53%**	**82%**	**85%**	**65%**	**70%**	**77%**	**80%**

[a] Weight % VOC excludes nitrogen, carbon dioxide, methane, and ethane.

Table 3-5. (continued) Measured Vent Gas Speciation Profiles in Weight Percent for Condensate Tank Batteries

	Weight %							
	Site 23	**Site 24**	**Site 25**	**Site 26**	**Site 27**	**Site 28**	**Site 29**	**Site 30**
County:	**Parker**	**Parker**	**Denton**	**Denton**	**Denton**	**Brazoria**	**Brazoria**	**Brazoria**
Nitrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon Dioxide	5.13	7.04	0.80	0.57	1.66	1.46	0.45	3.65
Methane	10.28	12.35	0.09	3.93	6.53	31.93	10.04	23.10
Ethane	3.79	10.46	0.19	6.35	5.83	11.46	6.54	11.31
Propane	3.31	12.62	0.43	12.70	9.84	15.54	21.42	16.47
Isobutane	3.58	5.99	0.43	5.82	5.17	7.81	24.37	8.90
n-butane	8.45	10.59	1.88	14.26	12.34	8.23	15.10	10.02
2,2-Dimethylpropane	0.16	0.17	0.02	0.13	0.10	0.10	0.17	0.19
Isopentane	9.76	6.89	4.69	9.59	8.76	4.57	8.77	6.60
n-pentane	9.87	6.44	7.67	11.47	10.03	3.35	4.75	4.37
2,2-Dimethylbutane	0.73	0.38	0.34	0.33	0.35	0.22	0.23	0.39
Cyclopentane	0.13	0.08	0.25	0.30	0.27	0.24	0.16	0.30
2,3-Dimethylbutane	0.84	0.46	0.78	0.62	0.56	0.33	0.45	0.50
2-Methylpentane	7.42	4.13	8.41	6.16	6.02	1.51	1.79	2.01
3-Methylpentane	3.90	2.18	4.31	2.97	2.94	0.78	0.81	1.06
n-Hexane	8.18	4.55	13.84	7.87	7.90	1.65	1.35	1.84
Methylcyclopentane	0.71	0.43	1.97	1.22	1.11	0.89	0.39	1.08
Benzene	0.39	0.19	0.52	0.27	0.27	1.07	0.28	1.35
Cyclohexane	1.39	0.75	3.08	1.37	1.49	1.01	0.51	1.09
2-Methylhexane	3.12	1.82	5.20	1.72	2.27	0.41	0.24	0.43
3-Methylhexane	2.43	1.45	4.43	1.50	1.94	0.40	0.21	0.40
2,2,4-Trimethylpentane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other C7's	1.82	1.00	4.22	1.74	1.94	0.80	0.47	0.87
n-Heptane	3.57	2.24	9.21	2.71	3.65	0.87	0.35	0.67
Methylcyclohexane	2.33	1.43	6.16	1.82	2.52	1.23	0.48	1.13
Toluene	1.08	0.67	2.12	0.56	0.83	0.68	0.10	0.67
Other C8's	4.16	2.82	9.77	2.24	3.34	1.09	0.32	0.73
n-Octane	1.06	0.80	3.05	0.59	0.87	0.45	0.08	0.21
Ethylbenzene	0.03	0.22	0.07	0.01	0.02	0.07	0.02	0.03
m+p-Xylene	0.43	0.32	0.98	0.20	0.29	0.21	0.02	0.13
o-Xylene	0.05	0.04	0.15	0.03	0.04	0.07	0.01	0.03
Other C9's	1.41	0.93	3.23	0.62	0.84	0.55	0.09	0.25
n-Nonane	0.22	0.23	0.64	0.13	0.14	0.23	0.02	0.07
Other C10's	0.25	0.30	0.77	0.18	0.13	0.41	0.03	0.11
n-Decane	0.04	0.06	0.28	0.05	0.02	0.11	0.00	0.02
Undecanes Plus	0.01	0.00	0.03	0.00	0.01	0.26	0.01	0.05
Sum	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Wt% VOC [a]	**80%**	**70%**	**99%**	**89%**	**86%**	**55%**	**83%**	**62%**

[a] Weight % VOC excludes nitrogen, carbon dioxide, methane, and ethane.

Table 3-5. (continued) Measured Vent Gas Speciation Profiles in Weight Percent for Condensate Tank Batteries

	Weight %							
	Site 2	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 32**	**Mean**	**Std**
County:	**Montgomery**					**Galveston**		
Nitrogen	0.57	0.00	0.00	0.00	0.00	0.00	0.03	0.12
Carbon Dioxide	4.24	3.54	7.44	9.10	5.81	0.83	2.72	2.64
Methane	39.71	26.30	22.07	12.06	19.27	2.15	15.34	10.73
Ethane	8.83	8.31	13.15	8.76	10.22	9.59	8.87	2.99
Propane	14.21	16.42	17.25	17.54	19.05	26.38	14.33	5.72
Isobutane	4.52	5.79	5.09	6.47	6.34	16.38	6.99	4.86
n-butane	8.44	10.73	8.70	11.92	11.79	14.83	11.26	3.47
2,2-Dimethylpropane	0.02	0.04	0.06	0.07	0.00	0.29	0.09	0.08
Isopentane	3.89	5.10	4.12	5.91	5.61	9.70	7.05	2.04
n-pentane	3.32	4.35	3.53	5.03	4.90	5.20	6.93	2.63
2,2-Dimethylbutane	0.11	0.18	0.15	0.21	0.18	0.83	0.31	0.17
Cyclopentane	0.37	0.57	0.44	0.68	0.62	0.22	0.27	0.17
2,3-Dimethylbutane	0.23	0.34	0.32	0.41	0.39	0.58	0.47	0.15
2-Methylpentane	1.19	1.72	1.51	2.05	1.97	2.25	3.64	2.03
3-Methylpentane	0.62	0.90	0.82	1.07	1.03	1.21	1.85	1.03
n-Hexane	1.21	1.79	1.68	2.13	1.97	1.94	4.48	3.11
Methylcyclopentane	1.35	2.01	1.80	2.40	2.05	0.77	1.10	0.58
Benzene	0.34	0.63	0.57	0.75	0.49	0.44	0.41	0.31
Cyclohexane	1.16	1.83	1.73	2.18	1.72	0.83	1.25	0.59
2-Methylhexane	0.33	0.50	0.40	0.60	0.37	0.45	1.27	1.15
3-Methylhexane	0.15	0.22	0.40	0.26	0.35	0.42	1.08	0.98
2,2,4-Trimethylpentane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other C7's	0.77	1.17	1.25	1.39	1.17	0.89	1.40	0.75
n-Heptane	0.47	0.76	0.81	0.91	0.64	0.69	2.00	1.90
Methylcyclohexane	1.52	2.54	2.51	3.03	1.94	0.93	1.85	1.16
Toluene	0.53	1.10	1.02	1.32	0.56	0.48	0.70	0.43
Other C8's	0.82	1.39	1.46	1.66	0.83	0.70	2.15	1.97
n-Octane	0.17	0.32	0.34	0.38	0.06	0.24	0.59	0.62
Ethylbenzene	0.04	0.06	0.06	0.07	0.03	0.03	0.04	0.04
m+p-Xylene	0.17	0.38	0.34	0.45	0.12	0.15	0.26	0.20
o-Xylene	0.04	0.08	0.07	0.10	0.02	0.04	0.05	0.03
Other C9's	0.31	0.54	0.57	0.64	0.39	0.26	0.75	0.67
n-Nonane	0.07	0.11	0.10	0.13	0.03	0.09	0.16	0.14
Other C10's	0.18	0.23	0.19	0.28	0.07	0.13	0.24	0.19
n-Decane	0.03	0.03	0.02	0.04	0.01	0.03	0.05	0.06
Undecanes Plus	0.07	0.05	0.05	0.05	0.02	0.07	0.06	0.09
Sum	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
Wt% VOC [a]	**47%**	**62%**	**57%**	**70%**	**65%**	**87%**	**73%**	**14%**

[a] Weight % VOC excludes nitrogen, carbon dioxide, methane, and ethane.

Table 3-6. Total Vent Gas and VOC Emissions for East Texas Counties

Region	County	Oil (bbl)	Condensate (bbl)	VOC (tons/day)
BPA	HARDIN	1,240,479	470,853	24.2
BPA	JEFFERSON	844,405	1,962,565	91.4
BPA	ORANGE	334,317	631,687	29.6
BPA Total		**2,419,201**	**3,065,105**	**145.2**
DFW	COLLIN	0	0	0.0
DFW	DALLAS	0	0	0.0
DFW	DENTON	31,209	729,760	33.4
DFW	ELLIS	15	2	0.0
DFW	JOHNSON	0	16,334	0.7
DFW	KAUFMAN	55,574	0	0.1
DFW	PARKER	15,760	65,330	3.0
DFW	ROCKWALL	0	0	0.0
DFW	TARRANT	0	5,298	0.2
DFW Total		**102558**	**816,724**	**37.5**
HGB	BRAZORIA	1,697,448	719,494	36.5
HGB	CHAMBERS	902,015	399,981	20.2
HGB	FORT BEND	1,758,404	1,062,906	52.3
HGB	GALVESTON	686,061	698,427	33.4
HGB	HARRIS	1,529,176	515,274	26.8
HGB	LIBERTY	1,412,532	2,256,552	106.1
HGB	MONTGOMERY	756,038	142,456	8.1
HGB	WALLER	1,134,184	63,314	5.3
HGB Total		**9,875,858**	**5,858,404**	**288.7**
East Texas	ANDERSON	717,299	77,859	5.1
East Texas	ANGELINA	4,022	3,831	0.2
East Texas	ARANSAS	75,617	120,035	5.6
East Texas	ATASCOSA	729,802	11,624	2.1
East Texas	AUSTIN	265,450	138,234	6.9
East Texas	BASTROP	93,440	12,139	0.8
East Texas	BEE	320,007	202,036	9.9
East Texas	BEXAR	122,739	0	0.3
East Texas	BOSQUE	0	0	0.0
East Texas	BOWIE	98,673	6,372	0.5
East Texas	BRAZOS	1,960,987	83,578	8.0
East Texas	BURLESON	2,157,633	89,232	8.7
East Texas	CALDWELL	911,418	189	2.0
East Texas	CALHOUN	372,434	129,446	6.7
East Texas	CAMP	230,512	0	0.5
East Texas	CASS	299,994	25,840	1.8
East Texas	CHEROKEE	207,869	105,810	5.3
East Texas	COLORADO	191,399	207,831	9.9
East Texas	COOKE	1,573,679	22,650	4.4
East Texas	DE WITT	63,426	660,652	30.3
East Texas	FALLS	1,895	0	0.0
East Texas	FAYETTE	1,432,596	306,067	17.1
East Texas	FRANKLIN	387,794	59,908	3.6
East Texas	FREESTONE	70,730	212,035	9.8
East Texas	GOLIAD	337,355	581,157	27.3
East Texas	GONZALES	214,143	11,900	1.0
East Texas	GRAYSON	1,462,839	15,484	3.8
East Texas	GREGG	2,738,433	203,848	15.2
East Texas	GRIMES	122,487	55,957	2.8
East Texas	GUADALUPE	1,349,477	353	2.9
East Texas	HARRISON	459,255	530,475	25.2
East Texas	HAYS	0	0	0.0
East Texas	HENDERSON	575,893	42,701	3.2
East Texas	HILL	2	0	0.0
East Texas	HOOD	0	29,818	1.4
East Texas	HOPKINS	361,851	2,612	0.9
East Texas	HOUSTON	745,024	27,023	2.8

Table 3-6. (continued) Total Vent Gas and VOC Emissions for East Texas Counties

Region	County	Oil (bbl)	Condensate (bbl)	VOC (tons/day)
East Texas	HUNT	0	0	0.0
East Texas	JACKSON	747,698	309,131	15.7
East Texas	JASPER	192,489	261,183	12.3
East Texas	KARNES	266,421	82,701	4.3
East Texas	LAVACA	138,396	395,281	18.3
East Texas	LEE	1,599,865	51,564	5.8
East Texas	LEON	954,219	65,828	5.1
East Texas	LIMESTONE	91,433	73,589	3.6
East Texas	LIVE OAK	440,424	191,048	9.7
East Texas	MADISON	499,267	34,036	2.6
East Texas	MARION	124,307	52,424	2.7
East Texas	MATAGORDA	525,512	655,690	31.1
East Texas	MCLENNAN	1,787	0	0.0
East Texas	MILAM	509,923	225	1.1
East Texas	MONTAGUE	1,453,589	8,246	3.5
East Texas	MORRIS	2,218	0	0.0
East Texas	NACOGDOCHES	3,510	278,609	12.7
East Texas	NAVARRO	266,939	8,330	1.0
East Texas	NEWTON	590,680	48,582	3.5
East Texas	NUECES	532,854	861,081	40.5
East Texas	PANOLA	382,559	1,768,349	81.6
East Texas	POLK	548,423	523,988	25.1
East Texas	RAINS	0	0	0.0
East Texas	RED RIVER	167,665	0	0.4
East Texas	REFUGIO	4,903,379	49,884	12.8
East Texas	ROBERTSON	1,093,976	34,972	3.9
East Texas	RUSK	2,373,074	329,178	20.1
East Texas	SABINE	5,246	0	0.0
East Texas	SAN AUGUSTINE	5,693	67	0.0
East Texas	SAN JACINTO	34,696	194,018	8.9
East Texas	SAN PATRICIO	408,206	967,860	45.1
East Texas	SHELBY	62,081	173,367	8.0
East Texas	SMITH	1,200,518	402,060	20.9
East Texas	SOMERVELL	0	0	0.0
East Texas	TITUS	503,970	0	1.1
East Texas	TRAVIS	1,449	0	0.0
East Texas	TRINITY	88,108	2,804	0.3
East Texas	TYLER	298,463	2,143,080	98.5
East Texas	UPSHUR	150,052	504,137	23.3
East Texas	VAN ZANDT	936,231	7,734	2.4
East Texas	VICTORIA	650,188	176,360	9.4
East Texas	WALKER	3,093	2,885	0.1
East Texas	WASHINGTON	484,995	150,890	7.9
East Texas	WHARTON	1,234,462	715,697	35.3
East Texas	WILLIAMSON	8,966	0	0.0
East Texas	WILSON	281,082	68	0.6
East Texas	WISE	387,282	639,902	30.1
East Texas	WOOD	4,127,875	30,314	10.2
East Texas Total (Excluding HGB, BPA, and DFW)		**49,939,437**	**16,171,858**	**845.7**
Grand Total		**62,337,054**	**25,912,091**	**1317.1**

4.0 Control Options

This section provides a general discussion of control technologies that are relevant to vent gas from produced oil and gas condensate storage tanks. Table 4-1 outlines the advantages and disadvantages of each technology. The technology choice for a given vent stream is dependent on the vent flow, vent composition, and site considerations.

4.1 Common Control Options

The use of flares and vapor recovery units (VRUs) are the most common control methods for the control of volatile organic compound (VOC) emissions due to flash streams. A more detailed economic comparison of these methods is shown in Section 4.4.

4.1.1 Open Flares

Open flares are the lowest capital cost emission control device for vent gases from produced oil and gas condensate storage tanks. A typical open flare for this application would be a 2” to 4” diameter pipe that is approximately 20’ tall. The burner tip (flare tip) is located at the top of the pipe. A continuously lit pilot ensures that vent gases are combusted at the flare tip. Pilot fuel requirements are estimated at 20 scfh (standard cubic feet per hour) for this device.

A flame or detonation arrestor is recommended to ensure safe operation in this application. A small air blower may also be provided to prevent visible smoke at the top of the stack, depending on the composition of the vent gases. Solar powered piezoelectric ignition and flame detection can be used at sites that do not have electricity.

A properly operated flare can achieve a destruction efficiency of 98 percent or greater (EPA, 1991).

4.1.2 Enclosed Flares

Enclosed flares combust the vent gases inside of the stack, avoiding the aesthetic concerns that can accompany visible flames produced by open flares. A typical open flare for this application would be a 24” to 48” diameter pipe and the stack would be approximately 10’ – 20’ tall. More burner tips are provided than for the open flare and the burner tips are located low enough inside the stack that there is no visible flame outside the stack. Air is drawn in through an adjustable opening in the bottom of the flare stack. A continuously lit pilot ensures that vent gases are combusted at the flare tip. Pilot fuel requirements are estimated at 20 scfh for this application.

Table 4-1. Advantages and Disadvantages of Emission Control Devices and Emission Control Strategies for Vent Gases from Produced Oil and Gas Condensate Storage Tanks[5]

Control Device / Control Strategy	Advantages	Disadvantages
Open Flare	Low capital cost. Low maintenance. Electricity not required.	Visible flame. Wastes potential value of vent stream. Pilot fuel requirements.
Enclosed Flare	Low capital cost. Low maintenance. Electricity not required.	Wastes potential value of vent stream. Pilot fuel requirements.
Compressor-Based Vapor Recovery	Recovers high value vent stream. Compress into sales gas line or use for fuel gas requirement.	More expensive than flares. Requirement for on-site fuel is needed or sales gas compressor inlet must accept gas at ~ 30 – 70 psig.
Eductor-Based Vapor Recovery	Recovers high value vent stream. Compress into sales gas line or use for fuel gas requirement. Avoids moving parts and operating costs associated with a mechanical compressor.	Relatively new technology for this application. May require use of high pressure (sales) gas for motive force in eductor. Requirement for on-site fuel is needed or sales gas compressor inlet must accept gas at eductor discharge pressure (~ 40 psig).
Pressurized Storage Tanks	Gases that would previously have been emissions are trucked out as revenue generating liquid at higher pressure or vapors can be used on-site for fuel or further compressed to sales gas pressure.	Pressurized transport trucks are required. Capital costs approximately two times higher than atmospheric storage tanks.
Micro-turbine Generators	Gases that would have previously been emissions are converted into electricity. It is possible to replace combustion-driven equipment with electrical driven equipment on-site, resulting in more sales gas and lower emissions.	On-site need for electricity or access to local power grid required. Relatively expensive equipment requires longer operation time to recoup costs.
Refrigeration-Based Vapor Recovery	Gases that would previously been emissions are converted into liquid hydrocarbon for sales.	Electricity is required for condenser for refrigeration system. Non-condensable vapors must be controlled or compressed and used as fuel or sales gas to achieve complete emission control.
Tank Consolidation	Emissions are reduced, but not eliminated. Minimal capital expenditure. Lowers cost of future emission controls that may be added. Lowers maintenance costs.	Not a significant reduction in flash emissions – just fugitive and breathing losses.
Adding Intermediate Pressure Separator or Lowering Separator Pressure	Additional gas and liquid hydrocarbon recovery is possible. Low capital expenditure.	Must use on-site for fuel or a control device for additional vapors generated by intermediate and/or lower pressure separator.

[5] Biofiltration and activated carbon adsorption were not considered viable control techniques for vent gas emissions because of the relatively high operation and maintenance requirements and cost, respectively.

A flame or detonation arrestor is recommended to ensure safe operation in this application. Solar powered piezoelectric ignition and flame detection can be used at sites that do not have electricity.

A properly operated flare can achieve a destruction efficiency of 98 percent or greater (EPA, 1991).

4.1.3 Compressor-based Vapor Recovery Units

Higher oil and gas prices favor recovery of vent gases from produced oil and gas condensate storage tanks in lieu of combustion for the sake of emission control. Vapors can be collected from the storage tank vents and compressed to a pressure of 30 to 70 psig using a reciprocating, rotary vane or flooded screw compressor. The intermediate pressure vapors are used on on-site as fuel for combustion-fired process units such as heater-treaters and glycol dehydrator reboilers or they are routed to the suction side of sales gas compressors where they are further compressed to pipeline specification pressure and sold as product. Any liquids produced are collected in knockout pots and are returned to condensate storage tanks. The compressors are equipped with pressure sensors and bypass capability to prevent pulling a vacuum on the storage tanks. Properly maintained vapor recovery units can recover over 95% of potential vent gas emissions (EPA, 2003).

4.1.4 Eductor-based Vapor Recovery Units

Eductor systems have been developed for compression of produced oil and gas condensate storage tank vapors. High velocity liquid water or high velocity natural gas is used as the motive force to boost the pressure of the vent gases in the eductor. Vapors are collected from the storage tank vents and compressed to a pressure on the order of 40 psig at the outlet of the eductor. This system is equipped with flow safety valves, flow control mechanisms, pressure sensing, and temperature sensing devices which allow the system to operate under varying vent gas flow rates and prevent pulling a vacuum on the storage tanks. The intermediate pressure vapors are used on on-site as fuel for combustion-fired process units such as heater-treaters or glycol dehydrator reboilers or they are routed to the suction side of sales gas compressors where they are further compressed to pipeline specification pressure and sold as product. The eductor avoids the moving parts and energy costs associated with a compressor-based VRU.

Vapors are compressed using high velocity (high pressure) liquid water or natural gas as the motive force to boost the pressure of the vent gases entering the eductor. The eductor can only boost pressure to about 50 psig (typical site fuel gas pressure). If the vapors must be further compressed to reach a sales pipeline, a conventional compressor would be required.

Properly maintained vapor recovery units can recover over 95% of potential vent gas emissions (EPA, 2003).

4.2 Site-specific Control Methods

Other emission control devices that are potentially applicable, but less likely to be universally implemented at East Texas oil and gas production sites are described below. If site and vent stream conditions are favorable, these methods can be competitive with the more common types already discussed.

4.2.1 Pressurized Storage Tanks

Pressurized storage tanks are another method that can be used to effectively eliminate emissions. The pressurized tank operates at high enough pressure that vapors from it can be used in local heaters or more easily compressed into the sales gas line. Costs for the tanks are estimated at $ 2.15 to $ 2.75 per gallon of storage capacity. Unless a condensate stabilizer is also used to reduce the oil vapor pressure, this approach also requires the use of pressurized transport vehicles, which are more expensive and less available than conventional atmospheric transport vehicles. An increase in product recovery is projected to compensate for the higher storage and transportation costs over a two year period. To be economical, this control method requires a rich vent gas stream and a high flow rate. It is more applicable to a central processing facility or a large tank battery. The reduction in vent gas emissions using pressurized tanks and a pressurized load out truck should be almost 100%.

4.2.2 Micro-turbine Generators

Vent gases from produced oil and gas condensate storage tank can be compressed in a compressor and then burned in micro-turbines to generate electricity. This approach will be most applicable at sites that have a relatively steady vent gas supply from the storage tank battery and also a demand for electrical power or access to a utility power grid. It is also possible in some cases to replace aging combustion-driven equipment on site with electric-driven equipment which results in more sales gas and lower emissions.

Micro-turbine generators are more expensive than other control strategies and will require maintenance from experienced technicians. A longer expected period of production at the site is required to recoup the higher capital and operating costs.

4.2.3 Refrigeration-based Vapor Recovery

Refrigeration may be used to condense vent gases from produced oil and gas condensate storage tanks. This results in a liquid hydrocarbon product that will help to offset the operating and capital cost of the refrigeration equipment. Electrical power is required to operate the refrigeration system. The non-condensable vent gases can be compressed and used for fuel on-site or sent to sales in order to achieve complete control of the emissions using this approach. Non-condensable gases could also be routed to a small flare. These units are more expensive than other vapor recovery units.

4.3 Emission Control Strategies

In some cases, operational changes can result in emissions reductions from produced oil and gas condensate storage tanks. Such changes will reduce emissions, but the amount of the reduction is dependent on stream and site conditions. Strategies that involve operational changes, which might also be considered "best practices", are described below.

4.3.1 Storage Tank Consolidation

Tank consolidation is one method that will help reduce emissions from produced oil and gas condensate storage tanks. Use of fewer hydrocarbon liquid storage tanks at a given site will reduce fugitive emissions and standing (breathing) losses due to temperature variations. The reduction of emissions due to tank consolidation will be more significant in fields where production levels have dropped, but multiple tanks are still being used.

Reducing the number of hydrocarbon liquid storage tanks in service at a given site also reduces maintenance costs and makes implementation of any subsequent emission control devices more economical.

4.3.2 Lower Operating Pressure in Separators

If the pressure of the liquids entering the produced oil and gas condensate storage tanks is higher than 40 or 50 psig, installation of an intermediate pressure separator and lowering the existing separator pressure to approximately 30 psig or just lowering the operating pressure in the existing separator to approximately 30 psig will reduce flashing losses from the storage tanks. Additional liquid hydrocarbons may also be recovered if an intermediate separator is added. It would be advantageous to use an intermediate separator if there is a site fuel gas requirement. Flash gas from the separator could supply a fuel gas header. Flashing losses can also be reduced by lowering the temperature of the heater treater, although that may adversely affect crude oil quality.

4.4 Economic Comparison of Common Control Technologies

Two of the most common technologies for controlling flash emissions are flares and compression-based VRUs. To compare the costs of these control technologies, a design basis was developed that encompassed the sampling results described in Section 3 of this report. A request for quote was prepared and sent to companies that provide open flares, enclosed flares, VRUs with compression, and VRUs with eductor. The request for quote is attached in Appendix B of this report.

Two flow rates, 5 Mscfd (Thousand Standard Cubic Feet per Day) and 25 Mscfd were listed in the request. Assuming 50% of the vent stream is non methane/ethane and the molecular weight is 35, the VOC emissions for the two flow rates are:

- 42 tpy VOC at 5 Mscfd; and
- 211 tpy VOC at 25 Mscfd.

For the purposes of these cost estimates, the installed capital costs for flares and VRUs were equal to 1.5x and 2.5x the equipment cost, respectively. Note that the actual costs will vary from site to site depending on the lengths of piping required and other factors. No interviews with oil and gas production site operators were conducted to bracket the actual installed costs that might be incurred installing flares or VRUs at East Texas tank battery sites. Other cost assumptions were:

- Capital cost amortized over 5 years (Table 4-2) and 2 years (Table 4-3);
- Natural gas had a value of $5/Mscf for calculating fuel gas requirement; and
- Vent gas value calculated as NG value x 2 (accounts for 2000 Btu/scf heating value).

Although two flow rates were listed in the request for quote, the vent gas flows are relatively low, and most vendors used the same equipment to handle both. As a result, the control cost of each technology in $/ton controlled is much lower for the higher flow case (25 Mscfd).

The results of the comparison are illustrated in Tables 4-2 and 4-3. Table 4-2 spreads the capital cost over five years, more typical of control technology evaluations. Table 4-3 shortens this period to two years because of the short production life that can be experienced at many of these sites. Table 4-3 represents a source that may have a high vent gas rate due to initial production rates, but experiences a sharp decline. In such a case, control might not be required and also might not be economical after two years. These control technologies are designed to be mobile and can be moved to a new site once the proper site preparation is done.

Table 4-2. Vent Gas Emission Control Technology Review
Economic Comparison of Flare and VRU Technology
(5-year straightline amortization of capital

Case 1 - High Flow	Units	Value
Inlet gas rate	Mscfd	25
Inlet VOC content	vol%	50%
VOC Emissions	tpy	210.67
Natural Gas Cost/Value	$/Mscf	5
Vent stream MW	lb/mol	35
Vent Heating Value	Btu/scf	2000

Case 2 - Low Flow	Units	Value
Inlet gas rate	Mscfd	5
Inlet VOC content	vol%	50%
VOC Emissions	tpy	42.13
Natural Gas Cost/Value	$/Mscf	5
Vent stream MW	lb/mol	35
Vent Heating Value	Btu/scf	2000

Technology	Total Installed Capital Cost ($)	Capital Contribution to Total Treating Cost ($/yr)	Operating Cost Cost ($/yr)		Operating Credit Recovered fuel gas ($/yr)		Average Total Treating Cost ($/yr)		Average Total Treating Cost ($/ton VOC)		DRE %
			25 Mscfd	5 Mscfd	25 Mscfd	5 Mscfd	25 Mscfd	5 Mscfd	25 Mscfd	5 Mscfd	
Open Flare *	$22,000	$4,400	$900	$900	NA	NA	5,300	5,300	$25	$126	98
Enclosed Flare	$40,000	$8,000	$900	$900	NA	NA	8,900	8,900	$40	$210	98
VRU - Compression	$60,000	$12,000	$11,400	$2,000	$91,300	$18,300	(67,900)	(4,300)	-$320	-$100	99+
VRU - Eductor**	$95,000	$19,000	$ 0 **	$ 0 **	$91,300	$18,300	(72,300)	700	-$340	$20	99+

Notes:
1) 1.5x capital installation factor for flares, 2x capital installation factor for VRUs
2) Operating cost represents cost of fuel requirement, uses NG cost factor above, $5/Mscf
3) Operating credit represents the value of vent gas recovered, calculated as NG value x (vent gas heating value / 1000)
4) Price quoted for VRU - Eductor was turn-key installed price, no multiplier is used for installation
5) VRU capital and operating costs do not include costs to compress from fuel gas pressure (30-70 psig) to sales gas/pipeline pressure.

* Open flare prices are based on vendor quotes with guaranteed performance. Flares can be constructed in the field for a fraction of these costs.

** VRU - Eductor has 0 operating cost if on-site demand for fuel gas exceeds volume of gas leaving the eductor. Otherwise operating costs would be higher for recompression of gas leaving the eductor than those for recompression of gas leaving a VRU-compressor to sales gas/pipeline pressure due to higher volume of gas requiring compression in the VRU - Eductor case.

Table 4-3. Vent Gas Emission Control Technology Review
Economic Comparison of Flare and VRU Technology
(2-year straightline amortization of capital

Case 1 - High Flow	**Units**	**Value**
Inlet gas rate	Mscfd	25
Inlet VOC content	vol%	50%
VOC Emissions	tpy	210.67
Natural Gas Cost/Value	$/Mscf	5
Vent stream MW	lb/mol	35
Vent Heating Value	Btu/scf	2000

Case 2 - Low Flow	**Units**	**Value**
Inlet gas rate	Mscfd	5
Inlet VOC content	vol%	50%
VOC Emissions	tpy	42.13
Natural Gas Cost/Value	$/Mscf	5
Vent stream MW	lb/mol	35
Vent Heating Value	Btu/scf	2000

Technology	Total Capital Cost ($)	Capital Contribution to Total Treating Cost ($/yr)	Operating Cost Cost ($/yr)		Operating Credit Recovered fuel gas ($/yr)		Average Total Treating Cost ($/yr)		Average Total Treating Cost ($/ton VOC)		DRE %
			25 Mscfd	5 Mscfd	25 Mscfd	5 Mscfd	25 Mscfd	5 Mscfd	25 Mscfd	5 Mscfd	
Open Flare *	$22,000	$11,000	$900	$900	NA	NA	11,900	11,900	$56	$282	98
Enclosed Flare	$40,000	$20,000	$900	$900	NA	NA	20,900	20,900	$100	$500	98
VRU - Compression	$60,000	$30,000	$11,400	$2,000	$91,300	$18,300	(49,900)	13,700	-$240	$330	99+
VRU - Eductor**	$95,000	$47,500	$ 0 **	$ 0 **	$91,300	$18,300	(43,800)	29,200	-$210	$690	99+

Notes: 1) 1.5x capital installation factor for flares, 2x capital installation factor for VRUs
2) Operating cost represents cost of fuel requirement, uses NG cost factor above, $5/Mscf
3) Operating credit represents the value of vent gas recovered, calculated as NG value x (vent gas heating value / 1000)
4) Price quoted for VRU - Eductor was turn-key installed price, no multiplier is used for installation
5) VRU capital and operating costs do not include costs to compress from fuel gas pressure (30-70 psig) to sales gas/pipeline pressure.

* Open flare prices are based on vendor quotes with guaranteed performance. Flares can be constructed in the field for a fraction of these costs.

** VRU - Eductor has 0 operating cost if on-site demand for fuel gas exceeds volume of gas leaving the eductor. Otherwise operating costs would be higher for recompression of gas leaving the eductor than those for recompression of gas leaving a VRU-compressor to sales gas/pipeline pressure due to higher volume of gas requiring compression in the VRU - Eductor case.

4.5 Site-specific Factors

Site specific factors play a critical role in determining the best choice of VOC emission control from produced oil and gas condensate storage tanks. Some of these factors include:

1. Composition of the vent gas;
2. Field pressure or intermediate separator pressure;
3. Pressure of the vent gas;
4. Value of the vent gas (as fuel gas, sales gas or as a recovered liquid);
5. Availability of electricity;
6. Need for on-site fuel gas;
7. Sales gas compressor suction and discharge pressure specifications; and
8. The site's progress along the declining production curve that defines the projected lifetime and production rates for the site.

It is important to consider these and other factors in the analysis of what technology to apply at a location.

5.0 Discussion, Conclusions, and Recommendations

This document reports measurements of speciated volatile organic compound (VOC) emissions from oil and condensate storage tanks at wellhead and gathering site tank batteries in East Texas. The measurements were made by directly monitoring the flow rates of gases escaping from storage tank vents and sampling the vent gases for chemical composition. An emission factor reflecting tank working, breathing, and flashing losses for each tank was calculated by dividing the measured emission rate by the amount of oil or condensate produced during the sampling period. The emission factors are expressed in units of pounds of VOC per barrel of liquid hydrocarbon produced (lb/bbl). Average emission factors for oil and condensate storage tanks were multiplied, respectively, by oil and condensate production totals for East Texas counties, including the Dallas-Fort Worth (DFW), Houston-Galveston-Brazoria (HGB), and Beaumont-Port Arthur (BPA) ozone nonattainment areas, to estimate regional emissions.

Emission measurements were made at 11 oil and 22 condensate tank battery sites in the BPA, DFW, and HGB areas during May-July, 2006. The average VOC emission factors for oil and condensate storage tanks were 1.6 ± 99% lb/bbl and 33.3 ± 73% lb/bbl, respectively, where the uncertainties are represented by the 95% confidence intervals of the means. Variable site characteristics such as separator temperature, separator pressure, and the physicochemical properties of the liquid hydrocarbons, as well as very low condensate production rates at well sites in Denton and Parker counties are probable leading causes of uncertainty.

The average emission factor for condensate storage tanks reported here is more than twice the average reported for condensate storage tanks in Colorado that were sampled as part of an earlier study for the Colorado Oil & Gas Association (Lesair, 2003). The Lesair study estimated vent gas VOC emissions for 25 condensate storage tanks statewide, 16 of which were in the DJ Basin, near Denver. The average emission factors from that study were 13.7 ± 32% lb/bbl and 17.0 ± 32% lb/bbl for the statewide and DJ Basin tanks, respectively. Note that the Lesair study did not measure vent gas emissions directly but modeled emissions using E&P Tanks and the compositions and properties of pressurized liquid hydrocarbons sampled from the separator. Other explanations for the higher condensate tank emission factor reported here might include differences in wellhead or separator pressures, or the very hot ambient temperatures that persisted during the 9-day period when all the Denton and Parker county condensate storage tanks were sampled.[6]

The total *uncontrolled* VOC emissions estimated for wellhead and gathering site storage tanks in the HGB, DFW, and BPA based on the arithmetic mean emission factors reported here are 289 tons/day, 38 tons/day and 145 tons/day, respectively. These estimates assume no vent

[6] Daytime high temperatures at DFW Airport ranged from 98 – 107 F.

gas controls at any source; although, it is evident based on screening of candidate host sites that vent gas is recovered at some undetermined number of tank batteries in East Texas. Additional uncertainties in the regional emissions estimates stem from the average emission factor uncertainties, which as noted above are close to a factor of 2, and the small number of test sites relative to the entire population of storage tank batteries in East Texas.

The number and selection of tank batteries that were sampled in this study were limited by budget and schedule constraints in addition to the finite pool of host sites that provided voluntary access. Future studies can reduce average emission factor uncertainty and broaden their applicability by sampling a larger number of tank batteries and by conducting the tests during a wider variety of weather conditions, respectively.

6.0 **References**

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APPENDIX A

Tank Battery Summary Information

Site: Texas Tank Battery #1

Sampling Date: May 2, 2006

County and Geologic Formation: Liberty County

Well Type: Oil Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: 85ºF

Amount of Oil or Condensate produces during sampling period:
250 BBLS/D Oil, 0 MMSCF/D Gas, 0 BBLS/D Water

Temperature of Liquid Product: 85ºF

Number of tanks in the tank battery: Two

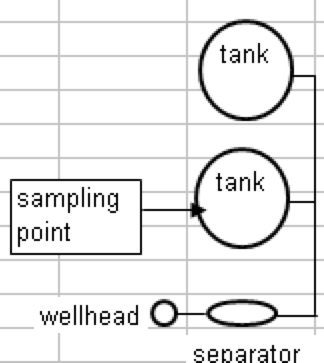
Approximate tank capacity and dimensions: 400 Barrels Each

Type of tanks: (2) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Silver Color, Thirty Years Old, Poor Condition, Bolted Tanks.

Approximate age of the processing equipment: Thirty Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #2

Sampling Date: May 11, 2006

County and Geologic Formation: Montgomery County

Well Type: Oil Well

Number of wells served by the tank battery: Three

Temperature of product leaving the seperator: 85ºF

Amount of Oil or Condensate produces during sampling period:
105 BBSL/D Oil, 7 MMSCF/D Gas, 400 BBLS/D Water

Temperature of Liquid Product: 85ºF

Number of tanks in the tank battery: Three

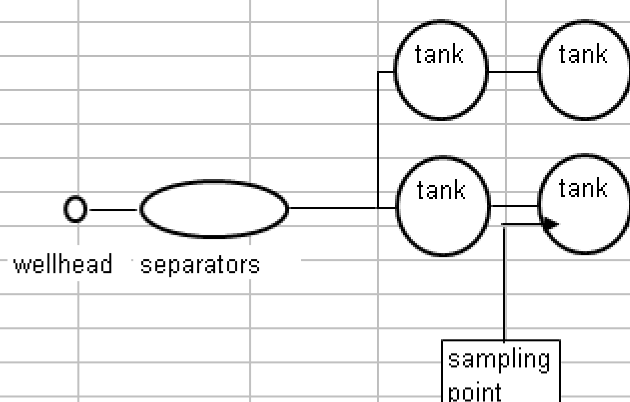
Approximate tank capacity and dimensions: 300 BBL Each

Type of tanks: (1) Water Tank, (2) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Beige Color, Ten Years Old, Good Condition, Welded Tanks.

Approximate age of the processing equipment: Ten Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #3

Sampling Date: May 9, 2006

County and Geologic Formation: Montgomery County

Well Type: Oil Well

Number of wells served by the tank battery: Four

Temperature of product leaving the seperator: 85ºF

Amount of Oil or Condensate produces during sampling period:
87 BBLS/D Oil, 13 MMSCF/D Gas, 0 BBLS/D Water

Temperature of Liquid Product: 85ºF

Number of tanks in the tank battery: Six

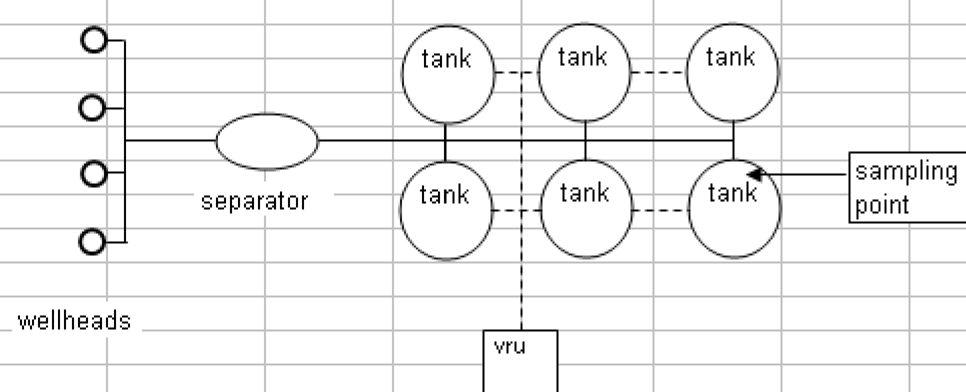
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (5) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Beige Color, Ten Years, Good Condition, Oil-Welded, Water-Fiberglass.

Approximate age of the processing equipment: Ten Years

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #4

Sampling Date: May 10, 2006

County and Geologic Formation: Montgomery County

Well Type: Oil Well

Number of wells served by the tank battery: Three

Temperature of product leaving the seperator: 86ºF

Amount of Oil or Condensate produces during sampling period:
120 BBLS/D Oil, 32 MMSCF/D Gas, 0 BBLS/D Water

Temperature of Liquid Product: 86ºF

Number of tanks in the tank battery: Five

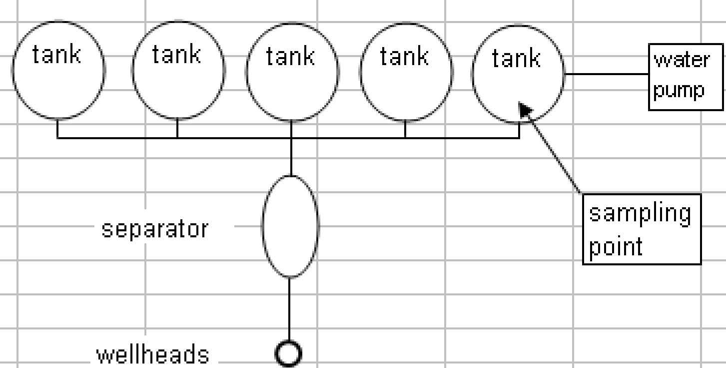
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (4) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Beige Color, Ten Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Ten Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #5

Sampling Date: May 10, 2006

County and Geologic Formation: Montgomery County

Well Type: Oil Well

Number of wells served by the tank battery: Four

Temperature of product leaving the seperator: 88ºF

Amount of Oil or Condensate produces during sampling period:
100 BBLS/D Oil, 0.2 MMSCF/D Gas, 0 BBLS/D Water

Temperature of Liquid Product: 86ºF

Number of tanks in the tank battery: Five

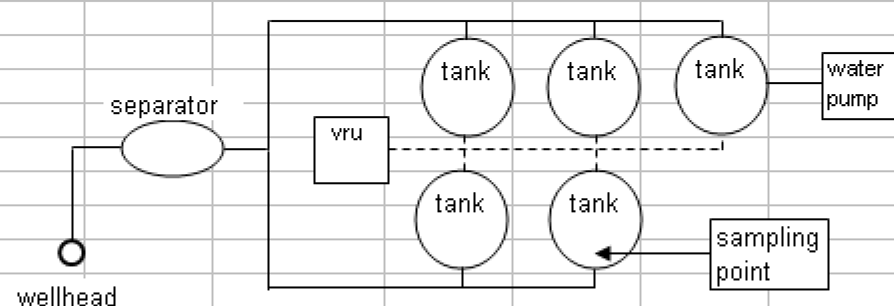
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (4) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Beige Color, 10 Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Ten Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #6

Sampling Date: May 9, 2006

County and Geologic Formation: Montgomery County

Well Type: Oil Well

Number of wells served by the tank battery: Six

Temperature of product leaving the seperator: 89ºF

Amount of Oil or Condensate produces during sampling period:
130 BBLS/D Oil, 8 MMSCF/D Gas, 0 BBLS/D Water

Temperature of Liquid Product: 89ºF

Number of tanks in the tank battery: Four

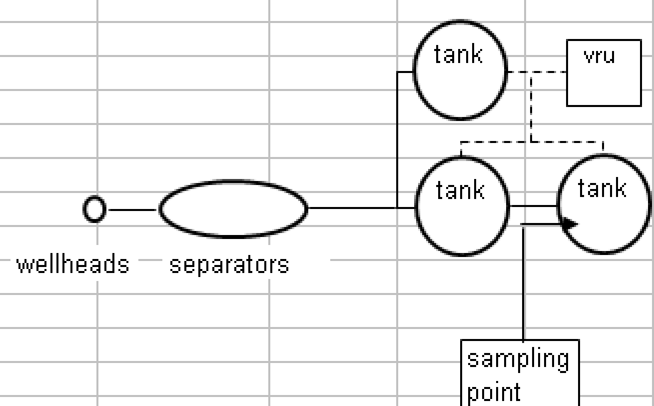
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (3) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Beige Color, 8 Years Old, Good Condition, Welded.

Approximate age of the processing equipment: 8 Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #7

Sampling Date: May 16, 2006

County and Geologic Formation: Waller County

Well Type: Oil Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
200 BBLS/D Oil, 0 MMSCF/D Gas, 20 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Four

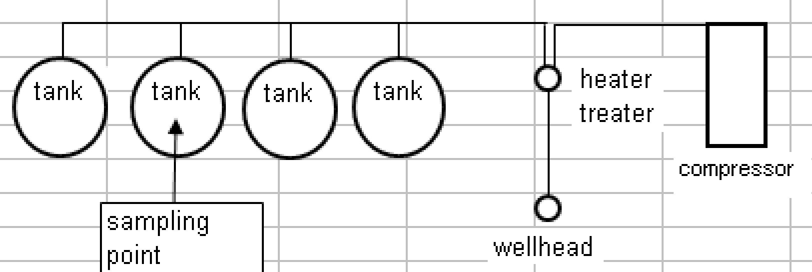
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (3) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Blue Color, 3 Years Old, Good Condition, Welded.

Approximate age of the processing equipment: 3 Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #8

Sampling Date: May 17, 2006

County and Geologic Formation: Waller County

Well Type: Oil Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
50 BBLS/D Oil, 0 MMSCF/D Gas, 700 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Five

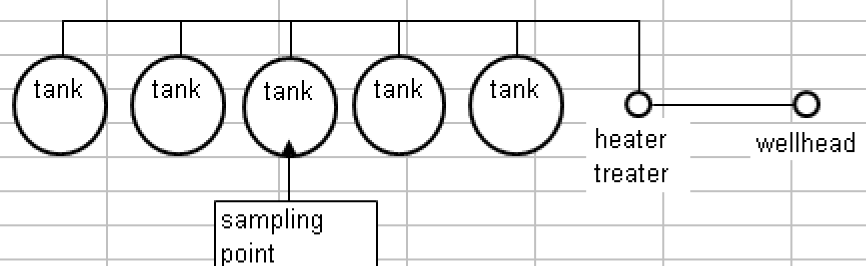
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (4) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Blue Color, 2 Years Old, Good Condition, Welded.

Approximate age of the processing equipment: 2 Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #9

Sampling Date: May 16, 2006

County and Geologic Formation: Waller County

Well Type: Oil Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period: l
65 BBLS/D Oil, 0 MMSCF/D Gas, 200 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Four

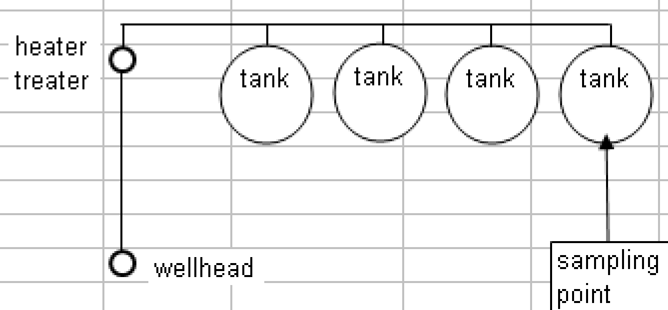
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (3) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Beige Color, Two Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Two Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #10

Sampling Date: May 17, 2006

County and Geologic Formation: Waller County

Well Type: Oil Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
30 BBLS/D Oil, 0 MMSCF/D Gas, 600 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Five

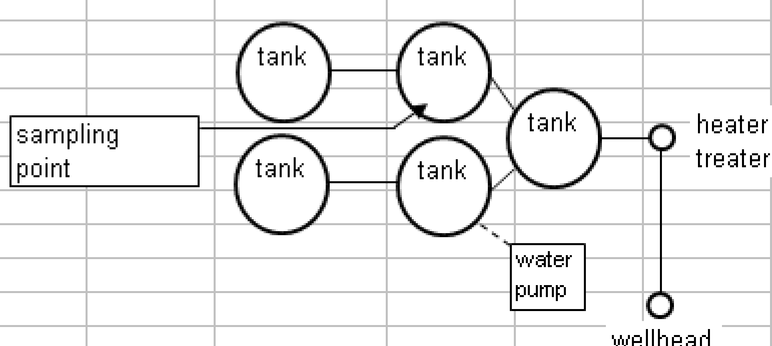
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (4) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Beige Color, Two Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Two Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #11

Sampling Date: June 9, 2006

County and Geologic Formation: Jefferson County

Well Type: Oil Well

Number of wells served by the tank battery: Five

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
250 BBLS/D Oil, 2.5 MMSCF/D Gas, 1500 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Four

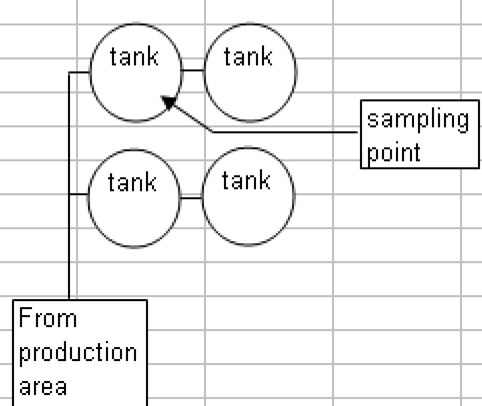
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (3) Oil Tanks

Color, approximate age, condition and construction of the tanks:
White Color, Fifteen Years Old, Weathered Condition, Bolted

Approximate age of the processing equipment: Fifteen Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #12

Sampling Date: June 9, 2006

County and Geologic Formation: Jefferson County

Well Type: Oil Well

Number of wells served by the tank battery: Five

Temperature of product leaving the seperator: N/A, Gathering Station

Amount of Oil or Condensate produces during sampling period:
250 BBLS/D Oil, 0 MMSCF/D Gas, 0 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Three

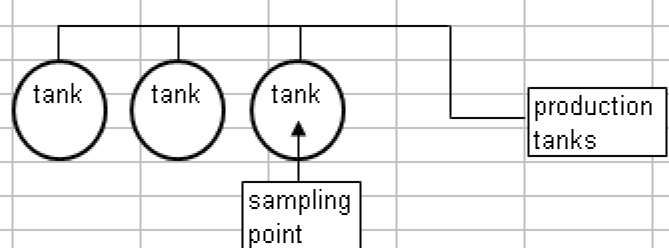
Approximate tank capacity and dimensions: (2) 5000 BBL, (1) 10,000 BBL

Type of tanks: Oil Tanks

Color, approximate age, condition and construction of the tanks:
White Color, 20 Years Old, Good Condition, Bolted

Approximate age of the processing equipment: 20 Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #13

Sampling Date: July 10, 2006

County and Geologic Formation: Denton County

Well Type: Gas-Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
2 BBLS/D Oil, 0.129 MMSCF/D Gas, 4 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

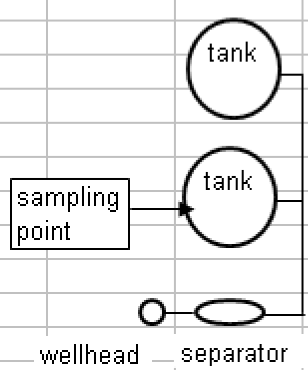
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Ten years Old, Good Condition, Welded.

Approximate age of the processing equipment: Ten Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #14

Sampling Date: July 10, 2006

County and Geologic Formation: Denton County

Well Type: Gas-Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
4 BBLS/D Oil, 0.062 MMSCF/D Gas, 6 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Tjwo

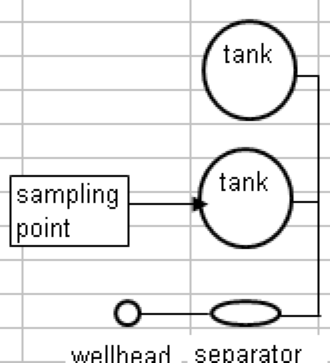
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Ten Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Ten Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #15

Sampling Date: July 11, 2006

County and Geologic Formation: Denton County

Well Type: Gas-Condensate Well

Number of wells served by the tank battery: Two

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
5 BBLS/D Oil, 0.159 MMSCF/D Gas, 8 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

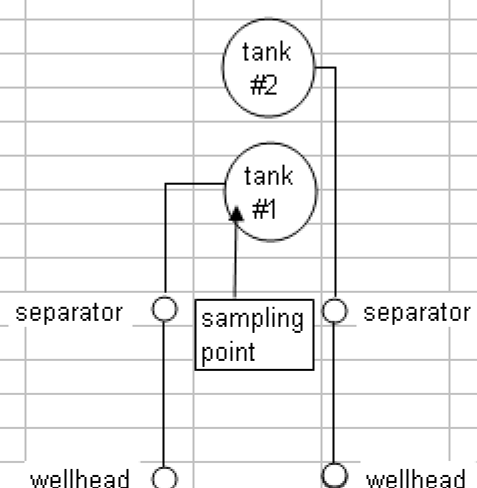
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Ten Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Ten Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #16

Sampling Date: July 11, 2006

County and Geologic Formation: Denton County

Well Type: Gas-Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
2 BBLS/D Oil, 0.132 MMSCF/D Gas, 4 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

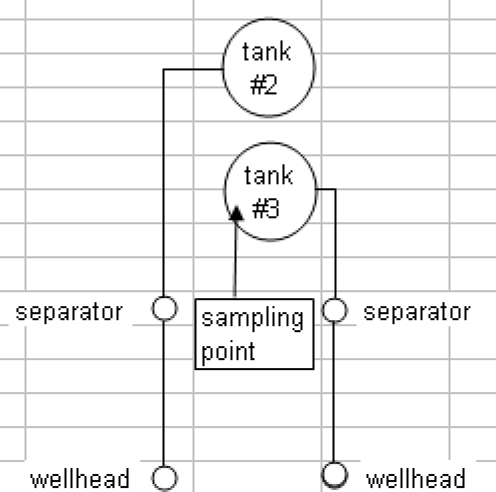
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: **(1) Water Tank, (1)** Condensate Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Eight Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Eight Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #17

Sampling Date: July 13, 2006

County and Geologic Formation: Denton County

Well Type: Gas-Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period
2 BBLS/D Oil, 0.072 MMSCF/D Gas, 4 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

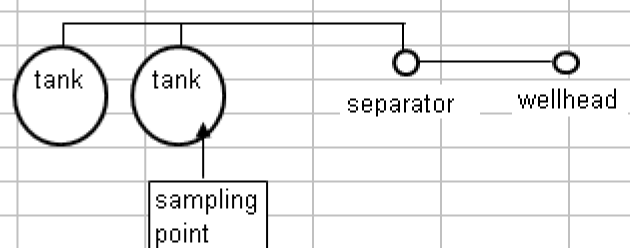
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Eight Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Eight years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #18

Sampling Date: July 13, 2006

County and Geologic Formation: Denton County

Well Type: Gas- Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
10 BBLS/D Oil, 0.254 MMSCF/D Gas, 6 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

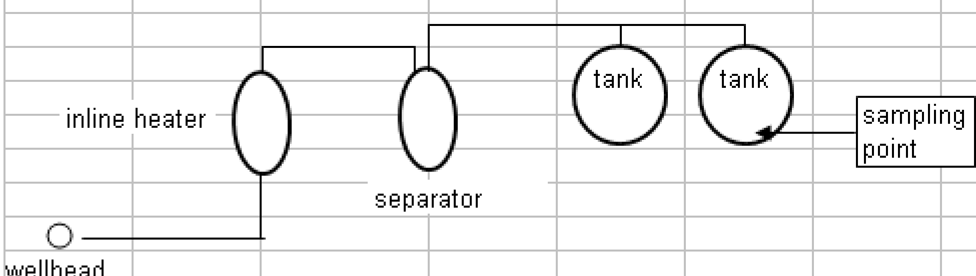
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Eight Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Eight Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #19

Sampling Date: July 14, 2006

County and Geologic Formation: Denton County

Well Type: Gas-Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
2 BBLS/D Oil, 0.104 MMSCF/D Gas, 5 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

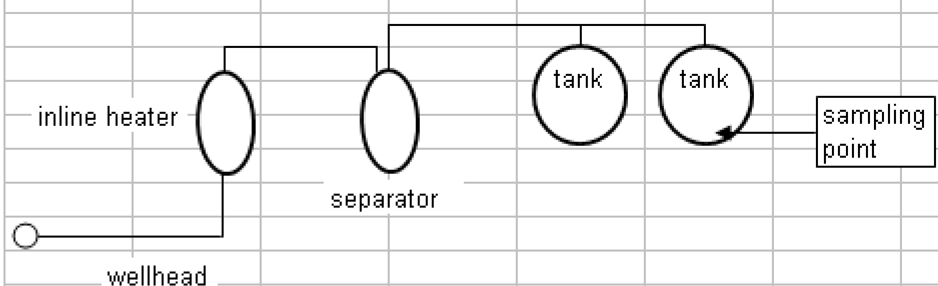
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

Color, approximate age, condition and construction of the tanks:
Biege Color, Eight Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Eight Years

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #20

Sampling Date: July 14, 2006

County and Geologic Formation: Denton County

Well Type: Gas-Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
10 BBLS/D Oil, 0.254 MMSCF/D Gas, 8 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

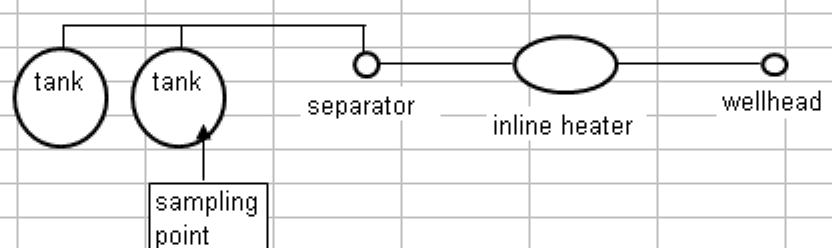
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Eight Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Eight Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #21

Sampling Date: July 19, 2006

County and Geologic Formation: Montague County

Well Type: Oil Well

Number of wells served by the tank battery: Six

Temperature of product leaving the seperator: 110ºF

Amount of Oil or Condensate produces during sampling period:
180 BBLS/D Oil, 0.654 MMSCF/D Gas, 15 BBLS/D Water

Temperature of Liquid Product: 85ºF

Number of tanks in the tank battery: Six

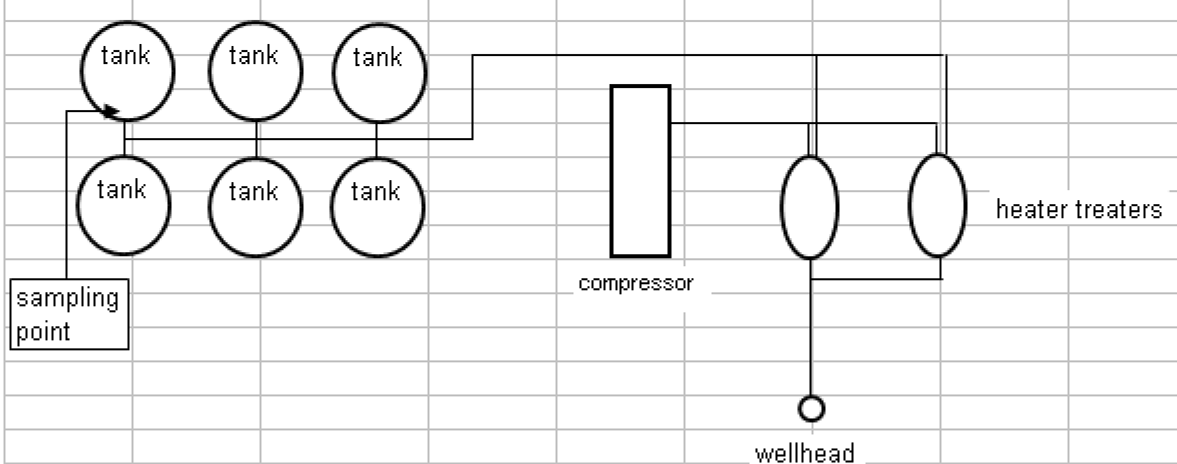
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (5) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Biege Color, Five Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Five Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #22

Sampling Date: July 19, 2006

County and Geologic Formation: Montague County

Well Type: Oil Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: 86ºF

Amount of Oil or Condensate produces during sampling period:
63 BBLS/D Oil, 0.234 MMSCF/D Gas, 9 BBLS/D Water

Temperature of Liquid Product: 86ºF

Number of tanks in the tank battery: Four

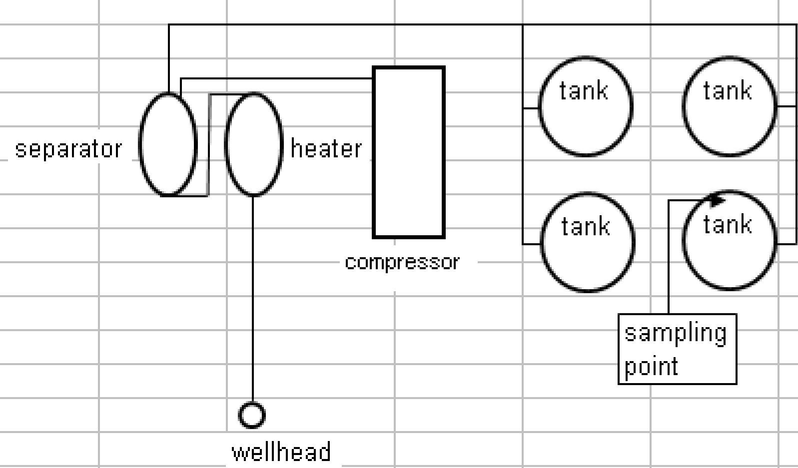
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (3) Oil Tanks

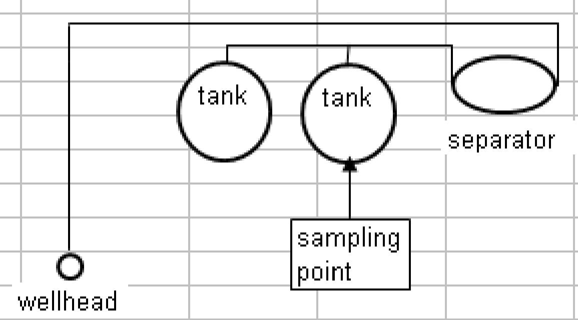
Color, approximate age, condition and construction of the tanks:
Beige Color, Five Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Five Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



1	**Site:** Texas Tank Battery #23
2	**Sampling Date:** July 20, 2006
3	**County and Geologic Formation:** Parker County
4	**Well Type:** Gas
5	**Number of wells served by the tank battery:** One
6	**Temperature of product leaving the seperator:** Ambient Temperature
7	**Amount of Oil or Condensate produces during sampling period:** 27 BBLS/D Oil, 0.895 MMSCF/D Gas, 5 BBLS/D Water
8	**Temperature of Liquid Product:** Ambient Temperature
9	**Number of tanks in the tank battery:** Two
10	**Approximate tank capacity and dimensions:** 400 BBL
11	**Type of tanks:** (1) Water Tank, (1) Oil Tank
12	**Color, approximate age, condition and construction of the tanks:** Beige Color, Two years Old, Good Condition, Welded.
13	**Approximate age of the processing equipment:** Two Years
14	**Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:**



Site: Texas Tank Battery #24

Sampling Date: July 20, 2006

County and Geologic Formation: Parker County

Well Type: Natural Gas Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: 89ºF

Amount of Oil or Condensate produces during sampling period:
1 BBL/D Oil, 0.756 MMSCF/D Gas, 3 BBLS/D Water

Temperature of Liquid Product: 89ºF

Number of tanks in the tank battery: Two

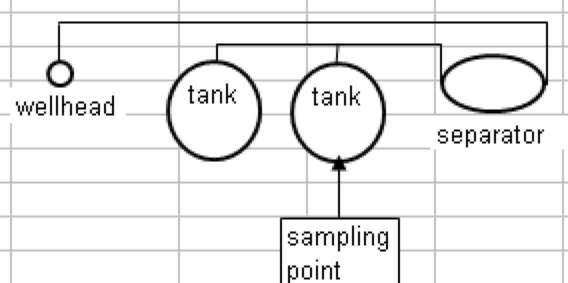
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (1) Oil Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Two Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Two Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #25

Sampling Date: July 17, 2006

County and Geologic Formation: Denton County

Well Type: Gas-Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
1 BBL/D Oil, 0.144 MMSCF/D Gas, 4 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

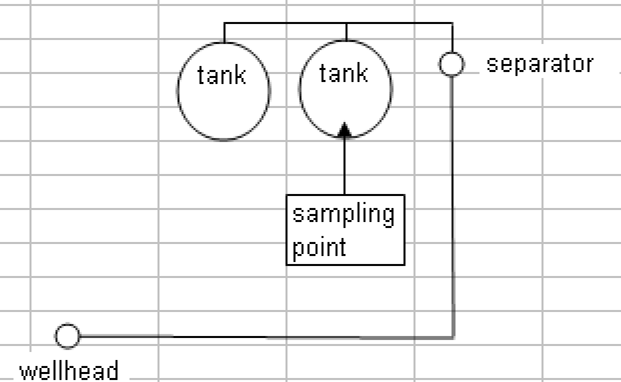
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Two Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Two Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #26

Sampling Date: July 17, 2006

County and Geologic Formation: Denton County

Well Type: Gas Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
1 BBL/D Oil, 0.11 MMSCF/D Gas, 57 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

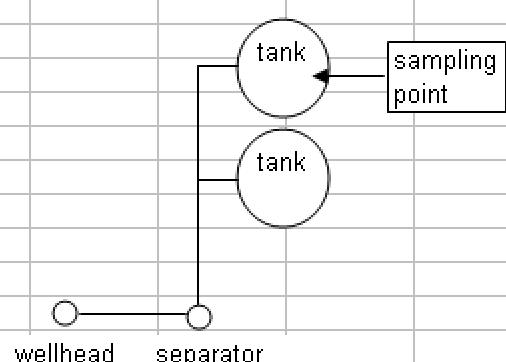
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

Color, approximate age, condition and construction of the tanks:
Beige Color, Two Years Old, Good Condition, Welded.

Approximate age of the processing equipment: Two Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #27

Sampling Date: July 18, 2006

County and Geologic Formation: Denton County

Well Type: Gas-Condensate Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
2 BBLS/D Oil, 0.187 MMSCF/D Gas, 9 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Two

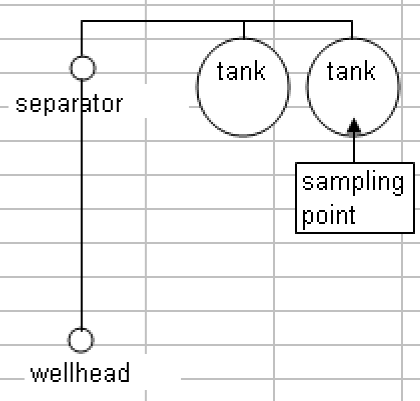
Approximate tank capacity and dimensions: 300 BBL

Type of tanks: (1) Water Tank, (1) Condensate Tank

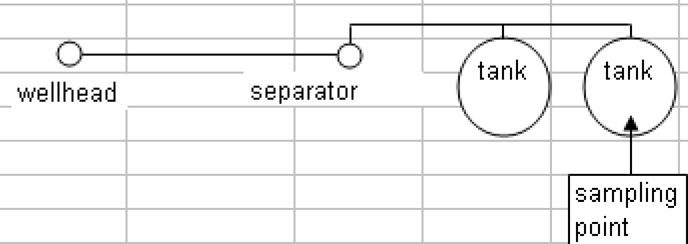
Color, approximate age, condition and construction of the tanks:
Beige Color, Three Years Old, Good Condition, Welded

Approximate age of the processing equipment: Three Years Old

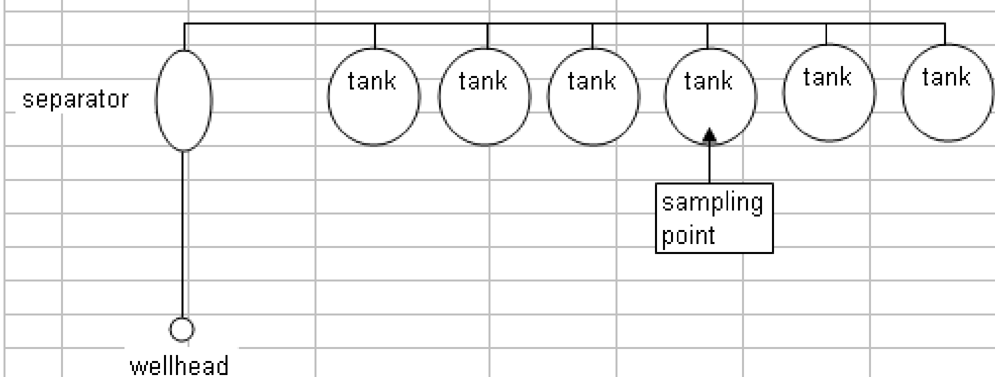
Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



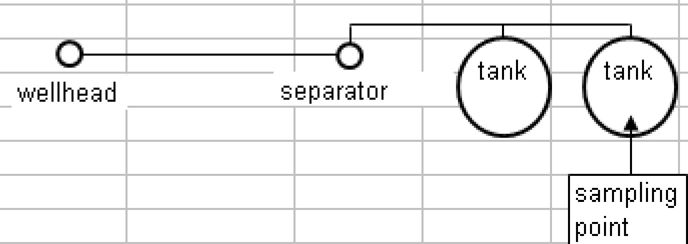
1	**Site:** Texas Tank Battery #28
2	**Sampling Date:** July 15, 2006
3	**County and Geologic Formation:** Brazoria County
4	**Well Type: Gas** Well
5	**Number of wells served by the tank battery:** One
6	**Temperature of product leaving the seperator:** Ambient Temperature
7	**Amount of Oil or Condensate produces during sampling period:**
	30 BBLS/D Oil, 0.852 MMSCF/D Gas, 12 BBLS/D Water
8	**Temperature of Liquid Product:** Ambient Temperature
9	**Number of tanks in the tank battery:** Two
10	**Approximate tank capacity and dimensions:** 400 BBL
11	**Type of tanks:** (1) Water Tank, (1) Oil Tank
12	**Color, approximate age, condition and construction of the tanks:**
	Silver Color, Two Years Old, Good Condition, Welded
13	**Approximate age of the processing equipment:** Two Years Old
14	**Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:**



1	**Site:** Texas Tank Battery #29
2	**Sampling Date:** July 26, 2006
3	**County and Geologic Formation:** Brazoria County
4	**Well Type:** Gas Well
5	**Number of wells served by the tank battery:** One
6	**Temperature of product leaving the seperator:** Ambient Temperature
7	**Amount of Oil or Condensate produces during sampling period:**
	61 BBLS/D Oil, 0.422 MMSCF/D Gas, 195 BBLS/D Water
8	**Temperature of Liquid Product:** Ambient Temperature
9	**Number of tanks in the tank battery:** Six
10	**Approximate tank capacity and dimensions:** 400 BBL
11	**Type of tanks:** (1) Water Tank, (5) Oil Tanks
12	**Color, approximate age, condition and construction of the tanks:**
	Beige Color, Two years Old, Welded
13	**Approximate age of the processing equipment:** Two Years Old
14	**Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:**



1	**Site:** Texas Tank Battery #30
2	**Sampling Date:** July 26, 2006
3	**County and Geologic Formation:** Brazoria County
4	**Well Type:** Gas Well
5	**Number of wells served by the tank battery:** One
6	**Temperature of product leaving the seperator:** Ambient Temperature
7	**Amount of Oil or Condensate produces during sampling period:**
	15 BBLS/D Oil, 0.892 MMSCF/D Gas, 121 BBLS/D Water
8	**Temperature of Liquid Product:** Ambient Temperature
9	**Number of tanks in the tank battery:** Two
10	**Approximate tank capacity and dimensions:** 400 BBL
11	**Type of tanks:** (1) Water Tank, (1) Oil Tank
12	**Color, approximate age, condition and construction of the tanks:**
	Beige Color, Two Years Old, Good Condition, Welded
13	**Approximate age of the processing equipment:** Two Years Old
14	**Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:**



Site: Texas Tank Battery #31

Sampling Date: July 27, 2006

County and Geologic Formation: Galveston County

Well Type: Oil Well

Number of wells served by the tank battery: One

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
125 BBLS/D Oil, 0.25 MMSCF/D Gas, 75 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Five

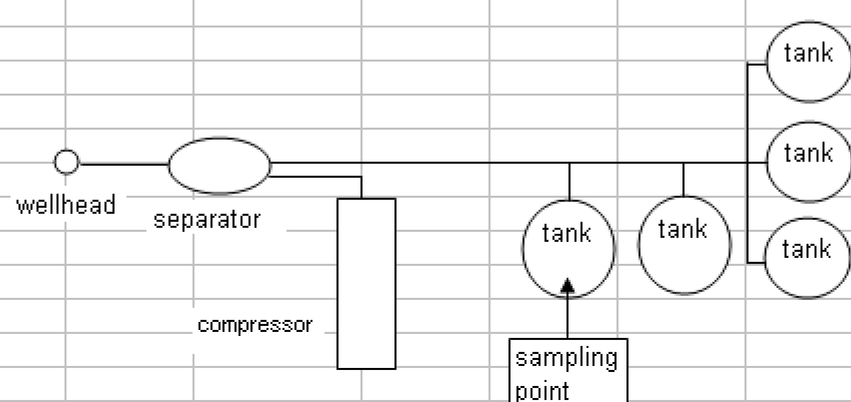
Approximate tank capacity and dimensions: 400 BBL

Type of tanks: (1) Water Tank, (4) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Black Color, Two Years Old, Good Condition, Welded

Approximate age of the processing equipment: Two Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



1 Site: Texas Tank Battery #32

2 Sampling Date: July 27, 2006

3 County and Geologic Formation: Galveston County

4 Well Type: Gas Well

5 Number of wells served by the tank battery: Two

6 Temperature of product leaving the seperator: Ambient Temperature

7 Amount of Oil or Condensate produces during sampling period:
1420 BBLS/D Oil, 1.912 MMSCF/D Gas, 24 BBLS/D Water

8 Temperature of Liquid Product: Ambient Temperature

9 Number of tanks in the tank battery: Six

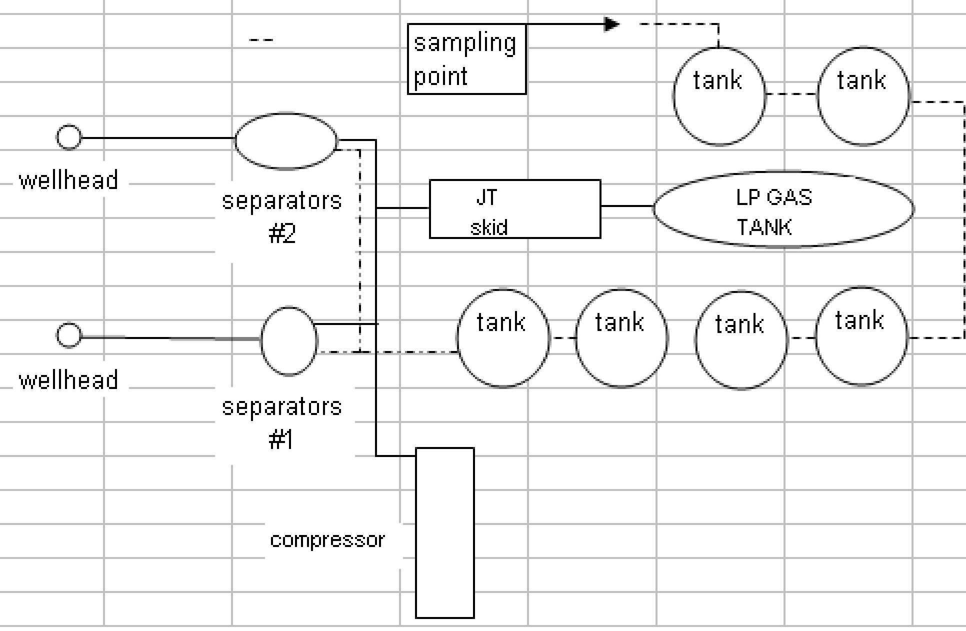
10 Approximate tank capacity and dimensions: 500 BBL

11 Type of tanks: (1) Water Tank, (4) Oil Tanks, (1) LNG Tank

12 Color, approximate age, condition and construction of the tanks:
Black Color, Ten Years Old, Good Condition, Welded

13 Approximate age of the processing equipment: Ten Years Old

14 Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



Site: Texas Tank Battery #33

Sampling Date: July 27, 2006

County and Geologic Formation: Galveston County

Well Type: Oil Well

Number of wells served by the tank battery: Two

Temperature of product leaving the seperator: Ambient Temperature

Amount of Oil or Condensate produces during sampling period:
60 BBLS/D Oil, 0.181 MMSCF/D Gas, 503 BBLS/D Water

Temperature of Liquid Product: Ambient Temperature

Number of tanks in the tank battery: Four

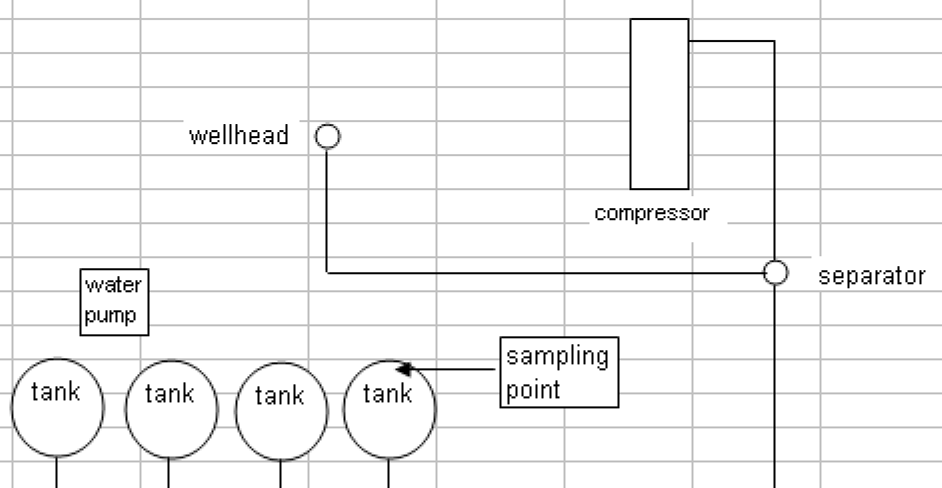
Approximate tank capacity and dimensions: 500 BBL

Type of tanks: (1) Water Tank, (3) Oil Tanks

Color, approximate age, condition and construction of the tanks:
Black Color, Ten Years Old, Good Condition, Welded

Approximate age of the processing equipment: Ten Years Old

Simple schematic diagram of the tank battery operation with processing equipment and showing the location of the sampling port:



APPENDIX B

Request for Quotation for Produced Oil and Gas Storage Tank Vent Gas

Request For Quotation for Produced Oil and Gas Storage Tank Vent Gas

Background:

A client needs to evaluate control options to recover or destroy a vent stream for VOC emission reasons.

Sources are storage tank batteries for produced oil and gas condensate.

There are two flow rate options to consider because there are several sources (similar in size) separated by some distance. The decision to treat at each site or a central facility will be made based on the cost of control and other logistical issues.

Vent Stream Composition:

Nitrogen	0.5	
Carbon Dioxide	4.0	
Methane	45.5	
Ethane	12.0	
Propane	15.0	
Isobutane	4.0	
N-butane	7.0	
2-2 Dimethylpropane	< 0.1	
Isopentane	2.5	
N-pentane	2.5	
Hexanes	2.5	
hexanes plus	5.0	
Pressure (psig)	< 1	
Temperature (F)	100	
Flow Rate Cases		
1) Individual site	5	Mscfd
2) Central facility	25	Mscfd

Facility Information:

- All equipment must be gas fired
- All instruments must be pneumatic

Quote Detail (be sure to include the following):

- Provide description of equipment, including approximate footprint
- Equipment cost
- Utility requirement to calculate operating costs (i.e., fuel gas)
- Destruction or recovery efficiency

Fax or Email Quote To

joe.lundeen@trimeric.com or ray.mckaskle@trimeric.com
425-963-1139 (efax)

Contact for Questions/Clarification

Joe Lundeen - 512-658-6313 Ray McKaskle - 512-785-4939

EVALUATION OF VOC EMISSIONS FROM FLASH AND CONDENSATE TANKS (H-51-C)

QUALITY ASSURANCE PROJECT PLAN

Prepared by:
URS Corporation
9400 Amberglen Blvd.
Austin, TX 78729

Prepared for:
Houston Advanced Research Center
4800 Research Forest Drive
The Woodlands, TX 77381

January 13, 2006

Approvals:

Albert Hendler, URS Project Manager: ______________________________
Date

Don Burrows, URS QA Coordinator: ______________________________
Date

Kevin Fisher, Trimeric Project Manager: ______________________________
Date

Alex Cuclis, HARC Project Manager: ______________________________
Date

A2. Table of Contents

A3. Distribution List

Albert Hendler	URS	Al_hendler@urscorp.com	512-419-6438
Carl Galloway	URS	Carl_galloway@urscorp.com	512-419-5335
Don Burrows	URS	Don_burrows@urscorp.com	512-454-4797
Alex Cuclis	HARC	acuclis@harc.edu	281-364-4049
Ita Ufot	TCEQ	iufot@tceq.state.tx.us	512-239-1935
Martha Maldonado	TCEQ	mmaldona@tceq.state.tx.us	512-239-1999
Teresa Hurley	TCEQ	thurley@tceq.state.tx.us	512-239-5316
Russ Nettles	TCEQ	rnettles@tceq.state.tx.us	512-239-1493
Bertie Fernando	TCEQ	bfernand@tceq.state.tx.us	512-239-1536
Dave Harper	TCEQ	dharper@tceq.state.tx.us	512-239-5746
Kevin Fisher	Trimeric	Kevin.fisher@trimeric.com	512-431-6323
Joe Lundeen	Trimeric	Joe.Lundeen@trimeric.com	512-658-6313

A4. Project Organization

A4.1 Purpose of Study

The purpose of this project is to develop speciated VOC emission factors and an inventory of speciated VOC emissions from liquid hydrocarbon (i.e., oil and condensate) storage tanks and pressurized vessels (i.e., separators and heater treaters) at oil and gas production sites in east Texas. The emission factors and emissions inventory are intended to be used by the Texas Commission on Environmental Quality (TCEQ) for evaluating ozone control strategies for the Dallas-Fort Worth (DFW) and Houston-Galveston-Brazoria (HGB) ozone nonattainment areas. Storage tanks and pressurized vessels at oil and gas production sites may emit a significant fraction of the total anthropogenic VOC emitted in east Texas; however, no accurate regional emissions inventory currently exists for this source category.

A4.2 Roles and Responsibilities

The project organization is presented in Figure A-1. The responsibilities of the key project staff follow the organizational chart.

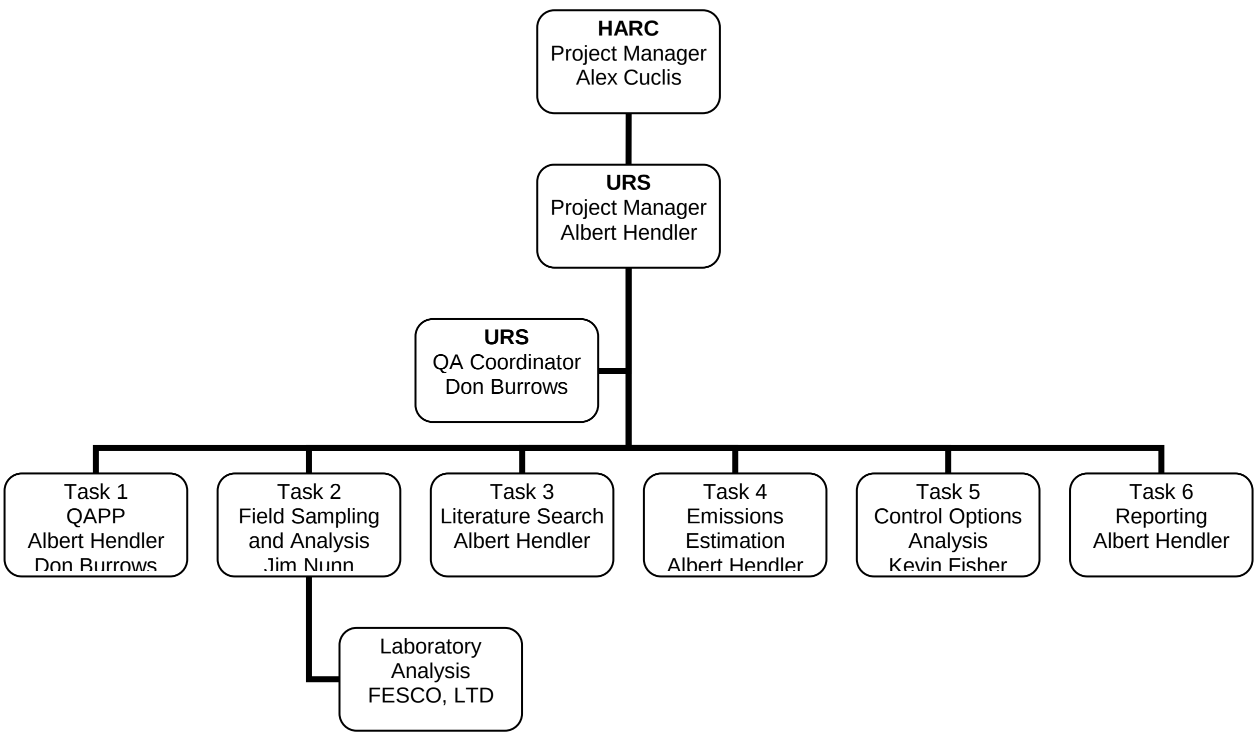


Figure 1. Project Organization

The responsibilities of the project staff as they relate to the six tasks described in Section A6 are given below.

Albert Hendler (URS):

Task 1: QAPP
- Prepare QAPP

Task 3: Literature Search
- Perform literature search
- Document results

Task 4: Estimate Emissions
- Perform emissions estimate calculations

Task 6: Management and Reporting
- Provide project management, primary contact point for HARC
- Prepare monthly progress reports
- Track status of budget, schedule, and deliverables

Don Burrows (URS):

Task 2: QAPP
- Review QAPP
- Execute QA activities throughout project

Jim Nunn (COMM Engineering):

Task 2: Field Sampling and Analysis
- Lead field sampling effort
- Document field measurements and activities
- Coordinate laboratory analyses

Kevin Fisher (Trimeric):

Task 1: QAPP
- Identify candidate sampling sites
- Perform and document site visits
- Recommend sampling protocols

Task 6: Management and Reporting
- Manage Trimeric subcontract budget and deliverables
- Assist with report preparation

Joe Lundeen (Trimeric):

Task 1: QAPP
- Identify candidate sampling sites
- Perform and document site visits
- Recommend sampling protocols

Task 5: Control Options Analysis
- Manage Task

Task 6: Management and Reporting
- Assist with report preparation

Ray McKaskle (Trimeric):

Task 5: Control Options Analysis
- Perform control options analysis

FESCO, Ltd.:

Task 2: Field Sampling and Analysis
- Perform compositional analysis of vent gas samples by GPA Method 2286

A5. Problem Definition and Background

Storage tanks and pressurized vessels at oil and gas production sites may emit a significant fraction of the total anthropogenic VOC emitted in east Texas; however, no accurate regional emissions inventory currently exists for this source category. Unconfirmed estimates of VOC emissions from oil and condensate storage tanks are given in Table A-1. These estimates were derived using an emission factor of 13.7 pounds per barrel and oil and condensate production data from the Texas Railroad Commission website (www.rrc.tx.state.us). The emission factor was developed by the Colorado Department of Public Heath and Environment (CDPHE) based on sampling at condensate production sites in northeastern Colorado. Actual emission factors for east Texas oil and gas production sites may differ from the CDPHE estimate due to differences in the processing equipment on site and in the physical properties of the hydrocarbon liquids that are produced. The estimates in Table A-1 assume no controls on vent gas emissions; however, in reality the extent of controls throughout the region is unknown.

Table A-1. Oil and Condensate Production in East Texas for January-September 2005 and Estimated Uncontrolled VOC Emissions for Storage Tanks

Area	Oil Production (BBL)	Condensate Production (BBL)	Estimated VOC (Tons/Day) [1]
HGB	7,299,830	4,056,616	288
DFW	64,115	572,249	16
BPA	1,830,510	2,342,594	106
Rest of East Texas	36,762,823	10,806,740	1,207

[1]Based on the CDPHE condensate production emission factor of 13.7 pounds per barrel.

Emissions from flashing are a significant, perhaps the major, component of storage tank vapor emissions to the air at oil and gas production sites. Flashing occurs when liquid hydrocarbons undergo pressure drops from processing pressures to atmospheric pressures as the liquids are transferred from high pressure separators or heater treaters into storage tanks. Unlike working and breathing losses, the two other components of storage tank emissions, flashing losses are not accounted for by the EPA Tanks model; however, several alternate methods for estimating flash emissions are available. For this project, flash emissions, along with working and breathing emissions, will be measured by direct sampling of the tank vent gas and measurement of the vent gas flow rate.

A6. Project Description

URS will develop speciated VOC emission factors and an inventory of speciated VOC emissions from liquid hydrocarbon storage tanks and pressurized vessels at oil and gas production sites in east Texas, with emphasis on the DFW and HGB ozone nonattainment areas as well as Jefferson County. This will be achieved in two steps. First, field sampling will be conducted at a number of oil and gas production sites to measure VOC emission rates and collect data on liquid hydrocarbon, i.e., oil or condensate, production. Second, regionally representative emission factors (in units of pounds of VOC emitted per barrel of oil or condensate produced) will be derived from the field data and applied to archived east Texas oil and gas production data to estimate monthly, annual, and average ozone season daily emissions on a county-by-county basis. A literature search for related emission factors and an analysis of control strategy options will also be conducted. This section gives a summary of the work to be performed. Specific data collection and analysis activities are described in greater details in Sections B1-B10 of this QAPP.

Task 1: Quality Assurance Project Plan

URS will develop a Quality Assurance Project Plan (QAPP) that describes the methods that will be used to acquire and analyze data as well as the procedures that will be used to assure the quality of the collected data and the accuracy of all calculations. The QAPP will conform, in content and format, to guidelines offered by the U.S. EPA document, titled *EPA Requirements for Quality Assurance Project Plans QA/R-5*. The QAPP will be drafted by the URS Project Manager and reviewed by the URS Quality Assurance Coordinator for this project. A draft QAPP will be submitted to HARC for review. Comments on the draft QAPP will be addressed and a revision will be submitted to HARC for approval within seven days after the comments are received.

Task 2: Field Sampling and Data Collection

Field sampling and measurement data will be gathered at approximately 30-40 representative oil and gas well sites in the DFW, HGB areas and Jefferson County. The composition of vent gases escaping from storage tanks will be measured by collecting grab samples from tank vents (or other suitable access ports, such as thief hatches, that would allow collection of samples from the vapor space) and sending the samples to SPL, Inc. laboratory for analysis. Flow rate measurements at each site will be made continuously over a 24-hour period to account for fluctuations that result from the tank loading cycles. Samples for compositional analysis and measurements of flow rate will also be collected from separators or heater treaters that are vented to the atmosphere. Emission rate measurements, based on vent gas composition and flow rate, will be divided by the barrels of oil or condensate produced during the 24-hour flow rate measurement to derive emission factors in units of pounds VOC emitted per barrel of oil or condensate produced (lbs/bbl).

Task 3: Literature Search

Information on emission factors reported in the literature or used by state regulatory agencies to estimate VOC emissions from liquid hydrocarbon storage tanks at oil and gas production sites will be gathered and summarized. As part of this task, URS will also survey emission inventory specialists from other oil and gas producing states over the telephone to identify emission factors and the approaches used for developing emission factors for oil and gas production sites. Information acquired by this task will be compared with field measurements from Task 2 and possibly used to supplement the field measurements when applying representative emission factors to parts of east Texas that will not be directly sampled.

Task 4: Emission Inventory Development

URS will develop a regional inventory of VOC emissions from liquid hydrocarbon storage tanks at oil and gas production facilities in east Texas (Figure A-2). Emission factors developed from Task 2 (and perhaps supplemented with information from Task 3) will be applied to archived oil and gas production data to estimate monthly, annual, and ozone season daily average emission rates on a county-by-county basis for east Texas. C1 through C12 alkanes, along with benzene, toluene, ethylbenzene, and xylene will be reported.

Task 5: Control Technology Evaluation

The approximate costs and benefits of available options for controlling VOC emissions from liquid hydrocarbon storage tanks at oil and gas production facilities will be analyzed and reported. As part of this task, the applicability of vapor recovery to oil and gas production sites in east Texas will be evaluated.

Task 6: Management and Reporting

The URS project manager will track the budget, schedule, and status of all project deliverables, and report to HARC via monthly progress reports and periodic teleconferences on progress made toward achieving the project goals. In addition to providing an update on project financials, activities, and milestones achieved, each progress report will identify problems encountered as well as recommendations or efforts made toward problem resolution. Draft and final reports will be prepared and submitted to HARC to document the methods, results, and conclusions of this project.

Figure A-2. East Texas Study Area (ERG, 2005)

A7. Quality Objectives

Table A-2 gives the quality objectives for direct measurements made as part of this project. Vent gas flow rate measurements will be made over 24-hour periods using an instrument capable of measuring flow rates to an accuracy of ± 10% of the average reading during the test. A broad range of flow rates is likely to be encountered which may require the use of different kinds of flow measurement instruments to meet the accuracy requirement. For example, extremely low vent flow rates may be more amenable to measurement by vane anemometer while a pitot tube or orifice plate meter may be used for the higher flow rates.

Additionally, vent gas grab samples for offsite compositional analysis will be collected, one per site, with the analytical accuracy objective being ± 10% for each reported compound. The completeness objective for vent gas flow rate and compositional analysis is at least 30 measurements (with each flow rate measurement reported as a 24-hour average).

Table A-2. Quality Objectives for Direct Measurements

MEASUREMENT VARIABLE	SAMPLE DURATION	SAMPLE FREQUENCY	ACCURACY	COMPLETENESS
Vent Gas Flow Rate	24-hours	Continuous/recorded as 1-minute averages	± 10% of reading	≥30 sites monitored
Vent Gas Composition	< 1 minute grab sample	One per site	± 10% defined as analytical repeatability	≥30 sites sampled

Section A8. Special Training/Certification

No special training or certifications are required for the project personnel; however, knowledge of the oil and gas production industry and possession of the source sampling technical skills needed to adapt to the wide range of source configurations likely to be encountered in this project are essential. The project team drawn together for this project possesses those attributes.

The field sampling task leader for this project has 25 years experience in emissions measurements, specializing in the development and application of sampling systems and measurement techniques for the types of adverse conditions likely to be encountered.

The field work will be supported by a team of chemical engineers and engineering technicians with 15+ years experience, most of which has been in the oil and gas production industry. The team has led and conducted numerous field tests involving flow measurements, sample collection, and analysis of various hydrocarbon streams. The team has direct experience in the use of a wide range of measurement techniques and equipment, e.g. pitot-tubes, vane anemometers, and orifice meters. This same team is also experienced in the process design and troubleshooting of oil and gas facilities, as well as in making emission estimates for such facilities.

A9. Documents and Records

A9.1. Communicating QA Project Plan Information

At the start of the project, the URS Project Manager will prepare a Project Management Plan containing information on the technical scope, budget, schedule, deliverables and contact information for all key project personnel. The Project Management Plan will also delineate the roles and responsibilities of key project staff. In addition to the Project Management Plan, this QAPP and any future revisions will be provided by the Project Manager to each project team member via hardcopy or email according to the distribution list given in Section A3 of this QAPP. Version control will be maintained using the document control format prescribed by the EPA QA/R-5 guidance document, an example of which is shown in the page header.

A9.2 Information Included in the Reporting Package

A list of documents and records that will be developed and maintained by the project team follows. Each item will be submitted to HARC as a draft for review before being submitted in final form. Note that information identifying the specific oil and gas production sites from where measurements were made, and the site operating companies, will be deleted from all hardcopy and electronic files delivered to HARC or its designees. The following items will be delivered:

- Field sampling logs (hardcopy);
- Raw flow rate measurement data (electronic spreadsheet);
- Laboratory data reports (hardcopy or electronic spreadsheet);
- Data used for emission factor calculations (electronic spreadsheet);
- Data used for emission inventory development (electronic spreadsheet);
- Speciated VOC emissions for east Texas counties (electronic spreadsheet); and
- Report of methods, activities, and results (hardcopy and electronic document).

Field sampling logs, which will be included in the reporting package, will contain the following information:

- A simple schematic diagram of the tank battery operation, with processing equipment and showing the location of the sampling port;
- County and geologic formation;
- Sampling date and time;
- Temperature of liquid product (if available);
- Amount of oil or condensate produced during the sampling period (in barrels);
- The well type (i.e., oil, gas, or casinghead);
- The number of wells served by the tank battery;
- The temperature of product leaving the separator (if available);
- The number of tanks in the tank battery;
- The approximate tank dimensions (i.e., diameter and height);

- The type of tank (i.e., oil, condensate, saltwater, gun barrel);
- The color, approximate age, condition and construction (i.e., bolted or welded) of the tanks; and
- The approximate age of the processing equipment.

A9.3 Retention and Final Disposition of Records

URS will store all records and documents developed for this project in a centralized filing system maintained by its Austin office for at least ten years following the completion of the project.

B1. Experimental Design

Field sampling and measurements will be performed at representative oil and gas production sites in the DFW Ozone Nonattainment Area as well as the HGB Ozone Nonattainment Area and the neighboring Jefferson County. Approximately 30-40 oil and gas production sites will be sampled. The sampling and measurement data will be used to derive factors for speciated VOC emissions in units of pounds of VOC emitted per barrel of oil and condensate produced, and ultimately used to develop a regional inventory of storage tank emissions from oil and condensate production in east Texas.

Figure B-1 is a schematic diagram of a typical oil or gas production site (Southern Research Institute, 2002). The well stream is first passed through a separator or a heater treater where liquid hydrocarbons (i.e., oil or condensate), gas, and water are separated. The gas exiting the separator is routed to a gas dehydrator to remove excess water or to a field compressor that pressurizes the gas to pipeline sales pressure. Liquid hydrocarbons are routed to a tank (or a battery of more than one tank) where the hydrocarbons are stored in order to stabilize flow between production wells and pipeline or transportation by truck. Water is stored in a separate tank in preparation for disposal. Sites configured substantially different from the typical site will be not be sample since as they might be considered unrepresentative of the broader population of oil and gas production sites in the region.

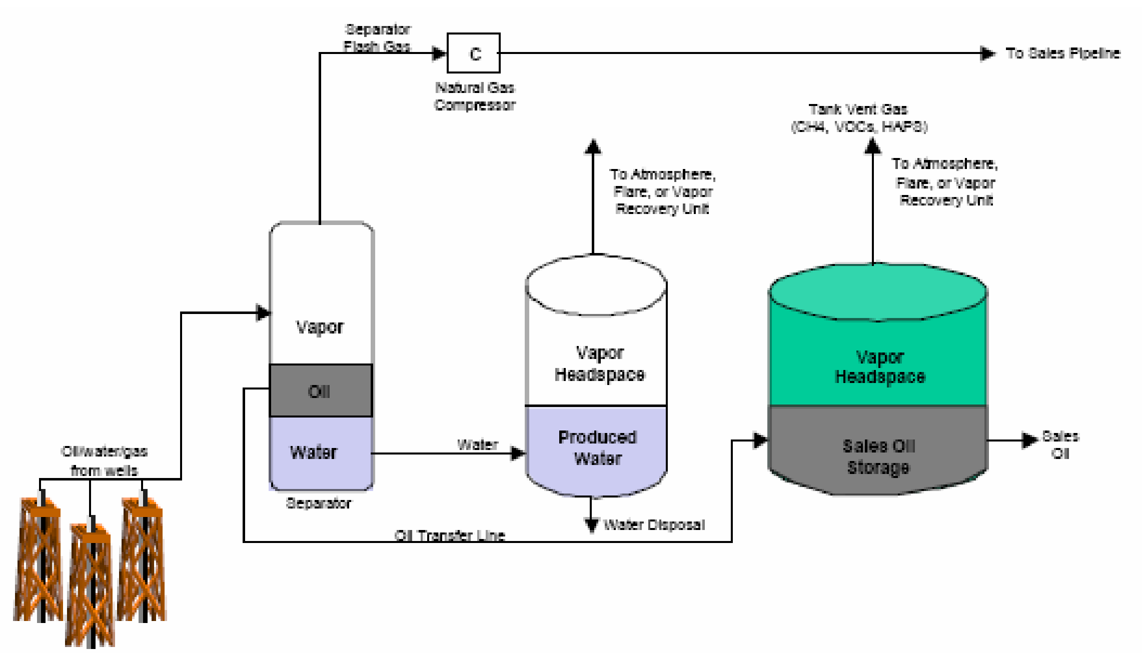


Figure B-1. Schematic Diagram of an Oil and Gas Production Facility (Southwest Research Institute, 2002)

VOC emission rates will be measured by sampling the tank vent gas for compositional analysis and measuring the vent gas flow rate. Measurements of separator gas vented to the atmosphere will also be made. The concentration of each C1-C6 gas component in the sample, plus benzene, toluene, ethyl benzene, xylene (BTEX) and other C6+ VOC will be multiplied by the flow rate (averaged over 24-hours) to produce measurements of mass emission rates for each of the reported gas constituents and other C6+ VOC in units of pounds per hour. The mass emission rates will then be divided by the number of barrels produced during the 24-hour flow measurement period to produce emission factors in units of pounds per barrel. Critical measurements for this approach include the following:

- Vent gas composition;
- Vent gas flow rate; and
- Oil or condensate production rate

Approximately 30-40 well sites in the DFW, HGB, and Jefferson County areas will be selected for sampling based on the following criteria:

- The chemical and physical properties of the oil or condensate produced at the site are typical of the region according to the expert opinion of the site operating company personnel;
- The processing equipment at the site are typical of the region according to the expert opinion of the site operating company personnel;
- No equipment is used to control vapor emissions from liquid storage tanks;
- The oil or condensate production rate is at least 2 barrels per day;
- The liquid storage tanks are of welded construction; and
- The site is easily accessible

The minimum number of oil and gas production sites that will be sampled in each geographic region is given in Table B-1. In determining these numbers, emphasis was placed on the HGB area due to the greater oil and condensate production rates (see Table A-1, for example) and the greater numbers of oil and gas fields contributing to the regional production.

Table B-1
Approximate Number of Oil and Gas Production Sites to be Sampled in Each Region

Region	Oil Production Sites	Gas/Condensate Production Sites
DFW	0	3-6
HGB	9-12	9-12
Jefferson Co.	1-3	1-3

Average oil production and condensate production emission factors will be developed for each geographic region and applied to liquid hydrocarbon production data available from the Texas Railroad Commission to estimate monthly, annual, and ozone season daily emissions for 2005 or other year of interest to HARC. The emissions inventory will be expressed in terms of county-wide totals for east Texas counties identified in Figure A-1. Emissions inventories for counties where no direct sampling or measurements were conducted will be based on the average factor derived from all the sampling sites, from a subset of all sites deemed most representative, or factors identified from the literature review if appropriate.

B2. Sampling and Measurement Methods

Vapor grab samples for compositional analysis will be collected using evacuated, passivated stainless steel canisters. The canisters will be supplied by the analytical laboratory and will be pre-evacuated in the laboratory to vacuums of at least 27 inches of mercury (i.e., 2 inches of mercury absolute). The canister vacuums will be checked in the field, prior to sampling, to ensure the absence of measurable gas leakage during transport to the field and handling. Any canisters found to have less than 27 inches Hg vacuum will not be used for sampling. The gas samples will be collected from the tank vents or another suitable access port such as a thief hatch. The samples will be collected at least 2 feet from the flow measuring device to avoid disturbances in the flow measurement. A sampling probe made of stainless steel will be used to draw the gas sample from approximately 2 feet within the vent stack or tank vapor space and avoid possible entrainment of ambient air into the sample canister. The canisters will be filled to less than atmospheric pressure (e.g., approximately 5 inches Hg vacuum) to reduce the potential for moisture condensation. For sites having batteries of more than one liquid storage tank, only a single gas sample will be collected. For example, if all the storage tanks share a common vent, the gas sample would be collected from the common vent stack. Otherwise, a temporary manifold made of Teflon tubing may be constructed to channel the gas flow to a common sampling port.

Measurements of vent gas flow rates will be made using a Fox Instruments Model 10A Thermal Mass Flow Meter. This instrument uses a thermal flow sensor, which operates on the principle that fluids absorb heat. A heated sensor placed in the gas stream transfers heat to the gas in proportion to the mass flow rate. Using a bridge circuit, one sensor detects the gas temperature while a second sensor is maintained at a constant temperature above the gas temperature. The temperature difference results in a power demand that equals the gas mass flow rate. . The flow rate will be measured and recorded continuously over a 24-hour period at each sampling site. At sites having batteries of more than one liquid storage tank, the tank vents will be manifolded together to create a single port for measuring the total tank battery vent flow. The air surrounding each tank will be screening using a portable total hydrocarbon analyzer to help in the detection and elimination of tank vapors that might be escaping for places other than from where the flow is to be measured.

The liquid production rates will be determined during the test period either by reading the level gauge on the tanks (if present at the site), or by manually gauging the tanks. The manual tank readings will be adjusted to account for any unloading of the tanks into tank trucks during the test.

B3. Sample Handling and Custody

The chain of custody for vent gas samples will begin and end with the laboratory performing the compositional analysis. Sample canisters will be evacuated in the laboratory and then shipped to the field sampling team along with chain of custody records documenting the initial canister vacuum. No special procedures are required for handling or storing sample canisters in the field; however, vacuum checks will be made and recorded prior to sampling to verify that no air leakage into the canister has occurred following evacuation by the laboratory. Additionally, the canister vacuum will be checked after a sample has been collected for the laboratory to use as a reference to check whether air has leaked into the canister following sample collection. Samples will be returned to the laboratory via FedEx or other registered carrier along with chain of custody records and other associated documentation within seven days after sample collection. The samples will be analyzed and results reported to URS within seven days after receipt by the laboratory.

All samples collected in the field will be labeled to identify the gas well or oil lease site where it was collected, the date and time of collection, and the sampling personnel. Samples will be identified with sequential numbers beginning with H51C-001, H51C-002, etc.

B4. Analytical Methods

The compositional analysis of tank vent gas samples will be conducted according to Gas Processors Association (GPA) Method 2286 for quantification of speciated hydrocarbons including methane (C1) through C12 and benzene, toluene, ethylbenzene, and xylene (BTEX). During this analysis, the sample gas is heated to the gas temperature recorded during sample collection and injected into a gas chromatograph (GC) where it is split into three sections. The first section separates and detects oxygen, nitrogen, and methane using a thermal conductivity detector. The second section separates methane through n-pentane using a different column and a flame ionization detector (FID). The third section separates isopentane through dodecane using a third column and a second FID. The analytical results will be reported in units of mole percent per reported compound. Details of GPA Method 2286 are provided in Appendix A

B5. Quality Control

The quality of field measurement data used for deriving emission factors will be controlled by measuring vent gas flow rates over approximately 24 hours using a measurement device capable of accurately measuring flow rates over the broad range likely to be encountered. The 24-hour measurement period will allow for averaging short-term fluctuations in vent gas flow rate caused by oil and condensate production cycles. Additionally, a portable hydrocarbon vapor analyzer will be used to screen the air around the storage tanks and pressurized vessels for leakage. URS will notify the site operating personnel of any measureable gas leakage and work with that individual to seal any leaks prior to conducting flow rate measurements.

The quality of gas compositional measurements will be controlled by using standardized analytical methods appropriate for the type of samples that will be collected. Duplicate vent gas samples for compositional analysis will be collected at a minimum of three sites (at least 10% of all oil and gas production sites) to assess measurement precision.

The greatest source of uncertainty in the calculated emission factors is likely to be the estimation of oil or condensate produced over the sampling period. The accuracy of the emission factors derived from these tests will be limited to how accurately the production volumes can be determined during the sampling episode. While such production information is readily available on a monthly or annual basis from the Texas Railroad Commission, accurate production data over a 24-hour period is generally not available, and will have to be estimated from reading the tank level gauges (if present), manually gauging the tank level, or from production meters at the site if available. The specific methods and instruments used to estimate daily throughput will be recorded in the field sampling log; however, the sensitivities of these devices to oil or condensate throughput over 24-hours is unknown.

B6. Equipment Testing, Inspection, and Maintenance

All field measurement and sampling equipment will be inspected prior to use. Additionally, the analytical laboratory will maintain a Quality Program that delineates and verifies compliance with specifications for equipment inspection and maintenance.

B7. Instrument Calibration and Frequency

The gas chromatograph used for determination of vent gas composition will be calibrated at least once per week according to the GPA Method 2286 calibration procedures (see Appendix A). This method requires the determination of response factors using the peak area counts for each reported gas component based on the analysis a gas reference standard of known composition. Additional calibrations will be performed whenever a new column is installed or maintenance is performed. A continuing verification of instrument calibration will be performed daily in accordance with the laboratory Quality Program.

The vent gas flow measuring device will be tested prior to use to verify agreement to within ± 10% of comparative measurements using a standard flow measurement device.

B8. Inspection/Acceptance of Supplies and Consumables

Vacuum checks on all canisters used for sampling vent gas streams will be performed prior to use in the field. Canisters with initial vacuums less than 27 inches of mercury will not be used for collecting field samples. No other consumables or supplies will be used in this sampling program.

The laboratory will be responsible for procurement of appropriate analytical standards in accordance with the specifications of GPA Method 2286.

B9. Non-direct Measurements

Non-direct measurements collected at each field site will include the separator pressure, the API gravity of the oil or condensate produced, and the oil or condensate production rate for the time period in which vent gas flow rate measurements are made. Additionally, annual and monthly oil and condensate production data from east Texas counties will be obtained from the Texas Railroad Commission.

The separator pressure and API gravity are two variables on which VOC emissions rates from storage tanks will depend most strongly. Therefore, these parameters will be recorded at each site and will be used to assess and document the representativeness of the measured emission factors. The API gravity of the oil or condensate will be obtained from site logs or by interviewing site operating personnel. Separator pressures will be obtained from site logs or separator pressure gauges.

Oil and condensate production during vent gas flow rate measurements will be determined from site logs or from liquid flow metering devices at the site. Annual and monthly oil an condensate production rates will be used, along with derived emission factors, to estimate emissions for east Texas on a county-by-county basis. Oil and condensate production rates are available from the Texas Railroad Commission website at www.rrc.state.tx.us.

B10. Data Management

Separator pressures, API gravities of the produced oil or condensate, and oil or condensate production rates will be recorded initially in a field logbook along with other information pertinent to identifying where and when field measurements and samples were collected and the weather conditions at the time. The field log notes will later be transferred to an electronic spreadsheet. Each data entry in the logbook and spreadsheet will be indexed according to the lease (site) name and number as described in the Texas Railroad Commission website. The gas or oil field from which the liquid hydrocarbon is produced will also be entered into these logs. At the completion of the project the electronic spreadsheet will copied to a compact disc and stored by URS for at least 10 years. A copy of the electronic log, minus the Lease name and number will be delivered to HARC. The log will contain entries for the following data fields:

- Lease (site) name;
- Lease number;
- County
- Oil or gas field name;
- API gravity of the oil or condensate;
- Separator pressure;
- Start and stop date/time of the flow rate measurement;
- Barrels of oil or condensate produced over the flow rate measurement period;
- Date/time of vent gas grab sample for compositional analysis;
- Vent gas sample identification number;
- Field sampling personnel;
- Ambient Temperature;
- Ambient Pressure
- A simple schematic diagram of the tank battery operation, with processing equipment and showing the location of the sampling port;
- Temperature of liquid product (if available);
- The well type (i.e., oil, gas, or casinghead);
- The number of wells served by the tank battery;
- The temperature of product leaving the separator (if available);
- The number of tanks in the tank battery;
- The approximate tank dimensions (i.e., diameter and height);
- The type of tank (i.e., oil, condensate, saltwater, gun barrel);
- The color, approximate age, condition and construction (i.e., bolted or welded) of the tanks; and
- The approximate age of the processing equipment.

Vent gas flow rate measurements will be recorded continuously and logged as 1-minute averages on a portable data recording system. The data will be backed up on compact disc and later transferred to computer spreadsheet for calculating the average flow rate at each site. Laboratory data reports of vent gas composition will be generated in hardcopy and electronic formats. All flow rate measurement data will be indexed according to the lease name and number and the date/time of the measurement. The raw measurement data and spreadsheets will be stored by URS for at least 10 years after the completion of the project. Copies of all raw measurement data and spreadsheets, minus the lease name and number, will be delivered to HARC after the completion of this project.

Annual and monthly oil and condensate production data are permanently stored in a Texas Railroad Commission database, which is accessible online at www.rrc.state.tx.us. County totals for east Texas will be extracted from the online database and stored in a computer spreadsheet.

C1. Assessments and Response Actions

No quality assurance audits of sampling or analysis activities are planned for this project. All data gathered and used as part of this project will be assessed for usability by the project QA coordinator, as described in Section D1 of this QAPP.

C2. Reports to Management

Field sampling personnel will communicate with the URS Project Manager via telephone or email at least twice per week during the sampling effort to report on progress and any problems encountered.

Laboratory staff will report the results of analytical quality control checks with each data reporting package.

D1. Data Review, Verification, and Validation

Data review, validation, and verification procedures are presented in this section. Three types of data are collected for this project:

- Continuous vent flow rate data collected over 24 hours;
- Concentrations of VOC species in vent grab samples collected in whole air canisters; and
- Oil or condensate production rates for periods concurrent with vent flow rate testing.

Data validation will be performed for all measurement results under the supervision of the Project Manager, who will verify that the sampling and analysis data are complete for each test site. Data will be declared invalid whenever documented evidence exists demonstrating that a sampler or analyzer was not collecting data under representative conditions or was malfunctioning.

The activities involved in validation of the data in general include the following:

- reviewing the site visit logs, calibration data, audit data, and project memoranda for indications of malfunctioning equipment or instrument maintenance events;
- reviewing the data packages from the analytical laboratory, which contains chain-of-custody, instrument calibration, and QC check results; and
- examining the continuous flow rate data for spikes, anomalous results, unusually high rates of change, or measurement values that seem incongruous with normal measurement ranges and/or diurnal variations.

Analysis data for VOC speciation data are checked by both laboratory and project QA staff. The lab quality control information is reviewed, and the project team verifies any data flags or reported anomalies in the analyses. The lab records are also checked against the field records created by the network operator to ensure that there are no discrepancies. If all quality control criteria are met, the results are annotated as valid.

Data are never declared invalid solely because they are unexpected, but may be flagged as suspect and be subjected to further review until the cause for the apparent anomaly is determined. The results from all quality control and quality assurance checks are evaluated to determine if the data quality objectives for each measurement are being met. Evidence of overwhelming measurement bias, external influences on the representativeness of the data, or lack of reproducibility of the measurement data may be cause for the data to be judged invalid.

The final, validated data set is then produced and peer reviewed to ensure that limitations in use of any data are clearly communicated to the data users, and that the validation process was consistent with project requirements and URS standard procedures.

D2. Verification and Validation Methods

The URS Project Manager will conduct the final review of the data and emission factor calculations prior to their being considered valid. Data from all the various sources, and emission factor calculation results, will be combined into a single spreadsheet to facilitate this review. Each row of the spreadsheet will represent a single oil or gas production site while the columns will represent all the different operating parameters (e.g., separator pressure, API gravity), measurement results, and derived emission factors. Graphical displays of each parameter will be made and any outlying data points will be investigated.

D3. Reconciliation with User Requirements

Emission factors and the regional emissions inventory developed from this project are intended for use by the TCEQ to evaluate ozone control strategies for the DFW and HGB areas. To meet the user requirements, the data resulting from this project must be of known and defensible quality. The quality control and chain of custody procedures to be implemented during the sampling program are intended to help achieve this objective. Emission factors derived from the measurement data must also be representative of the thousands of oil and gas production sites in east Texas. While efforts will be made to sample at oil and gas production sites that are reasonably representative, site-to-site variations in emission factors cannot be controlled – they can only be assessed. Calculations of the emission factor standard deviations and mean confidence intervals for the sampled populations of sites, which will be included in the project draft and final reports, will be used to evaluate emission factor variability and the representatives of the derived emission factors to broad regions or sub-regions of east Texas. Additionally, a follow up survey of the oil and gas production industry to assess the existing use of vapor recovery and other vent gas emission controls is recommended.