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UPSTREAM OIL AND GAS HEATERS AND BOILERS

FINAL REPORT

Prepared for:

Texas Commission on Environmental Quality

Air Quality Division

Prepared by:

Eastern Research Group, Inc.

August 30, 2013

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Upstream Oil and Gas Heaters and Boilers

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List of Acronyms

Acronym	Definition
AP-42	U.S. EPA's Compilation of Air Pollutant Emission Factors
API	American Petroleum Institute
BBL	Barrel
BPA	Beaumont-Port Arthur
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CENRAP	Central Regional Air Planning Association
CenSARA	Central States Air Resource Agencies
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group
FIRE	Factor Information Retrieval
GOR	Gas/Oil Ratio
H_2S	Hydrogen Sulfide
HAP	Hazardous Air Pollutants
HARC	Houston Advanced Research Center
HGB	Houston-Galveston-Brazoria
IPAMS	Independent Petroleum Association of Mountain States
lbs	Pounds
MMBtu	Million British Thermal Units
Mscf	Thousand standard cubic feet
MMscf	Million standard cubic feet
NESHAP	National Emission Standards for Hazardous Air Pollutants
NO_x	Nitrogen Oxides
NSPS	New Source Performance Standard
PM	Particulate Matter
ppm	Parts per million
psig	Pounds per square inch gauge
QA	Quality Assurance
RRC	Texas Railroad Commission
SO_2	Sulfur Dioxide
TCEQ	Texas Commission on Environmental Quality
TERC	Texas Environmental Research Consortium
VOC	Volatile Organic Compound
VRU	Vapor Recovery Unit
WRAP	Western Regional Air Partnership

Executive Summary

Eastern Research Group, Inc. (ERG) is currently under contract with the Texas Commission on Environmental Quality (TCEQ) to improve area source oil and gas emissions inventory estimates for heaters and boilers located at upstream oil and gas production sites in Texas. This report describes ERG's findings relative to survey efforts undertaken to collect information on the magnitude and prevalence of heaters used in the eight oil and gas basins found in Texas, and an analysis of available heater emission factor data.

Heaters are used at oil and gas production facilities to provide thermal energy to certain operations within the production process. They can be used as separator heaters (heater treaters) to provide heat to separation units, as inline heaters to maintain temperature within pipes and connections and to prevent hydrate formation, or as tank heaters to maintain storage tank temperatures. Heaters are also used in dehydrators; however, these sources are covered under the TCEQ oil and gas area source emissions inventory dehydrator source category and were not addressed under this study.

Heaters are typically field gas-fired external combustors and are a source of nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOC) and particulate matter (PM) emissions. Sulfur dioxide (SO_2) emissions may also occur if the gas used to fire the heaters contains hydrogen sulfide (H_2S), which will be subsequently converted to SO_2 during combustion. County-level emissions from heater sources have been estimated in the current inventory using the methodology from a 2008 study conducted for the Central States Regional Air Partnership (CENRAP).[1] The emissions from heater treaters, line heaters and tank heaters may be small at an individual facility level as the burners are small and don't burn a lot of fuel relative to other combustion sources at oil and gas production sites. However, these heaters may operate constantly all day and throughout the year. When emissions from all of the heaters in use in the state are totaled, the amount of emissions may be significant.

ERG recommends that the TCEQ calculate heater emissions from upstream oil and gas production sites across the state based on the number of operational wells, and using the updated activity and emission factor data obtained under this study. As described above, the emissions estimation activity data will vary on a region-by-region basis. An emission factor for NO_x emissions of 58.2 lb/MMscf will be used state-wide. County-level heater emissions may be calculated using this emission factor and the values shown in Table E-1.

[1] Bar-Ilan, A., R. Parikh, J. Grant, T. Shah, and A. Pollack. 2008. "Recommendations for Improvements to the CENRAP States' Oil and Gas Emissions Inventories." ENVIRON. Accessed online at: http://www.wrapair.org/forums/ogwg/documents/2008-11_CENRAP_O&G_Report_11-13.pdf

Table E-1. Recommendations for Calculating Heater Emissions

Basin	Average # of Heaters Per Well	Average Heater Size (MMBtu/hr)	Average Hours of Operation (hrs/yr)	Average Fuel Heat Content (Btu/scf)
Anadarko	1.35	0.658	5,483	1,116
Eagle Ford Shale	0.54	0.906	7,574	1,289
East Texas	0.0041	0.500	8,400	1,015
Arch Bend - Fort Worth	0.15	0.500	1,414	1,040
Permian	0.37	0.525	3,477	1,359
Western Gulf	0.20	1.897	6,935	1,102
Marathon Thrust Belt[a]	0.44	0.831	5,547	1,154
Palo Duro[a]	0.44	0.831	5,547	1,154

[a] Statewide average

1. Introduction

Eastern Research Group, Inc. (ERG) is currently under contract with the Texas Commission on Environmental Quality (TCEQ) to improve area source oil and gas emissions inventory estimates for heaters and boilers located at upstream oil and gas production sites in Texas. This report describes ERG's findings relative to survey efforts undertaken to collect information on the magnitude and prevalence of heaters used in the eight oil and gas basins found in Texas, and an analysis of available heater emission factor data.

Heaters are used at oil and gas production facilities to provide thermal energy to certain operations within the production process. They can be used as separator heaters (heater treaters) to provide heat to separation units, as inline heaters to maintain temperature within pipes and connections and to prevent hydrate formation, or as tank heaters to maintain storage tank temperatures. Heaters are also used in dehydrators; however, these sources are covered under the TCEQ oil and gas area source emissions inventory dehydrator source category and were not addressed under this study.

Heaters are typically field gas-fired external combustors and are a source of nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOC) and particulate matter (PM) emissions. Sulfur dioxide (SO_2) emissions may also occur if the gas used to fire the heaters contains hydrogen sulfide (H_2S), which will be subsequently converted to SO_2 during combustion. County-level emissions from heater sources have been estimated in the current inventory using the methodology from a 2008 study conducted for the Central States Regional Air Partnership (CENRAP).[2] The emissions from heater treaters, line heaters and tank heaters may be small at an individual facility level as the burners are small and don't burn a lot of fuel relative to other combustion sources at oil and gas production sites. However, these heaters may operate constantly all day and throughout the year. When emissions from all of the heaters in use in the state are totaled, the amount of emissions may be significant.

Purpose of This Study

The purpose of this study is to refine the estimates for the number and the activity level of heaters at oil and gas wells across Texas, and refine the heater emission factor used in the TCEQ area source inventory. This was accomplished by: conducting a review of available literature, conducting a phone and email survey of Texas oil and gas

[2] Bar-Ilan, A., R. Parikh, J. Grant, T. Shah, and A. Pollack. 2008. "Recommendations for Improvements to the CENRAP States' Oil and Gas Emissions Inventories." ENVIRON. Accessed online at: http://www.wrapair.org/forums/ogwg/documents/2008-11_CENRAP_O&G_Report_11-13.pdf

producers, evaluating the data collected in the Barnett Shale Area Special Inventory[3], evaluating point source emissions data as reported to TCEQ, and researching the availability of emission factors specific to heaters.

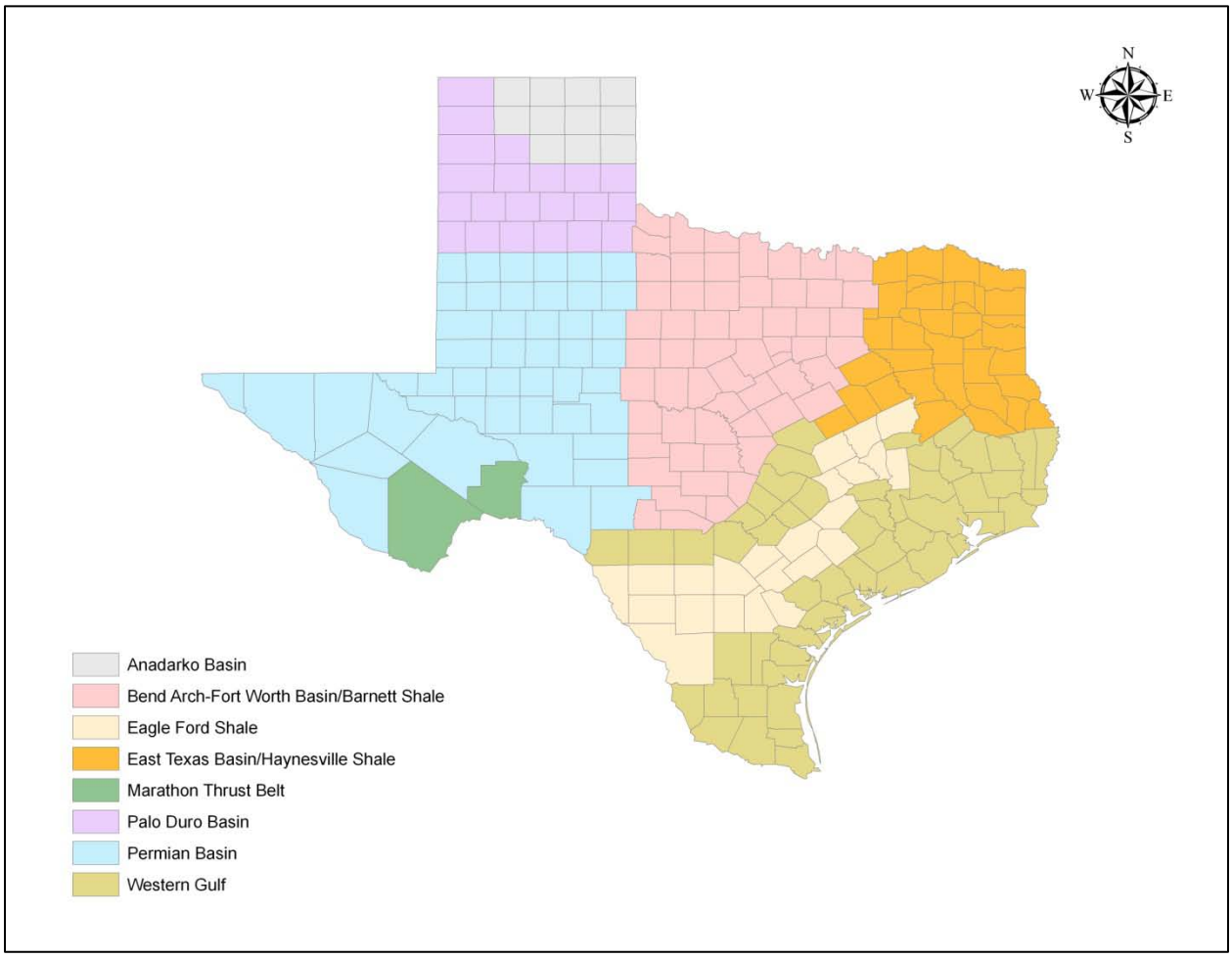
ERG conducted a review of available literature, looking for data on emissions testing and emissions estimates for oil and gas heaters in the Midwest and Mountain states surrounding Texas. Academic and technical literature on combustion emissions and emissions control and available state environmental agency guidance on calculating emissions from heaters at oil and gas wells were examined. ERG conducted a phone survey of Texas oil and gas producers, requesting information on the use of heaters at their oil and gas wells. Several oil and gas producers were interviewed at length, to gather information on current practices and trends in the industry that are specific to Texas. The data collected in the 2009 Barnett Shale Area Special Inventory was evaluated for its applicability to this effort, and compared with the responses to the voluntary survey conducted as part of this current study.

Finally, ERG conducted a technical review of the available studies on emission factors for small heat capacity heaters. These studies included a California study on heater treater emissions, as well as the supporting tests that form the basis of the AP-42[4] emission factors currently used by most of industry and state environmental agencies. Combining this information, ERG derived region-specific activity data and emission factors for use in updating the state-wide, oil and gas area source heater inventory. Figure 1-1 identifies the eight oil and gas basins found in Texas.

[3] "Barnett Shale Area Special Inventory, Phase One", TCEQ, 2009, http://www.tceq.texas.gov/assets/public/implementation/air/ie/pseiforms/Barnett%20Shale%20Area%20Special%20Inventory.pdf , "Barnett Shale Phase Two Special Inventory Data", TCEQ, http://www.tceq.texas.gov/assets/public/implementation/air/ie/pseiforms/summarydatainfo.pdf

[4] U.S EPA, AP-42, Compilation of Air Pollutant Emission Factors, http://www.epa.gov/ttn/chief/ap42/index.html.

Figure 1-1. Oil and Gas Basins in Texas



TCEQ's area source air emissions inventory estimates for heaters are currently based on the number of oil wells and gas wells at the county-level as reported on the Texas Railroad Commission (RRC) website and activity data derived from the 2008 CENRAP study.[5] The CENRAP data indicates that there is approximately one heater at every oil and gas well in the state, and that these heaters operate about 4,100 hours per year.

This survey study sought to determine:

- Are the 2008 CENRAP study estimates and the TCEQ air emissions inventory estimates still representative of heater use at oil and gas operations in Texas;
- Is the amount of petroleum liquids produced at a well a good predictor of the capacity and activity level of heaters; and
- Does the geographic area where the wells are located affect the need for heaters and treatment.

[5] Bar-Ilan, A, et.al., "Recommendations …", Op. Cit.

Oil or Condensate?

In this study, the Texas RRC designations for whether a well produces oil or condensate were used. The RRC distinguishes between oil and condensate, with ‘oil’ being the liquid produced at oil wells and ‘condensate’ being the liquid produced at gas wells. The RRC county level production data shows that the majority of petroleum-producing counties produce both ‘oil’ and ‘condensate’. This is usually due to the fact that, within the geographic boundary of many counties, there may be two or more petroleum producing formations stacked atop one another at different depths below ground. One of the formations may produce oil, while the other may produce gas, while perhaps a third formation yields gas from shale. Therefore, the estimates of emissions from any particular county or region could reflect the emissions from wells tapping one, two, or more petroleum-producing formations underground.

2. Heater Operations at Upstream Oil and Gas Sites

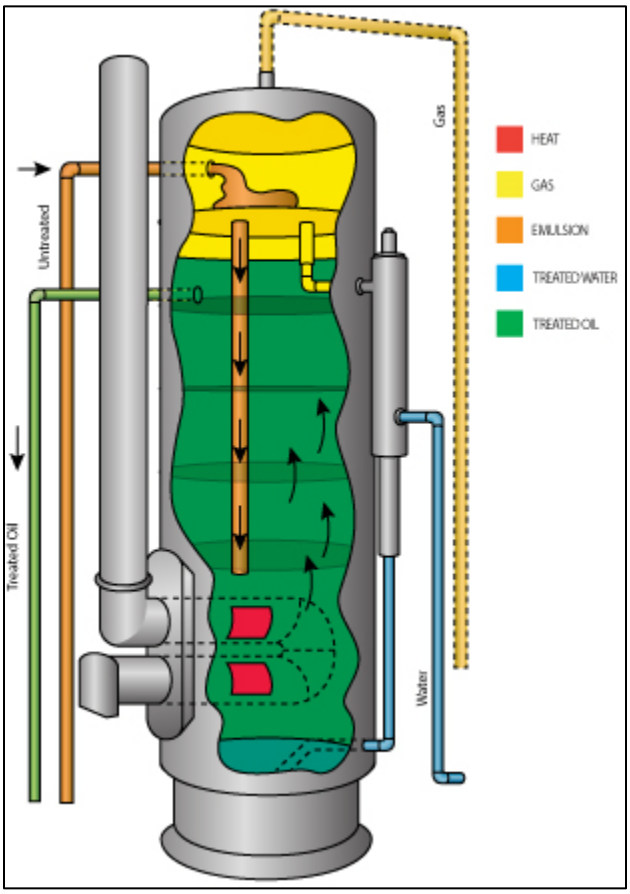
2.1 Heater Treaters

Heater treaters are used at upstream oil wells to break up oil/gas/water emulsions and to separate the crude oil from water and other foreign materials. At gas wells, a heater-treater may be used to remove contaminants (liquid hydrocarbons and water) from the natural gas at or near the well head before the gas is sent down the production line to the gas plant. The heater-treater is a combination of a heater, free-water knockout, and oil/condensate and gas separator. It prevents the formation of ice and natural gas hydrates that may form under the high pressures associated with the gas well production process. These solids can plug the wellhead. Since chokes in the wellhead restrict the flow of the oil and gas from the well, temperatures may drop due to the pressure changes of the choke. This may cause the water or hydrates to freeze and plug the well, thereby slowing or stopping the condensate and gas production.[6]

The most commonly used single-well treater is the vertical heater treater. A vertical heater treater consists of three major sections: gas separation, free water knockout, and a heating section. The mixture of hydrocarbon liquids, gases, and water from the wellbore enters the top of the treater into a gas separation section. Oil and water travel down through the vessel to the heated section where the heat breaks the emulsion, allowing the water and oil to separate into distinct constituents. The water then settles to the bottom of the vessel while the oil rises to the top. Horizontal heater treaters are used in a similar fashion, but the elongated shape allows for a long "U" shaped firetube with a higher heating capacity and more efficient separation.
Figure 2-1 presents a schematic of a typical vertical heater treater[7].

[6] Colorado Department of Public Health and Environment's Air Pollution Control Division, "Heater-Treater Source Category - NO_x Emission 4-Factor Analysis for Reasonable Progress (RP)" http://www.colorado.gov/cs/Satellite?blobcol=urldata&blobheadername1=Content-Disposition&blobheadername2=Content-Type&blobheadervalue1=inline%3B+filename%3D%22Heater+Treaters.pdf%22&blobheadervalue2=application%2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1251808868243&ssbinary=true
[7] Diverse Energy Systems, accessed online at: http://www.des-co.com/portfolioentry/heater-treaters/

Figure 2-1. Heater Treater

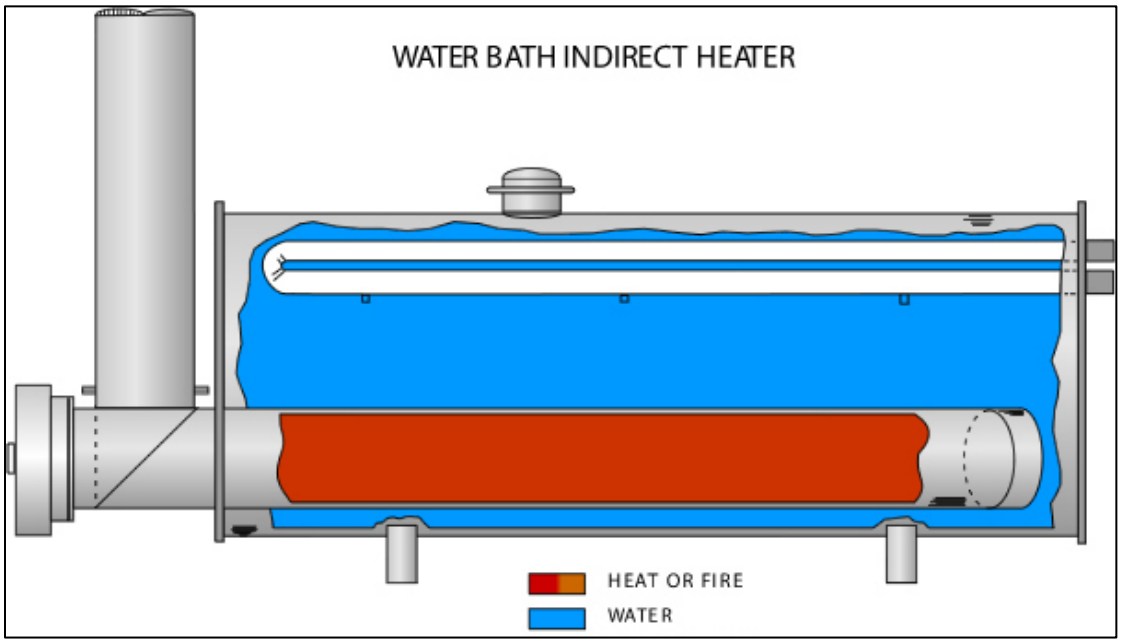


2.2 Line Heaters

Line heaters are used to maintain temperatures in well operations as pressures in the process stream are rapidly reduced to sales line requirements, as well as to prevent formation of hydrates during pressure reductions. They counteract the effect of abrupt temperature drop that occurs when the well stream passes through a pressure-reducing choke. They can also be used to heat gas transmission lines. A line heater typically consists of three components: the shell, the firetube, and the coil. The process stream flows through the coil, which is immersed in the upper portion of the liquid media bath (typically water) of the shell. The coil preheats the flow stream before reducing the pressure across a restricting choke followed by post-heating coils. Fuel is burned in the firetube and indirectly transfers heat to the media, then to the coil, and finally to the process stream. Figure 2-2 presents a schematic of a typical water bath line heater[8].

[8] KW International, accessed online at: http://www.kwintl.com/line-heaters.html

Figure 2-2. Line Heater



2.3 Tank Heaters

Tank heaters are used to maintain temperatures in storage tanks to prevent freezing of saltwater or condensate, and prior to pumping into a pipeline to keep paraffin in solution or to improve pump efficiency by reducing viscosity of the fluids. As with a line heater, fuel is fired in a firebox and the heat is transferred to the liquid medium, which may be brought to the boiling point to produce steam. The heated liquid, or steam, is then piped to a heat exchanger or coil where it is used to heat the storage tank fluids.

3. Heater Emission Factor Review

This section discusses the methods that ERG used in conducting research for emission factors for heaters. ERG performed the following activities to identify data on emissions testing and emissions estimates for heater: 1) interviewed equipment manufacturers, 2) conducted a phone survey of oil and gas producers, 3) examined the Barnett Shale Special Inventory data, 4) examined state environmental agency guidance on calculating heater emissions, 5) conducted a literature review of studies, papers, and books discussing combustion emissions, 6) examined EPA's RACT/BACT/LAER Clearinghouse (RBLC) database[9], and 7) looked into boiler design and how it affects emissions. As NO_x is the primary pollutant of concern, the focus of this review was on NO_x emissions. TCEQ currently uses the AP-42 emission factor for NO_x in calculating heater emissions in the upstream oil and gas air emissions inventory. The TCEQ also recommends that permit applicants use AP-42 emission factors in its guidance for calculating emissions.

3.1 Vendor Data

ERG reviewed the Barnett Shale Area Special Inventory data and responses from this 2013 survey and identified several manufacturers of heater treaters. The brand names, makes, models, and sizes were also noted. In total, 16 companies were identified. ERG attempted to contact these companies by phone and email. Due to industry consolidation, many of these manufactures are no longer in operation. Others have migrated out of the commercial heater service. For example: Hanover Compressor Company is now part of Exterran Holdings Inc. while Titan Oil & Gas now specializes in coiled tubing.[10,11] Five original equipment manufacturers (OEM), who produce heaters were contacted and asked to provide performance data, including NO_x emission rates.

After speaking with the technical and sales representatives of these five heater manufacturers, it became clear that air emissions from heaters are not a primary concern to the OEMs. Most manufacturers are small companies and do not have staff dedicated to supporting environmental compliance. The exception is Exterran, whose website has materials to inform customers of recent changes to Federal rules that might impact engines.[12] ERG contacted the Exterran air quality team, but they did not share heater performance data.

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[9] U.S EPA, RACT/BACT/LAER Clearinghouse (RBLC), http://cfpub1.epa.gov/RBLC/

[10] Industry law firm - Robbins Arroyo LLP, accessed online at: http://www.robbinsarroyo.com/noteworthy-cases/hanover-compressor-company/

[11] Titan Oil and Gas, accessed online at: http://www.titanoilgas.com/titan-oil-history.htm

[12] Exterran brochure discussing the impact of modifications to the National Emissions Standards for Hazardous Air Pollutants (NESHAP) Subpart ZZZZ which now regulates was accessed online at: http://www.exterran.com/Products/air-emissions-services

One heater manufacture, Energy Weldfab, contacted their burners manufacture, Flameco Industries, and inquired about burner emissions performance. Flameco did not have data, but indicated that burner designs have not changed significantly in the past 30-years. Flameco also said that NO_x emissions are hard to accurately predict given the variability in well pressure.

Based on these phone conversations and the lack of availability of any online performance specification documentation, ERG determined that heater manufacturers do not place a high priority on quantifying emission for the burners on their units. This may be due to the fact that heater burners are typically very small, with a heat input capacity of less than 1 MMBtu per hour, and are not subject to any emissions standards under federal environmental regulatory programs, such as NSPS or NESHAP. Table 3-1 shows the five heater manufacturers that ERG contacted, along with notes on what products and equipment the company produces, the number of employees, and the geographic range of their sales territory.

Table 3-1. Heater Treater Manufacturers/Vendors

Heater Vendors	Notes
Cameron	Cameron is a leading provider of flow equipment products, systems and services to worldwide oil, gas and process industries. They employ 27,000+ employees globally and are headquartered in Houston, Texas.[13]
Exterran Holdings Inc.	Exterran Holding Inc. is a global leader in full-service natural gas compression and a premier provider of services and equipment for oil & gas production, processing, treating, transportation and storage. Exterran employs approximately 10,000 professionals working in more than 30 countries.[14]
Smith Industries Inc.	Smith Industries Inc. manufactures and sells oilfield equipment. They operate a new 50,000 sq. ft. shop in the Permian Basin of Texas.[15]
Diverse Energy Systems	Diverse Energy Systems serves global oil and natural gas markets by providing integrated solutions with products and field operations from the wellhead to the pipeline. They operate a 101,000 square foot manufacturing facility with 30+ acres for open storage and future expansion.[16]
Energy Weldfab Inc.	Energy Weldfab, Inc. was founded in 1990, and is headquartered in White Oak, Texas. They have grown into a leading manufacturer of oil & gas processing equipment that is sold throughout North America. They operate a 50,000 square foot manufacturing facility consisting of a fabrication shop, sandblast, and paint shops, situated on 13 acres. Their facilities incorporate state of the art equipment and techniques, allowing Energy Weldfab the space to execute job orders in a timely fashion.[17]

[13] Cameron, accessed online at: http://www.c-a-m.com/Forms/AboutUs.aspx
[14] Exterran Holdings Inc, accessed online at: http://www.exterran.com/AboutUs
[15] Smith Industries Inc, accessed online at: http://smithindustriestx.com/index.htm
[16] Diverse Energy Systems, accessed online at: http://www.des-co.com/who-we-are/
[17] Energy Weldfab Inc, accessed online at: https://www.energyweldfab.com/

3.2 Survey Findings and Barnett Shale Special Inventory Data

Our phone and email survey did not provide any new data on emission factors for heaters. All sources reported using the AP-42 emission factor for NO_x. Similarly, respondents to the Barnett Shale Special Inventory who reported using heaters indicated that they used the AP-42 emission factor for NO_x.

3.3 State Agency Guidance for Calculating Emissions From Heaters and Boilers

NO_x is the primary pollutant of concern from heaters. ERG examined available guidance from the state environmental agencies in oil and gas producing states to see how the various states recommended calculating NO_x emissions from heaters.

The Texas Commission on Environmental Quality requires that oil and gas handling and production sources use US EPA's AP-42 emission factors for heaters and boilers when calculating emissions from heaters for de minimis exclusions, exemptions, permits by rule, standard permits, and case-by-case permit applications.[18] The TCEQ allows sources to use EPA emission factors (e.g., AP-42), facility specific emission factors, manufacturer emission factors, trade group emission factors, or vendor emission factors in calculating emissions from oil and gas sources for their air emissions inventory.

The Louisiana Department of Environmental Quality's Emissions Reporting and Inventory Center (ERIC)[19] allows sources to use EPA emission factors (e.g., AP-42), facility specific emission factors, manufacturer emission factors, trade group emission factors, or vendor emission factors in calculating emissions from oil and gas sources for their air emissions inventory.

The New Mexico Environment Department[20] allows sources reporting their emissions for permit applications to use test data, equipment manufacturer data, or AP-42 for the emission factors, and they require that the applicant document the source of each emission factor used.

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[18] Texas Commission on Environmental Quality, Air Quality Standard Permit for Oil and Gas Handling and Production Facilities, Tools: Emission Calculations Spreadsheet, http://www.tceq.texas.gov/permitting/air/newsourcereview/chemical/oil_and_gas_sp.html

[19] Louisiana Department of Environmental Quality, Emissions Reporting and Inventory Center, "ERIC User Manual", Chapter 5.5 – Emission Factors, http://www.deq.louisiana.gov/portal/tabid/64/Default.aspx

[20] New Mexico Environment Department, Air Quality Bureau, Air Quality Permit Application Forms and Related Information, "Universal Application Form", Sections 6 and 7 – Emission Calculations, http://www.nmenv.state.nm.us/aqb/ , http://www.nmenv.state.nm.us/aqb/permit/ , http://www.nmenv.state.nm.us/aqb/permit/Permit_Apps/Permit_Apps_1_Universal_Application.html

The Colorado Department of Public Health and Environment's Air Pollution Control Division, [21] requires that sources that emit air pollutants file an Air Pollutant Emission Notice (APEN) that indicates the actual emissions from the facility. The emissions can be calculated using AP-42, FIRE, mass balance, or performance test results.

The Wyoming Department of Environmental Quality's Air Quality Division requires that all new or modified sources or facilities which may generate air emissions be permitted prior to startup. Wyoming's "Permitting Guidance"[22] requires sources to use AP-42 emission factors when calculating emissions from heaters.

North Dakota's Department of Health requires that any oil or gas well completed or recompleted after July 1, 1987 register with the state. As part of the registration, the operator is required to calculate the emissions from oil and gas production equipment, including the VOC, HAP, NO_x, CO, and SO_2 emissions from heater burners. A North Dakota guidance document[23] requires that applicants use AP-42 emission factors in calculating emissions from their heater treaters.

Oklahoma's Department of Environmental Quality[24] requires oil and gas sources that have a permit to file an emissions inventory report. The calculation workbook, provided by CenSARA[25], requires sources to use AP-42 emission factors when calculating NO_x emissions from heater treaters.

3.4 Literature Review

ERG conducted a review of available literature on combustion emissions, heaters, and NO_x control methods. The following studies were found to be relevant.

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[21] Colorado Department of Public Health and Environment's Air Pollution Control Division, http://www.colorado.gov/cs/Satellite/CDPHE-AP/CBON/1251597643322 , http://www.colorado.gov/cs/Satellite/CDPHE-AP/CBON/1251596441874 , http://www.colorado.gov/cs/Satellite?c=Page&childpagename=CDPHE-AP%2FCBONLayout&cid=1251597643327&pagename=CBONWrapper ,

[22] Wyoming Department of Environmental Quality, Air Quality Division, "Oil and Gas Production Facilities Chapter 6, Section 2 Permitting Guidance", August 2001, http://deq.state.wy.us/aqd/oilgas.asp , http://deq.state.wy.us/aqd/Oil%20and%20Gas/GUIDANCE2001.pdf

[23] North Dakota Department of Health, "Bakken Pool Oil and Gas Production Facilities - Air Pollution Control Permitting & Compliance Guidance", http://www.ndhealth.gov/AQ/OilAndGasWells_files/New%20Guidance%20O&G%20Files/20110502Oil%20%20Gas%20Permitting%20Guidance.pdf

[24] Oklahoma Department of Environmental Quality, Permitting, http://www.deq.state.ok.us/aqdnew/permitting/index.htm

[25] Oklahoma Department of Environmental Quality, 2011 Oil & Gas Area Emissions, http://www.deq.state.ok.us/aqdnew/emissions/OilandGasAreaEmissions/index.htm

3.4.1 Emission Characteristics of Crude Oil Production Operations in California

The California Air Resources Board published a study done in 1983 by KVB, Inc. on their behalf on the emissions from oil and gas production in the state entitled "Emission Characteristics of Crude Oil Production Operations in California".[26] This study included emissions test results from eight heater treaters used in the Californian oil industry, with burner sizes varying from 0.348 MMBtu/hr to 5 MMBtu/hr. Multiple tests were conducted on each heater at different heat input rates. The study notes that "A significant amount of variation in operating conditions and emission levels was found among the eight heaters and heater treaters tested."[27] The tests on five of the eight heaters showed that increasing the firing rate resulted in an increase in NO_x emissions, and variable changes in CO emissions, depending on the initial O_2 levels. These tests showed that the levels of NO_x emitted from these heater treaters were "low due primarily to the low heat release rates of the metal in conjunction with the long, lazy flame shapes observed."[28] The emission factors derived from testing heater treaters in the field were found to be lower than the AP-42 emission factor (100 lb NO_x /MMscf)[29] for heaters of this size. The emission factors from the tests on these eight heaters are presented in Table 3-2, Attachment C contains the complete data from this study.

Table 3-2. Emission Factors from Testing for Heaters and Heater Treaters

Description	Emission Factor (lb NO_x / MMBtu)	Fuel Heat Value and Type (Btu/scf)
C-E Natco Heater-Treater 5.0 MMBtu/hr x 2 burners	Right: 0.029, 0.027, 0.031 Left: 0.054, 0.042, 0.038	1,000 Btu/scf – Processed Field Gas
Trico Superior Heater-Treater 3.0 MMBtu/hr x 2 burners	South: 0.088, 0.077	1,070 Btu/scf – Processed Field Gas
Trico Superior Heater-Treater 3.0 MMBtu/hr x 2 burners	North: 0.104, 0.066, 0.071	1,070 Btu/scf – Processed Field Gas
Trico Superior Heater-Treater 0.5 MMBtu/hr	0.041	993 Btu/scf – Field Gas
Trico Superior Heater-Treater 0.5 MMBtu/hr	0.020	993 Btu/scf – Field Gas
C-E Natco Heater-Treater 0.348 MMBtu/hr	0.072, 0.072, 0.096	993 Btu/scf – Field Gas
Trico Superior Heater-Treater 4.0 MMBtu/hr x 2 burners	West: 0.043 East: 0.039, 0.070	993 Btu/scf – Field Gas
C-E Natco Heater	0.074	2,500 Btu/scf - LPG

[26] California Air Resources Board, "Emission Characteristics of Crude Oil Production in California", KVB, Inc. 1983. http://www.arb.ca.gov/research/apr/past/a8-127-31a.pdf
[27] Ibid.
[28] Ibid.
[29] U.S. Environmental Protection Agency, 1998. AP-42, Fifth Edition, Volume I, Chapter 1.4, Table 1.4-1: "External Combustion Sources - Natural Gas" U.S. Environmental Protection Agency, Research Triangle Park, NC, 1998. http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s04.pdf

Table 3-2. Emission Factors from Testing for Heaters and Heater Treaters

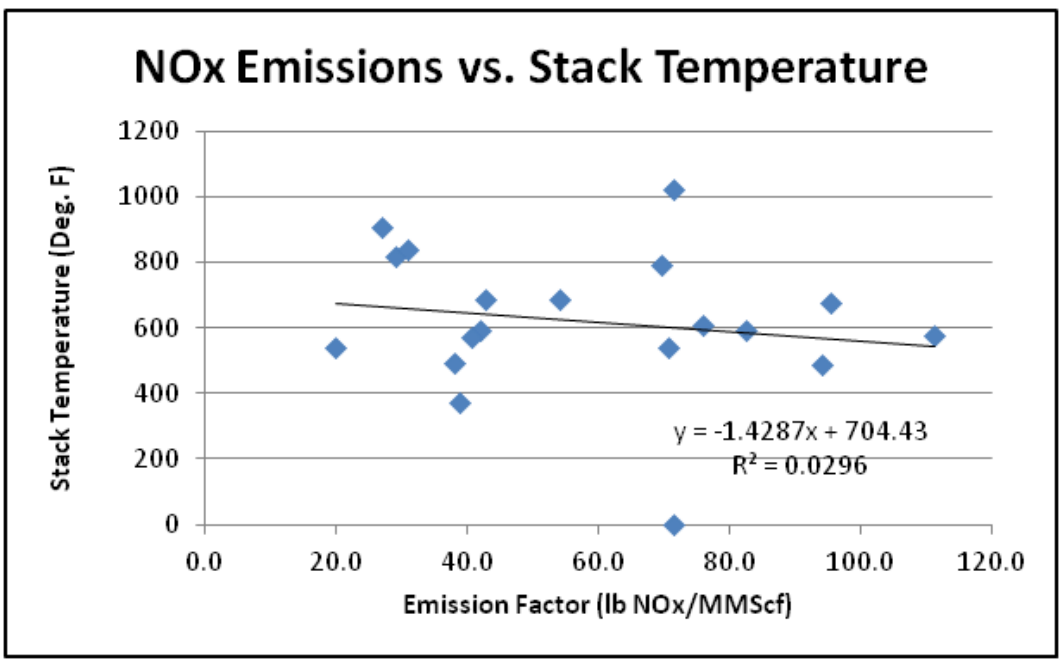
Description	Emission Factor (lb NO_x / MMBtu)	Fuel Heat Value and Type (Btu/scf)
0.348 MMBtu/hr [a]		
Average of 19 Tests[a]	0.057	1,015
Median of 19 Tests[a]	0.054	1,000

[a] The test results from the last heater in this list (a 0.348 MMBtu C-E Natco heater) were omitted when calculating the average and median values, as this heater was fueled with LPG. No heaters in the surveyed area were reported as being fueled with LPG, which has a very high heat value (2,500 Btu/scf).

For the data in Table 3-2 above, the average of the NO_x emission factors is 58.2 lb NO_x / MMscf. The calculation is shown in Attachment C.

Although these tests were conducted in 1983, the equipment designs for the heater treaters and heaters tested are similar to modern heater treaters. [30] Although no data was available for the firebox temperature, stack temperature data is available and was used as a surrogate for firebox temperature. A scatterplot of paired data for the 19 tests in Figure 3-1 shows that there is little correlation between stack temperature and NO_x emissions for the tested units.

Figure 3-1. Scatter Plot Showing Stack Temperature Versus NO_x Emissions for 19 Heater Tests



[30] Personal communication with Jacob Palmer of Energy Weldfab [Heater OEM]. July 2, 2013.

3.4.2 AP-42 Emission Factors for Natural Gas Combustion

The emission factors found in AP-42, Chapter 1.4 – Natural Gas Combustion are considered the benchmark standard for natural gas emissions and are accepted by the state agencies mentioned above. However, a careful examination of the data underlying the NO_x emission factors for very small natural gas fired units indicates that the AP-42 emission factors may not be appropriate for estimating emissions from small heaters used in the oil and gas industry. The source data used to develop the emission factors found in AP-42, Chapter 1.4 – Natural Gas Combustion were examined. Of the 151 boilers tested, only seven had a heat input rating less than 5 MMBtu/hr, and none had a heat input rating in the range of 0.5 MMBtu/hr, which is typical for small heaters used in the field. All of these smaller boilers tested for AP-42 emission factors were industrial boilers; none were heaters of the design and size used in the oil and gas industry. Therefore, the AP-42 emission factors may not be applicable for estimating emissions from small heaters, as the emission factors are based on emissions data from larger burners operating at higher temperatures. Scientific literature suggests that the higher the heat capacity and temperature in the flame zone, the larger the amount of NO_x produced per MMBtu of heat input.[31] This trend is shown in Table 3-3 below which provides the emission factors from Chapter 1.4, Table 1.4-1 of AP-42: the larger the heat input capacity, the higher the NO_x emissions.

Table 3-3. AP-42, Chapter 1.4, Table 1.4-1 Emission Factors for Nitrogen Oxides from Natural Gas Combustion

Combustor Type (MMBtu/hr Heat Input)	NO_x Emission Factor (lb/10^6 scf)
Large Wall-Fired Boilers (>100) Uncontrolled (Pre-NSPS)	280
Large Wall-Fired Boilers (>100) Uncontrolled (Pre-NSPS)	190
Tangential-Fired Boilers (All Sizes) Uncontrolled	170
Small Boilers (<100) Uncontrolled	100
Residential Furnaces (<0.3) Uncontrolled	94

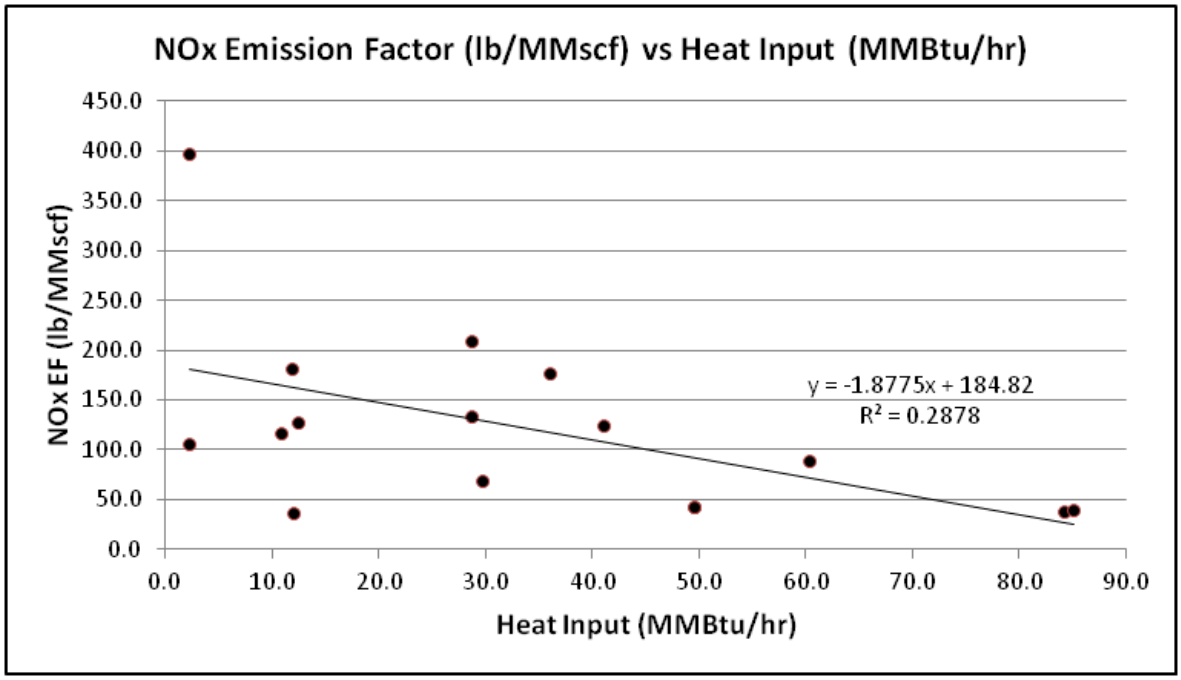
Next, the data used to develop the emission factors found in AP-42, Chapter 1.4 – Natural Gas Combustion were examined. The Access© database[32] containing the test report data from the boilers used in developing AP-42 emission factors was downloaded and examined. The dataset was filtered to remove test data from units that utilized NO_x controls, as small heaters do not typically utilize these devices. Emission units with heat input values above 100 MMBtu/hr were also removed. Sixteen (16) emission units

[31] The John Zink Combustion Handbook, Chapter 6, Charles E. Baukal, Jr. and Joseph Colaninno, CRC Press LLC, 2001.

[32] U.S. Environmental Protection Agency, 1998. AP-42, Fifth Edition, Volume I, Chapter 1.4, "Related Information", http://www.epa.gov/ttn/chief/ap42/ch01/related/c01s04.html

remained that matched these criteria (see Attachment C). Emission units for which the heat input capacity was reported only in megawatts were converted to MMBtu per hour with the conversion factor of 1 megawatt = 3,415,179 Btu/hr. A scatterplot of the remaining data points is shown in Figure 3-2 below.

Figure 3-2. Test Data from AP-42, Chapter 1.4 for Natural Gas-Fired Boilers with Heat Input Rating Less Than 100 MMBtu, and No NO_x Controls



Adding a linear regression trendline to this data produces the counter-intuitive prediction that the emission factor decreases with increasing heat input, which contradicts the trend shown in the AP-42 emission factors in Table 3-3 above and in the literature on combustion[33]. The R-squared value for this predictive equation is very low, indicating that the regression equation has little value in predicting NO_x emissions from heat input capacity. Therefore, analysis of this data is inconclusive for predicting NO_x emissions from typical heaters with a heat input rating of less than 1 MMBtu/hr. Unfortunately, the AP 42 test data does not include firebox temperature or stack temperature, so the relationship of temperature to NO_x emissions could not be directly examined for this dataset.

ERG also examined the data used to determine the emission factor for residential furnaces with heat input capacity less than 0.3 MMBtu. Section 3.2.2.1 of the Background Document to Chapter 1.4 of AP-42 states that "The NO_x emission factor for

[33] The John Zink Combustion Handbook, Charles E. Baukal, Jr., Editor, Chapter 6: Pollutant Emissions, CRC Press, 2001.

residential furnaces is based on test data from 41 sources." [34] This emission factor (94 lb NO_x /10^6 scf) is meant to be applicable to natural gas-fired burners with a rating of less than 0.3 MMBtu/hr. This is lower than the typical heater treater or line heater burner size. AP-42 included two references for this emission factor, but only one is available and it contains only summary data. [35] Therefore, the data for smaller sized, natural gas-fired burners could not be examined. As the original source data and one of the reports are not available, it is unknown how U.S. EPA determined the emission factor for residential furnaces with heat input ratings less than 0.3 MMBtu/hr. Although AP-42, Chapter 1.4 was updated in July of 1998, the updates to Section 1.4 did not consider any new data.

3.4.3 RACT/BACT/LAER Clearinghouse

ERG reviewed the EPA's RBLC to identify facilities with heaters and to establish a demonstrated level of performance. The RBLC permit database contains determinations, made by permitting agencies nationwide, that require sources to minimize air emissions or install control devices. Often these permits require the facility to install the best available control technology (BACT) to protect air quality.

ERG filtered the RBLC permit data base to include any air permit issued within the past 10-years with a small (i.e., less than 100 MMBtu/hr) commercial/institutional size boiler or furnace that fires gaseous fuels (e.g., natural gas, field gas, refinery gas). In total, 30 units were identified. On average these units were 50 MMBtu/hr, much larger than the oil and gas production heaters that are the focus of this study. The two smallest units had maximum heat input capacities that were within an order of magnitude of the average maximum heat input capacity of production heaters. The NO_x permit limits were consistent with emission rates included in EPA's AP-42 (i.e., 100 lb/10^6 scf). These are shown in Table 3-4.

Table 3-4. RBLC Data on NO_x Limits for Small Emission Units

Facility (State)	Unit Details (Size)	NO_x Limit	Permit Details
Corus Tuscaloosa - Steel Mill (Alabama)	Natural gas fired furnace (1.8 MMBtu/hr)	200 lb/10^6 scf	Issued: 6/3/2003 Number: 413-0033-X005
BP Exploration Alaska, Endicott Production Facility, Liberty Development Project (Alaska)	Fuel gas/distillate oil fired heaters (4.2 MMBtu/hr)	0.55 lb/MMBtu (55 lb/10^6 scf) Control: low NO_x burner	Issued: 6/15/2009 Number: AQ0181CPT06, REVISION 2

[34] U.S. Environmental Protection Agency, 1998. AP-42, Fifth Edition, Volume I, Chapter 1.4, "Background Document", http://www.epa.gov/ttn/chief/ap42/ch01/bgdocs/b01s04.pdf

[35] Muhlbaier, J.L. "Particulate and Gaseous Emissions from Natural Gas Furnaces and Water Heaters," Journal of the Air Pollution Control Association, December 1981; and "Evaluation of the Pollutant Emissions from Gas-Fired Forced Air Furnaces: Research Report", No. 1503, American Gas Association Laboratories, Cleveland, OH. May 1975.

3.4.4 Heater-Treater Source Category – NO_x Emission 4-Factor Analysis for Reasonable Progress (RP)

Although the amount of NO_x and other pollutants emitted by any individual heater are small, the cumulative effect of the emissions from many heaters can add up to a substantial amount. Therefore, mitigation strategies are an important consideration in any state's air quality program. In the document "Heater-Treater Source Category - NO_x Emission 4-Factor Analysis for Reasonable Progress (RP)"[36], the Colorado Department of Public Health and Environment's (CDPHE) Air Pollution Control Division evaluated emission control strategies for NO_x emissions from heater treaters. The CDPHE evaluated five NO_x emission control strategies: lowering the heater treater temperature, installing insulation on the separator, retrofitting the heater treater with low-NO_x burners, adding a post-combustion NO_x reduction technology, and using central gathering facilities.

Lowering the heater treater temperature would lower NO_x emissions because NO_x is formed faster at higher temperatures. It would also reduce fuel usage. Adding insulation to the separator would reduce combustion emissions by reducing fuel use. Retrofitting with low-NO_x burners would reduce NO_x "by accomplishing the combustion process in stages ... resulting in a cooler flame which suppresses thermal NO_x formation."[37] However, the burners used on heater treaters are small, and commercial low-NO_x burners are not available for very small combustion units. Adding a post-combustion NO_x -reducing technology, such as selective catalytic reduction (SCR) or non-selective catalytic reduction (NSCR) is not practical or feasible for a small combustion source such as a heater treater. Pumping liquids from several area wells to a central gathering and processing facility is feasible, and many surveyed operators reported that they have already implemented this practice. Using a central processing facility reduces the amount of equipment in use, so the emissions from heater treaters would be reduced.

Thus, three feasible strategies for reducing NO_x emission from heater treater burners were identified: lowering the burner temperature, insulating the separator, and concentrating the separation/processing steps at a central facility. The CDPHE report found that all of these strategies were cost-effective and could be implemented in a timely manner. Centralizing the processing facilities does require planning and is better suited for new development where a larger contiguous geographic area can be controlled by a single operator. In certain developed oil/gas fields, operators could buy individual

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[36] Colorado Department of Public Health and Environment's Air Pollution Control Division, "Heater-Treater Source Category - NO_X Emission 4-Factor Analysis for Reasonable Progress (RP)" http://www.colorado.gov/cs/Satellite?blobcol=urldata&blobheadername1=Content-Disposition&blobheadername2=Content-Type&blobheadervalue1=inline%3B+filename%3D%22Heater+Treaters.pdf%22&blobheadervalue2=application%2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1251808868243&ssbinary=true

[37] Ibid.

wells from, or sell wells to other operators to establish the larger contiguous geographic areas needed to establish the economies of scale that would make centralized processing facilities cost effective and efficient. It is not known if the reported purchase and sale of wells by some companies who responded to the survey was a part of this process, or simply industry consolidation.

3.4.5 Alternative Control Techniques Document – NO_x Emissions from Process Heaters (Revised)

In 1993, US EPA published a study of NO_x emissions from process heaters. This study also examined ways in which these emissions could be mitigated.[38] The findings in this document "Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised)" are relevant to this study because the smaller heaters used in the field in oil and gas applications are similar to industrial process heaters and the primary pollutant of concern is NO_x.

The study notes that "Nitrogen oxides are produced by three different formation mechanisms: thermal, fuel, and prompt NO_x. Thermal NO_x is primarily temperature-dependent, fuel NO_x is primarily dependent on the presence of fuel-bound nitrogen and the local oxygen concentration, and prompt NO_x is the least understood formation mechanism."[39] The document also included performance test data. Of the model heaters tested, the NO_x emission factor for the low and medium temperature, natural draft, natural gas-fired heaters (0.098 lb NO_x /MMBtu) is half that of the mechanical (forced) draft heaters (0.197 lb NO_x /MMBtu); 118 and 236 lb NO_x/MMscf respectively.[40] The heaters found at oil and gas wells are natural draft heaters, and the temperatures in the flame zone tend to be lower, resulting in less formation of thermal NO_x. The burners on these heaters do not utilize any NO_x control techniques, such as low NO_x burners, flue gas recirculation, ultra-low NO_x burners, selective noncatalytic reduction, or selective catalytic reduction, as these technologies are not cost-effective for such small burners. The burners on oil and gas field heaters do not utilize preheated combustion air, which would raise NO_x emissions. Figure 4-4 of this study showed that thermal NO_x formation increases with increasing firebox temperature, and "that for gas-fired heaters, thermal NO_x emissions increase by a factor of about 1.5 when the firebox temperature is increased from 1300 degrees F to 1900 degrees F.[41]

The EPA study also presented data on NO_x emissions from a 1979 API-sponsored study that examined natural gas-fired, distillate-fired, and residual oil-fired natural draft and

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[38] US EPA, Office of Air and Radiation, OAQPS, Emissions Standards Division, EPA-453/R-93-034, "Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised)", September 1993, http://www.epa.gov/ttn/catc/dir1/procheat.pdf
[39] Ibid, Section 2.1, "Uncontrolled NOx Emissions".
[40] Assume that heaters operate on processed field gas with a heat value of 1200 Btu/scf.
[41] Ibid, Figure 4-4.

forced draft refinery heaters. This data was not applicable to this study, as there were no data for burners operating at less than 8 MMBtu/hr.[42]

3.4.6 Watertube versus Firetube Boilers

There are two common designs of boilers: water tube and fire tube. In a water tube boiler, the process fluid flows through pipes that run through the furnace chamber in which the fire burns. In a fire tube boiler, the process fluid surrounds pipes inside which the fire and hot flue gasses from the burner are channeled.[43] The EPA's study of process heaters[44] examined NO_x emissions from watertube boilers, while the California Air Resources Board's study of heater treaters[45] examined emissions from firetube boilers. An examination of the design of heaters used in the oil and gas industry reveals that these are all typically firetube boilers. [See Figures 2-1 and 2-2 above] This is an important distinction, as the two designs produce different conditions in the flame zone and thus lead to different levels of NO_x emissions. Firetube boilers are best suited for small heat input capacities, are not suitable for high pressure applications, and have limited capacity to produce lots of steam. Watertube boilers can handle very high heat input capacities, can handle very high pressures, and have the ability to reach very high temperatures. Firetube boilers operate at lower temperatures by design. Therefore, as thermal NO_x formation is temperature dependent, it is expected that NO_x formation in firetube boilers would be lower than that in watertube boilers, for a given heat input capacity.

[42] Ibid, Figures 4-6 and 4-7.
[43] P.C. McKenzie Company, Firetube or Watertube Boilers, http://www.mckenziecorp.com/boiler_tip_8.htm Wikipedia, https://en.wikipedia.org/wiki/Fire-tube_boiler , http://en.wikipedia.org/wiki/Water-tube_boiler
[44] US EPA, "Alternative …", op. cit.
[45] California Air Resources Board, op. cit.

4. Survey Findings

ERG contacted 138 companies operating throughout Texas and requested heater data. The companies selected were identified by a search of the Texas RRC website as major producers in the six regions of interest for the survey. The six regions of interest were the Anadarko, Permian, Western Gulf, Bend Arch-Fort Worth/Barnett Shale, East Texas/Haynesville Shale, and the Eagle Ford shale. As there is little gas or oil production in the Palo Duro and Marathon Thrust Belt basins, these areas were not targeted in this survey.

Letters were sent to a total of 214 contacts, representing 138 separate companies operating out of 142 regional offices. The letters explained the survey, requested cooperation in gathering data, and included sample data collection forms. See Attachments A and B for the letter and survey materials. ERG followed up the letters with phone calls to each company contact until contact was made. In some cases, emails were sent to the company as well (either as a follow up to a telephone conversation, or in the event no telephone contact could be made). ERG explained the survey to potential respondents and sent them an information collection form (spreadsheet). Forty (40) companies agreed to participate and sent data for their heaters.

4.1 Heater Activity Data

ERG collected well and heater data from 40 companies operating in Texas. The survey asked questions about:

- Location (County)
- 2012 Petroleum liquids production (bbl/yr)
- Are these oil or gas wells? (O or G)
- Number of wells at this site
- Total number of heaters at this site
- Heater firing rate by heater type (MMBtu/hr)
- Local heat value of fuel (Btu/scf)
- H_2S mass fraction in fuel (ppm)
- Type of heaters (Heater Treater, Line Heater, Tank Heater, Other Heater)
- Heater activity (hrs/yr)
- Heater NO_x emission factor (lb/MMBtu)
- Heater make and model #s

Twenty-six (26) companies submitted well data in response to the survey. The data submitted by these companies was compiled into a spreadsheet, and anomalies were cleaned up so that calculations could be performed. Fourteen (14) additional companies responded to the survey with the information that “Our company does not operate any heaters on any of our wells in those counties.” ERG considered this to be valid data, and

entered data for a limited number[46] of those company's wells from the RRC database for the counties of interest. This data is shown in Table 4-1.

Table 4-1. Number of Companies Responding to the Survey

Region	Number of Companies Who Filled Out Survey Completely	Average Number of Wells Reported	Median Number of Wells Reported	Number of Companies Who Reported Verbally
Anadarko	4	10	10	0
Eagle Ford	11	74	52	0
East Texas	1	21	21	6
Fort Worth	1	26	26	5
Permian	5	1089	345	1
Western Gulf	4	94	22	2

ERG examined the production reported by respondents and compared this to the Texas RRC statistics for production, on a region-by-region basis. As ERG asked producers to send data representative of their production in each region, it was assumed that the survey response is representative of the company's production in that region. ERG collected the regional production data for the companies responding to the survey, and compared this to the total production in the region, as reported to the Texas RRC. Table 4-2 shows the total production of the survey respondents as a percent of total production in each region. Although ERG attempted to gather data from the top 20 producers in each region, low response rates were observed for the Fort Worth, Permian, and Western Gulf regions.

Table 4-2. Survey Response as Representative of Regional Production

Region	Region-wide Production in 2012 (BBL)	Surveyed Production (BBL)	Total Production By The Surveyed Companies (BBL)	Surveyed Companies' Production as a % of Total Region-wide Production
Anadarko	21,711,341	221,059	9,007,297	41%
Eagle Ford	182,323,450	30,180,319	112,107,331	61%
East Texas	20,608,758	126,479	7,764,419	38%
Fort Worth	25,906,843	174,482	1,208,531	5%
Permian	304,471,986	23,484,482	30,039,347	10%
Western Gulf	45,509,083	1,439,319	3,537,578	8%

[46] Note: the number of wells selected and the selection process is described below in the section of the report "Other Possible Sources of Bias".

All of the data was sorted by region and county, and statistics of interest were derived from the data. Attachment C contains the data obtained from the survey, and a summary of the data is shown in Table 4-3.

Further examination of the data for each region revealed the following:

- Heater use, by any measure (average fuel use per year, average fuel use per barrel of liquids produced, and average number of heaters per well) varies widely by region.
- Gas wells in the dry gas regions of the Barnett Shale and East Texas use few or no heaters to treat any liquids that may be produced by those wells.

For data from each region, scatterplots of the individual well/site data for Heater Fuel Used vs. Hydrocarbon Production showed no clear trend. This is important, as it indicates that there is little or no relationship between the size and activity level of a heater, and the amount of liquids it may be required to process. This may be due to factors that were not examined in this study. An example scatterplot for the Anadarko basin showing this relationship is provided in Figure 4-1 below.

Figure 4-1. Scatterplot of Heater Fuel Used versus Liquid Hydrocarbon Production for the Anadarko Basin

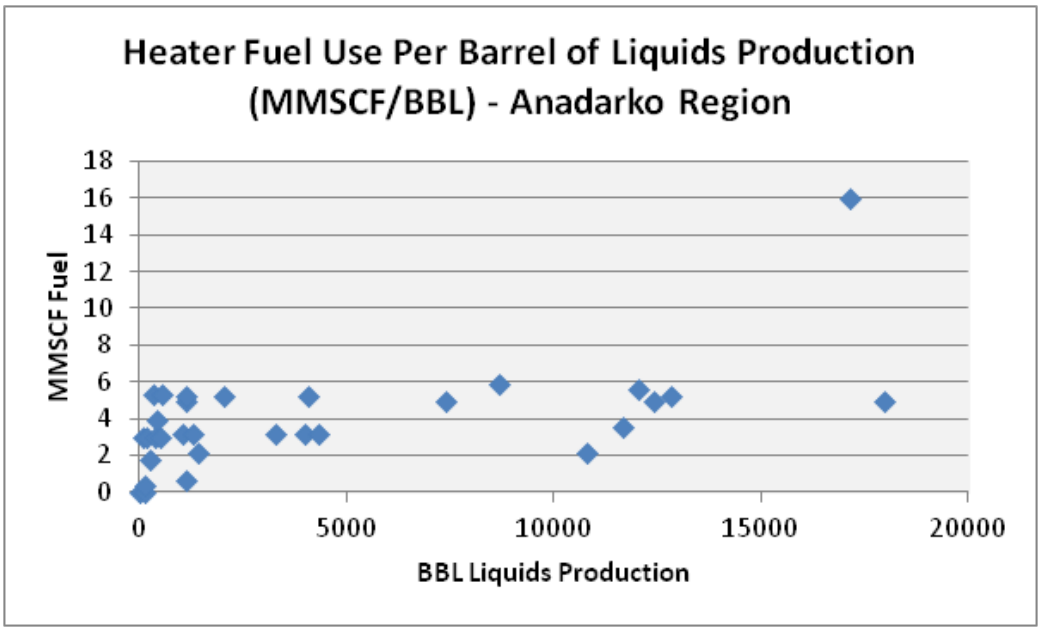


Table 4-3. Heater Data Summary

Basin	# of Companies Providing Data	# of Sites	# of Wells	Liquids Production Surveyed (BBL)	Average Heater Fuel Use (MMscf/yr)[1]	Average Fuel Use MMscf/BBL[1]	Average # of Heaters Per Well[1]	Average Heater Size[2] (MMBtu/hr)	Average Hours of Operation (hrs/yr)	Average Fuel Heat Content (Btu/scf)
Anadarko	4	38	39	221,059	4.20	0.0043	1.35	0.66	5,483	1,116
Eagle Ford	11	83	817	30,180,319	13.06	0.0013	0.54	0.91	7,574	2,922
East Texas	7	136	147	126,479	0.034	0.0000013	0.0041	0.50	8,400	1,015
Fort Worth	6	140	156	174,482	0.22	0.000032	0.15	0.50	1,414	1,040
Permian	6	137	5,489	23,484,482	1.70	0.00012	0.37	0.53	3,477	1,359
Western Gulf	6	71	412	1,439,319	2.78	0.000010	0.20	1.90	6,935	1,102
Statewide Average	NA	NA	NA	NA	3.67	0.00096	0.44	0.83	5,547	1,426
Production-Weighted Statewide Average	NA	NA	NA	173,446,231	4.40	0.00026	0.28	1.53	6,569	1,452

[1] For all wells with liquids production. Wells with zero liquids production are not included in these averages.

[2] For wells with operational heaters. Wells without heaters are not included in the average.

Based on these results, there is insufficient evidence to indicate that the TCEQ should change its methodology for calculating emissions from heaters and boilers at wells to a liquids-production based estimate.

4.2 Barnett Shale Inventory Data

ERG examined the "Barnett Shale Area Special Inventory, Phase II 2009"[47] (Barnett Shale Inventory) in order to compare the results with the current survey effort.

The Barnett Shale Inventory data contains 8,089 records for unique sites. 95% of these sites were gas wells, while the remaining 5% were oil wells. 192 of these sites, or 2.4% of the total sites, reported having a total of 215 active heaters onsite. Of the 192 sites with heaters: 180 are located in the northern part of the Barnett Shale in Cooke, Montague and Wise counties, and are not typical of the entire region. One hundred and eighty four (184) of the sites were operated by only two companies. Three (3) sites reported producing no gas or petroleum liquids, an additional seven (7) of these sites produced no petroleum liquids, and an additional six (6) sites produced no water. Four (4) other sites did not provide heater data.

The reporting threshold under this effort for individual heaters was 1 ton per year NO_x, and for an entire site it was 5 tons per year of NO_x. Therefore, if the heaters were small, or were not run full time they may not have had to report in the inventory. For example: a 0.5 MMBtu/hr heater, operating full time (8,760 hours/yr), emits approximately 0.215 tons of NO_x. This would preclude these heaters showing up in the Inventory, and may account for differences in the number of heaters reported in the Barnett Shale Inventory and this present study.

The sites producing petroleum liquids and using heaters produced 712,924 bbl of oil and condensate in 2009. 7.2% of the total liquids produced were oil, while the rest (92.8%) was condensate. The total oil and condensate produced at the 8,089 sites in the Barnett Shale was 3,725,374 bbl in 2009. Therefore, 19.1% of the petroleum liquids produced in the Barnett Shale required the use of heaters, while only 0.91% of the total gas production (casinghead gas and gas well gas) involved the use of heaters. The average heater has a heat input capacity of 0.517 MMBtu per hour and operates an average of 5,299 hours per year.

[47] "Barnett Shale Area Special Inventory", TCEQ, Op. cit.

5. Current Practices

During interviews with survey respondents, much valuable information was gained about practices in the oil and gas industry. Some of the industry-provided insights that might affect heater usage across the state are discussed below.

5.1 Seasonality of Heater Use

Survey respondents reported using heaters to process and separate water from oil and gas, to prevent formation of hydrates, or to prevent water from freezing in the equipment during the winter months. Many of the survey respondents who reported using heaters on their equipment reported that they use the heaters only during the winter months. This seasonal pattern of heater use may be important to the state agency using these estimates for modeling air quality. The NO_x emissions from combustion contribute to the formation of ozone, but the effect of NO_x on ozone formation would be more important in the summer months when atmospheric temperatures are high and the conditions exist for the formation of ground-level ozone.

Interviews with survey respondents and an examination of the survey data show that the activity pattern of heater use also varies across the state. From the "Hours of Operation" data in Table 4-3 above, it is seen that the average heater in the Eagle Ford, East Texas, and Western Gulf regions tends to operate year-round, the average heater in the Anadarko and Permian regions operates for half of the year, and the average heater in the Fort Worth region operates less than half the year. A closer examination of survey respondent data for each of the six regions of interest was performed. Reported data from completed surveys for wells in the East Texas, Fort Worth, and Western Gulf regions were insufficient to support any conclusions, as very few respondents reported using heaters on their wells in those regions. Reported data for the hours of operation of heaters at wells in the Anadarko, Eagle Ford, and Permian basins was more complete. These records show that some companies will operate all of their heaters part time, while other companies operate all of their heaters full time.

Although phone conversations with operators who reported operating their heaters part time verified that the heaters were only operated in the winter months, there is insufficient data to support a finding that a percentage of the total heaters in any region operate exclusively during the winter months (October – March).

5.2 Centralization of Treatment Facilities

Another practice noted during the survey is the centralization of treatment facilities. Several industry representatives verified that centralization is widespread for new production. In one variation on this approach, a company will drill multiple wells in a contiguous geographic area, each at its own well pad, and then pump all gas and liquids

from those wells to a gathering point on a single well pad, where the liquids are separated from the gas, water is separated from petroleum in a treater, and liquids are stored in tanks prior to loading into a tank truck. In another variation on this approach, a company will drill several directional wells from a single well pad. All liquids and gas from those wells would be processed at the well pad. In yet another variation on this system, several of these gathering points, or "satellites", pump the gas and liquids via pipelines directly to a centrally-located processing station, where larger processing facilities, including heater treater/separators, gas dehydrators, and storage tanks are located. One producer reported having two such central processing stations in the Eagle Ford region; each station processed the gas and liquids from 78 wells. A diagram of two of these gathering systems is shown in Figures 5-1 and 5-2 below.

Figure 5-1. Single Gathering Point with Heater Treater and Storage Tanks

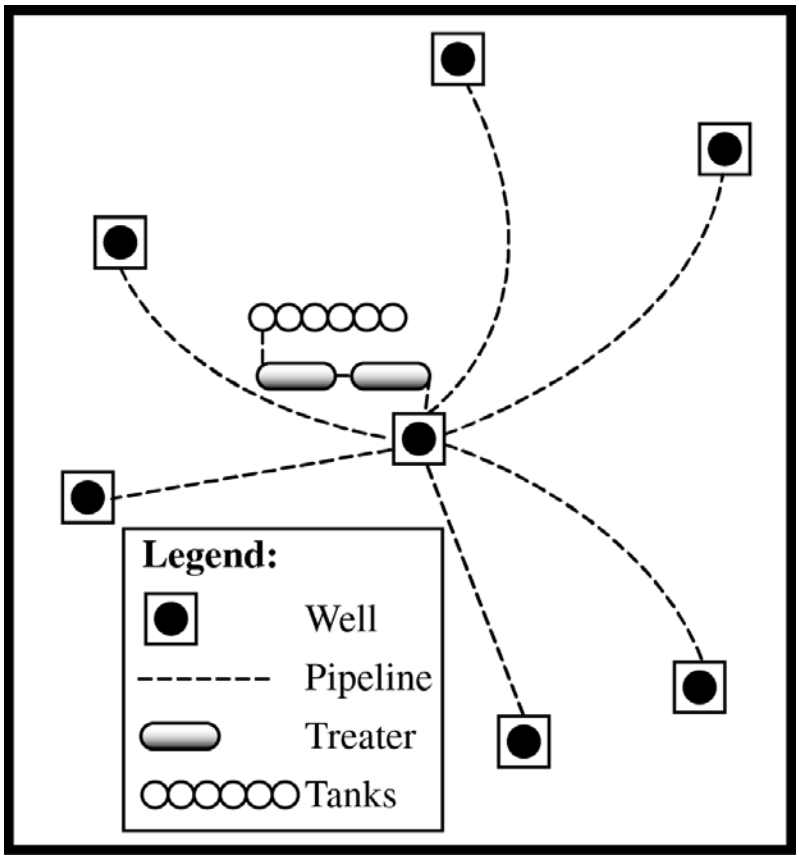
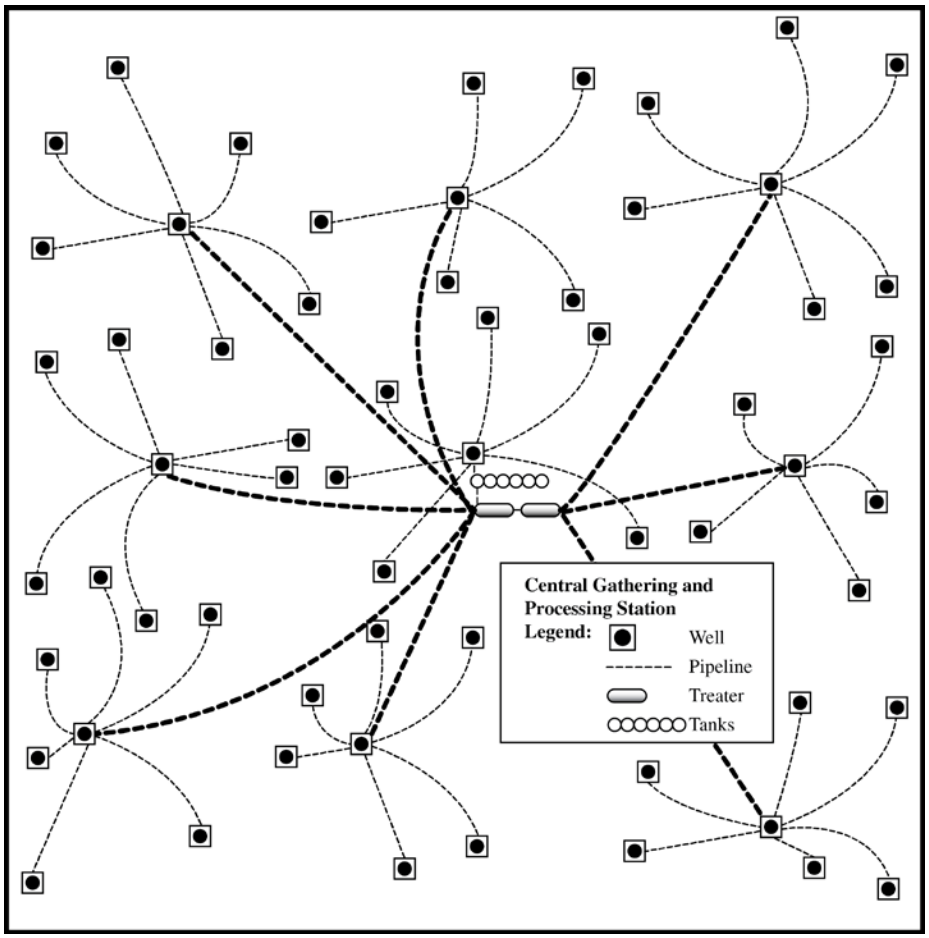


Figure 5-2. Multiple Wells Feeding Satellites into a Central Processing Station



The larger scale of these central gathering stations enables producers to use less equipment overall, and to use that equipment more efficiently, such that combustion emissions are minimal for the amount of petroleum liquids processed. It also allows the cost effective use of vapor recovery and emissions control equipment such that the loss of natural gas and VOC emissions are minimized. In this situation, the traditional heater treater and storage tank at a well site has been replaced with piping to a centralized processing facility. The gas and liquids are enclosed in pipes or treatment vessels nearly every step of the way to the refinery, allowing for very efficient rates of recovery and sale of petroleum products compared to what is extracted.

Companies reported that their newer well facilities, such as those in the Eagle Ford and Permian basin, utilized this approach for gathering and processing both gas and liquids. This approach represents a significant improvement in emissions reduction over the methods that were commonly used only a few years ago. Although these methods are most commonly implemented in new fields, it may be realistic to expect that, as producers buy and sell their assets in an area to consolidate their holdings, that it may

become economical to retrofit existing facilities with this more efficient gathering system. One company stated that this depends upon the age and production of the wells; the declining production of older wells would not support the cost of the equipment needed to implement this strategy.

5.3 Acreage Owned by a Single Landowner

One survey respondent indicated that the acreage owned by a single landowner had an impact on the amount of centralization of processing facilities, and that this varied across the state. In the Permian basin, this company has consolidated processing operations for many of its wells, and in one location, reported that 295 wells fed liquids to 11 satellite stations, which in turn pumped the liquids to one central tank battery. There were single heater treaters located at each satellite station, and an additional three heater treaters located at the central processing facility. This same respondent indicated that, in the Barnett Shale, where lease acreages were smaller, there was less centralization of facilities.

For ease of accounting, paying royalties to the landowner, and submitting reports and fees to the Railroad Commission of Texas, a producer may also arrange their equipment so that the measured amount of petroleum liquids taken from a single lease passes through a single point, usually the tank battery just prior to shipment to a refinery. Mixing liquids from multiple leases and owners at a single tank battery prior to shipment requires additional metering and complex accounting and recordkeeping.

Since the acreage owned by a single landowner varies across the state, the degree of centralization of facilities observed in the survey results also reflects the variation in patterns of land ownership across the state. Tracts owned by a single landowner in the Permian basin in west Texas may be very large. However, the land development pattern in metropolitan areas and in the eastern portions of the state, where population densities are higher, would suggest that smaller amounts of land are owned by a single landowner. This would have an effect on the degree to which operators could easily centralize their treatment facilities.

5.4 Self Selection Bias

For any survey, the researchers need to consider if the respondents have given them data that is representative of all of their operations. ERG specifically requested in the survey materials and phone conversations that companies submit a random, representative sampling of their wells. ERG stated that the information submitted would be held confidential, and that any company-identifying information would be removed from the final report and from all survey data submitted to TCEQ with the report. ERG has no direct knowledge that any of the companies who responded to this survey submitted data that was not representative of their overall operations.

For comparison of the current survey results with the results from a mandatory survey, the data collected in this study was compared with the data collected in 2009 by the TCEQ in the Barnett Shale Area Special Inventory effort. In this 2013 survey, ERG collected survey data from 6 large- and medium-sized companies operating in the Barnett Shale counties. Of these 6 respondents, one submitted data for their wells, while the other 5 companies noted that "All of our wells in that region do not use heaters." One of these 5 indicated that while their Barnett Shale wells were originally designed and constructed with heaters on-site, once the wells were brought into production it became apparent that heated separation was not needed and they no longer use the heaters (although they remain on-site).

Under the Barnett Shale Area Special Inventory, producers reported that only 2.4% of total sites used heaters. However, as mentioned above, there was an emissions cutoff threshold for the Barnett Shale Area Special Inventory (1 ton per year of NO_x for an individual unit, or 5 tons per year total NO_x for a site), so it is possible that sites with small heaters did not submit data for their heaters. Also, the results of the ERG survey were obtained voluntarily, whereas the Barnett Shale Area Special Inventory was a mandatory survey of all producers operating in that region. Therefore, it is difficult to accurately compare the results obtained from this survey with the results obtained from the Barnett Shale Area Special Inventory effort.

5.5 Other Possible Sources of Bias

For some respondents, 'participating' in the survey was relatively simple. In their phone conversations with the researchers, or in their email responses to the survey inquiries, they responded that "Our company does not operate any heaters on any of our wells in those counties." ERG considered this to be valid data, and included these companys' wells for those counties as valid data. The number of wells represented by these 'submissions' sometimes represented thousands of wells. Since ERG did not want these responses to out-weigh the responses from companies responding to the survey in the expected manner (reporting their heater use for a subset of their wells), these responses were weighted as though they represented the average or median number of wells reported by typical survey respondents. For each region, ERG tallied the number of wells submitted by each company who filled out the survey, and then computed the average and median values for the number of wells in the submitted data. Using the lower of the average or median values, ERG chose that number of wells at random from the RRC data for those companies who reported that they did not operate heaters at their wells. This data was entered alongside of the data submitted by survey respondents, with a note as to its source. Table 4-1 above shows the average and median values derived for each region from the companies who submitted complete data.

6. Conclusions

ERG recommends that the TCEQ calculate heater emissions from upstream oil and gas production sites across the state based on the number of operational wells, and using the updated activity and emission factor data obtained under this study. As described above, the emissions estimation activity data will vary on a region-by-region basis. County-level heater emissions may be calculated using the values shown in Table 6-1. Attachment D contains an updated version of TCEQ's Oil and Gas Area Source emissions estimation tool utilizing the recommended factors.

The recommended emission factor for NO_x combustion is from the California Air Resources Board 1983 study "*Emission Characteristics of Crude Oil Production Operations in California*" as shown in Table 3-2 above. The results of this study appear to be the most appropriate emission factors available for the relatively small size heaters found in the field in oil and gas wells and well pads. The average NO_x emission factor from this study is 58.2 lb/MMscf.

Table 6-1. Recommendations for Calculating Heater Emissions

Basin	Average # of Heaters Per Well	Average Heater Size (MMBtu/hr)	Average Hours of Operation (hrs/yr)	Average Fuel Heat Content (Btu/scf)
Anadarko	1.35	0.658	5,483	1,116
Eagle Ford Shale	0.54	0.906	7,574	1,289
East Texas	0.0041	0.500	8,400	1,015
Arch Bend - Fort Worth	0.15	0.500	1,414	1,040
Permian	0.37	0.525	3,477	1,359
Western Gulf	0.20	1.897	6,935	1,102
Marathon Thrust Belt[a]	0.44	0.831	5,547	1,154
Palo Duro[a]	0.44	0.831	5,547	1,154

[a] Statewide Average

Attachment A
Survey Letter

Dear [Insert Operator_Contact_Name], [Insert Operator_Contact_Title]
[Insert Operator_Company_Name] [Date]

Eastern Research Group (ERG), an independent research organization, is conducting a study on heater emissions for the Texas Commission on Environmental Quality (TCEQ). The purpose of this study is to develop updated equipment inventories and emission factors for estimating emissions from heater treaters, tank heaters, and inline heaters for each of the oil and gas producing regions in Texas. Dehydrator reboilers are not a focus of this effort. The study results will assist the TCEQ in refining the Texas area source air emissions inventory for oil and gas sources.

Heater emissions of nitrogen oxides (NO_x) and other pollutants are currently estimated by TCEQ using EPA emission factors and survey data from a 2008 CENRAP study "Recommendations for Improvements to the CENRAP States' Oil and Gas Emissions Inventories". Based on the CENRAP study, the TCEQ currently estimates that a typical oil well in Texas uses 0.79 heaters per well with a firing rate of 0.62 MMBtu/hr and operates 4,156 hours per year, and a typical gas well in Texas uses 0.92 heaters per well with a firing rate of 0.62 MMBtu/hr and operates 4,035 hours per year. To further increase the accuracy of its emissions estimates, the TCEQ is seeking information from Texas oil and gas operators to assist in development of refined, county-specific equipment inventories and emission factors.

We are asking for your participation in this study of emissions from heaters at oil and gas well sites in Texas that were in production during 2012. The study will involve sharing information regarding heater equipment and the fuels used through a voluntary survey. ***Individual wells do not need to be identified.*** The information your company provides will be used for statistical purposes only in order to develop county-level and basin-level estimates and will not be republished or disseminated for other purposes.

ERG will contact your company via phone to discuss this effort and collect any information you are willing to share. We are seeking basin-specific heater equipment and emissions information for your oil and gas well sites in the [Insert Basin_name] basin located in [Insert counties_text] The specific information we are requesting for each well site includes:

- County
- 2012 oil/condensate production
- Well type (oil or gas)
- Number of wells per site
- Number of heaters per site
- Type of heaters
- Local heat value of fuel (Btu/scf)
- Heater firing rate (MMBtu/hr)
- Heater activity (hrs/year)
- Heater NOx emission factor
- Heater make and model #s
- H_2S mass fraction in fuel (ppm)

A table on the reverse side of this letter shows the type of data we wish to collect.

We appreciate your assistance in this study. If you have any questions on the technical aspects of the study, please contact me at (919) 468-7902, or via email at stephen.treimel@erg.com. Completed surveys should be sent to my attention. Questions concerning the scope of this study or ERG's relationship with TCEQ may be directed to the TCEQ Project Manager, Michael Ege, at (512) 239-5706, or via email at Michael.Ege@tceq.texas.gov.

Sincerely,
Stephen Treimel, Environmental Scientist
Eastern Research Group, Inc.

Attachment B
Survey Materials – Word Table and Excel Spreadsheet

Operator Name: [Insert Operator_Company_Name]
Basin and Counties: [Insert Basin_name] basin: [Insert counties_text]
Instructions: Provide the data listed below for up to ten separate well sites located in the counties listed above. To avoid biasing the survey results, we ask that you please select the well sites at random from all of your producing wells in this region.

Site #	County	2012 Petroleum liquids production (bbl/yr)	Is this an oil or gas well? (O or G)[a]	Number of wells at this site	Total number of heaters at this site	Local heat value of fuel (Btu/scf)	H_2S mass fraction in fuel (ppm)	Type of heaters[b]	Heater firing rate by heater type (MMBtu/hr)	Heater activity (hrs/yr)	Heater NOx emission factor (lb/MMBtu)	Heater make and model #s

[a] Does the Texas Railroad Commission consider this well a gas well (G) or an oil well (O)?
[b] Heater Treater, Line Heater, Tank Heater, Other Heater (excluding dehydrator reboiler heaters)

Completed surveys can be emailed to me at stephen.treimel@erg.com or printed and mailed to my attention at: Eastern Research Group, 1600 Perimeter Park Drive, Morrisville, NC 27560.

TCEQ Heater Survey

Operator Name:
Basin and Counties:
Instructions: Provide the data listed below for up to ten separate well sites located in the counties listed above. To avoid biasing the survey results, we ask that you please select the well sites at random from all of your producing wells in this region.

Site #	County	2012 Petroleum liquids production (bbl/yr)	Are these oil or gas wells? (O or G)[a]	Number of wells at this site	Total number of heaters at this site	Heater firing rate by heater type (MMBtu/hr)	Local heat value of fuel (Btu/scf)	H_2S mass fraction in fuel (ppm)	Type of heaters [b]	Heater activity (hrs/yr)	Heater NOx emission factor (lb/MMBtu)	Heater make and model #s

[a] Does the Texas Railroad Commission consider this well a gas well (G) or an oil well (O)?
[b] Heater Treater, Line Heater, Tank Heater, Other Heater (excluding dehydrator reboiler heaters or heaters at amine units)

Completed surveys can be emailed to me at stephen.treimel@erg.com or bryan.lange@erg.com or printed and mailed to my attention at: Eastern Research Group, 1600 Perimeter Park Drive, Morrisville, NC 27560.

Attachment C
Survey Results
(TCEQ Heater Study Findings.xlsx)

Attachment D
Updated Oil and Gas Area Source Emissions Estimation Tool
(Appendix E_ERG Heater Updates.xlsx)