Natural Gas Compressor Engine Survey and Engine NO_x Emissions at Gas Production Facilities

FINAL REPORT

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EXECUTIVE SUMMARY

The objective of this study was to collect the technical information required by the Texas Commission on Environmental Quality (TCEQ) to estimate the distribution of compressor engines associated with natural gas wells in the eastern portion of Texas. This study is the first TCEQ effort to conduct a detailed survey of small compressor engines in this region; currently, there are no TCEQ rules or programs that inventory small compressor engines. The study area included 110 counties bisected by, and east of, Texas Interstate Highways 35 and 37 (IH-35 & 37).

The study consisted of 3 phases. The first phase included a field survey of 64 compressor engines selected from the three major gas producing districts in the study area. This field survey collected information on engine types, sizes and operating characteristics such as loads and schedules; as well as collecting information on site conditions. The second phase of the study involved collecting detailed information from the databases of the major compressor leasing companies who provide a majority of the compressor engines used in the study area. The information collected from the leasing companies included detailed engine population distributions by engine size, type and model. A database of almost 1300 leased compressor engines was acquired from the leasing companies. In the third phase of the study, the data collected from the field survey and from the leasing company survey were combined with the emission factor information in *AP-42* to develop an emission inventory of criteria pollutant emissions for compressor engines used in the eastern region of Texas for the years of 1999, 2002, 2007 and 2010.

Some of the findings of this study include:

1. The sizes of gas field compressor engines range from 25 to 1500 hp, with approximately 40% of the gas being compressed with engines smaller than 500 hp.
2. Gas field compressor engines are operated continuously through the year at constant loads. The average load on a compressor engine is 40%.
3. In the initial year of operation, most wells do not require compression. After the first year, almost all gas is compressed using reciprocating engines. Generally these engines are fueled with raw natural gas from the field, but many engines are fueled with treated natural gas. A very few gas compressors are driven with electric motors.
4. A majority of the compressor engines in the study area are leased. The current trend is for this fraction to increase.
5. The annual emissions from gas field compressor engines < 500 hp in the study area are listed in the following table. Overall, these emissions from small engines are additional to the point source emissions from natural gas operations. However, it is possible that an emission source included in the totals below is also reported in the point source inventory, if the site was required to report emissions for reasons other than the small engine.

Pollutant	Emissions in Designated Inventory Year (ton/yr)			
	1999	2002	2007	2010
CO	21,796	23,354	23,113	22,569
NO_x	19,561	20,949	20,786	20,298
VOC	573	613	610	596
$PM_{2.5}$	192	202	202	197
SO_2	6.4	6.6	6.6	6.5

6. The estimated uncertainty of the resulting inventory at the individual county level is 128%. This uncertainty is primarily attributable to the large uncertainty associated with the emission factors used in this study. It was also influenced significantly by the uncertainty in the distribution of engine types.

Recommendations for Further Study

The large uncertainty associated with the current study is largely a product of aggregating more than 50 engine types into only 3 categories and using the average emission factor for so many varied engines within each category. However, this approach is a necessary simplification since *AP-42* emission factors are only available for 3 engine types. This report identifies 10 engine models from 3 manufacturers that comprise 52% of the engine population in the study area. One means to significantly increase the accuracy of the compressor engine inventory is to conduct the analysis at the engine model level. This alternative approach might establish 13 engine groups: one for each of the 10 most common engine models and the 3 generic engine groups identified in *AP-42*. As an alternative, there may be several new engine groups that would address the remaining engine models better than the *AP-42* groups.

A key component of this alternative approach would be to collect specific emission information and develop revised emission factors for each of the 13 or more engine models and groups determined to be significant. Many western states in the Western Regional Air Program (WRAP) have also been addressing these same emission sources and may have collected emission information on the same engine models. Another source of emission information would always be the engine manufacturers. However, the manufacturer test results may reflect ideal engine conditions as opposed to typical engine conditions in the gas fields.

Another component of this alternative approach is the collection of accurate information on engine model distributions for all 110 counties in the study area, from the compressor engine leasing companies. Although this will involve collecting sensitive business information, with sufficient assurances from TCEQ as to the protection of their information, the leasing company managers would likely share this information.

The county-level uncertainty of the resulting compressor engine inventory that is conducted at the engine model level might be reduced from 128% to approximately 35 to 40%.

1.0 INTRODUCTION

This report presents the findings of a survey of gas field compressor engines located in the eastern portion of Texas. These compressors are used to boost the pressure of well-head natural gas so that it can be injected into higher pressure gathering lines. Reciprocating engines, fueled with raw natural gas, are normally used to drive the gas field compressors. Although these engines range in size from less than 25 horsepower (hp) to more than 1500 hp, most engines are less than 200 hp. Up to now, the emissions from these smaller engines have not been inventoried. The 110 counties that are included in this survey are highlighted in Figure 1-1.

Figure 1-1. Map of the Texas Counties included in the Survey

Table 1-1 lists the counties included in the study area and their respective TRRC Districts.

Table 1-1. List of Study Area Counties and TRRC Districts

County	Dist.	County	Dist.			County	Dist.
Anderson	6	Ellis	5	Karnes	2	Robertson	5
Angelina	6	Falls	5	Kaufman	5	Rockwall	5
Aransas	4	Fannin	5	Lamar	5	Rusk	6
Atascosa	1	Fayette	3	Lavaca	2	Sabine	6
Austin	3	Fort Bend	3	Lee	3	San Augustine	6
Bastrop	1	Franklin	6	Leon	5	San Jacinto	3
Bee	2	Freestone	5	Liberty	3	San Patricio	4
Bell	1	Galveston	3	Limestone	5	Shelby	6
Bexar	1	Goliad	2	Live Oak	2	Smith	6
Bosque	5	Gonzales	1	McLennan	5	Somervell	7B
Bowie	6	Grayson	9	Madison	3	Tarrant	5
Brazoria	3	Gregg	6	Marion	6	Titus	6
Brazos	3	Grimes	3	Matagorda	3	Travis	1
Burleson	3	Guadalupe	1	Milam	1	Trinity	3
Caldwell	1	Hardin	3	Montague	9	Tyler	3
Calhoun	2	Harris	3	Montgomery	3	Upshur	6
Camp	6	Harrison	6	Morris	6	Van Zandt	5
Cass	6	Hays	1	Nacogdoches	6	Victoria	2
Chambers	3	Henderson	5	Navarro	5	Walker	3
Cherokee	6	Hill	5	Newton	3	Waller	3
Collin	5	Hood	7B	Nueces	4	Washington	3
Colorado	3	Hopkins	5	Orange	3	Wharton	3
Comal	1	Houston	6	Panola	6	Williamson	1
Cooke	9	Hunt	5	Parker	7B	Wilson	1
Dallas	5	Jackson	2	Polk	3	Wise	9
Delta	5	Jasper	3	Rains	5	Wood	6
Denton	9	Jefferson	3	Red River	6		
De Witt	2	Johnson	5	Refugio	2		

Section 2 of this report discusses the results of a field survey of 66 gas field compressor engines. Section 3 discusses the results of a survey of companies which lease compressor engines in the study area. Section 4 discusses the construction of an emissions inventory for gas field compressor engines smaller than 500 hp. Appendix H presents the Quality Assurance Project Plan (QAPP) that served as the management plan and quality assurance plan for this study.

2.0 FIELD SURVEY

The objective of the field survey was to verify information provided by the owners and operators of gas-fired engines that are used to compress well head gas and to convey the gas into the gathering pipeline system. In addition, the field survey also provided a means to collect information from the compressor site that was not readily available from the central files of the site owner or operator. All of TRRC Districts 2, 3, 5, and 6 lie within the study area, as well as portions of Districts 1, 4, 7 and 9. However, since a majority of the gas production in the study area is from Districts 2, 3 and 6, it was decided that the field survey would focus on these latter three districts.

2.1 Approach

The field survey was conducted in four steps. First a questionnaire was mailed to gas production companies in the study area to gather the information needed to select compressor sites for the field survey. Based on the answers to the questionnaire, sites were selected and contacted to arrange for the site visits. The sites were visited in a three week period, and the results of the field survey were entered into a field survey database. The detailed activities involved with each of these four steps are discussed in this section.

2.1.1 *Questionnaire*

The objective of the questionnaire was to collect sufficient information from potential field survey sites to determine which sites would be ideal survey candidates. Another important consideration was to keep the questionnaire sufficiently simple, so that it did not discourage a high response rate. It was ultimately decided to develop a single page questionnaire that asked for readily available information on three compressor stations. A copy of the questionnaire is presented in Appendix A. A cover letter from the Director of the Air Quality Planning and Implementation Division of TCEQ was included with the questionnaire.

The mailing list for the questionnaire was compiled from the files of the Texas Railroad Commission (TRRC). It was decided to mail 70 questionnaires to each of the three TRRC Districts that comprised the majority of the study area, thus securing about 25 responses and yielding 10 sites for the field surveys in each district. The three TRRC Districts were: Districts 2, 3, and 6. Since the largest gas producers in each district produce the majority of the emissions 60 questionnaires were sent to the largest 60 gas producers. An additional 10 questionnaires were sent to the smallest producers in each district, to collect information on the operations of the smaller sources.

Since the field survey for a given district were to be conducted in a single week, it was also important to select sites that were within a reasonable driving distance from a central point in the district. To accomplish this objective, the 70 questionnaire recipients in each district were selected from 3 adjacent counties located in the heart of the gas production area of the district. However, in District 6, there were so many candidate survey sites in two of the counties, a third county was not needed. The surveyed counties in each district are identified in Table 2-1.

Table 2-1. Surveyed Counties in Each District

District	Counties
2	Lavaca, Victoria, De Witt
3	Brazoria, Ft Bend, Wharton
6	Panola, Rusk

A week after the questionnaires were received by the gas well operators, the operators were contacted by telephone to further encourage their participation in the study. As a result, responses were received from 53 of the 210 questionnaire recipients. Of these responses, 15 survey sites were not in operation, had been sold to other operators or did not use compressors. The remaining responses represented 85 compressor stations with a total of 99 compressors. The information provided by the questionnaires was entered into a spreadsheet database. A table summarizing the information in the database is presented in Appendix B.

2.1.2 *Site Selection*

The next step in conducting the field survey was the selection and scheduling of the compressor sites for conducting the site visits. The questionnaire results were grouped by their Texas Railroad Commission District (TRRC). The sites were then prioritized according to their ability to meet the following criteria:

1. Equipped with compressors ranging from 50 to 500 hp,

2. Number of compressors located on the same or adjacent sites,

3. Representativeness of the site, engine and compressor, and

4. Proximity to other sites of interest.

Based on their ability to meet these criteria, ten sites were chosen for site visits from each of the three TRRC districts in the study area: 2, 3, and 6. A data file of these selected sites was reviewed with HARC and TCEQ. With their approval the sites were contacted to schedule the site visits.

The point of contact for each site was contacted by telephone to schedule a site visit during the three week period of April 18 through May 6, 2005. The week of April 18 was reserved for sites in District 6, the week of April 25 was reserved for sites in District 2 and the week of May 2 was reserved for sites in District 3. The visits were also scheduled so that two sites in relative proximity were scheduled for the morning and afternoons of the same day, thereby allowing two sites to be visited in the same day. Before scheduling each site visit, the information provided on the questionnaire was confirmed, to assure that the site met the site selection criteria. There were no significant corrections needed to the data provided in the original questionnaire from each site.

2.1.3 *Conducting Site Visits*

Each site visit began with a meeting with the site representative. In this meeting the questionnaire data was again confirmed and additional data about the site was collected. At this time, the site representative also reviewed any site safety restrictions and any other administrative requirements of the host company. Following the meeting, the site representative conducted a visit to each compressor site.

To facilitate the site visits, a 3 page survey form was developed. A copy of the survey form is presented in Appendix C. The first page of the form collected data about the site owner and overall site operation. The second page collected data on each engine and compressor at the site. The third page collected information on the wells that produced gas for each compressor site. After the initial site visits were completed, several changes were made to the field survey forms:

1. A piping diagram to show the relationship between individual wells and the compressors was abandoned because the compression site managers were often not familiar with the piping between the wells and the compressor, the pipes were buried, and the wells were often several miles apart,

2. Site representatives did not know information on engine combustion settings or design, or the type of catalyst used in the catalytic converters,

3. Engine load and fuel use rate were not measured at any of the sites,

4. Since there were no seasonal variations in engine operation, the form was modified to collect the compressor data during the visit and the annual average data, and

5. The third page that collects well production data was abandoned since the compressor site representatives did not know well data (wells were often the responsibility of another manager and almost all, if not all, daily data is collected at the compressor station and not at the well). There was generally no production data or instrumentation available at the individual well sites.

Data on the engine manufacturer, model and serial numbers, rated capacity, speed (rpm) and year manufactured were typically collected from the engine nameplate. Inlet and discharge pressures and the daily flow rate were measured through meters on-site. At some sites, the engine nameplate was damaged, unreadable, or not present. In these cases, other staff familiar with the engine design in the district offices, or the leasing company if the compressor was leased, were contacted to provide the information over the phone. GPS coordinates were taken at each compressor site, using a standard hand-held GPS unit, with typical accuracies of +/- 15 to 25 feet.

2.1.4 *Constructing the Field Survey Database*

At the end of each week the completed field survey forms were entered into a MS Excel spreadsheet. After entry, the data for each site was checked against the survey form. A printout of the resulting database is presented in Appendix D. Selected portions of the database are presented in Table 2-2a, b, c.

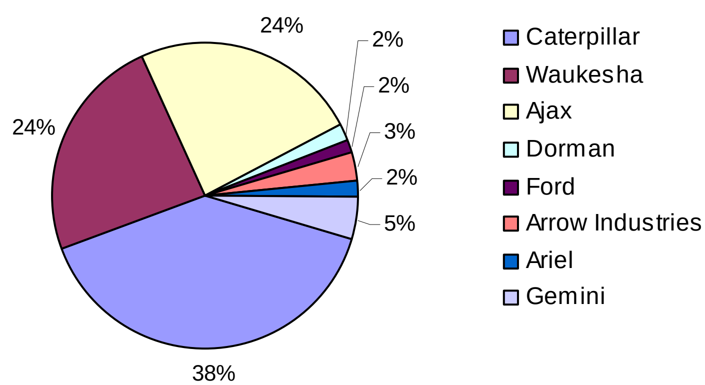
2.2 Findings

This section presents the observations resulting from the field survey of 66 compressors and engines at 62 sites.

2.2.1 *Engine Manufacturers*

The field survey of 66 compressor engines includes a diverse cross-section of engines. The engines were manufactured by 8 companies. However, Caterpillar, Waukesha, and Ajax manufactured 86% of the engines. Figure 2-1 illustrates the percentage of engine manufacturers represented in this survey.

Figure 2-1: Percentage of Engine Manufacturers Represented



2.2.2 *Engine Ages*

Among the engines surveyed, the engine manufacture date was not always obtainable. This information, when available on-site, was found on the engine nameplate. If the nameplate was damaged, unreadable, or not present, staff familiar with the engine design in the site's district offices, or with the leasing company if the compressor was leased, were contacted to provide the information over the phone. However, age information was only available for 18 of the engines. Of these engines, the ages ranged from 3 to 25 years old, with an average of 12 years. Figure 2-2 shows the distribution of engines according to manufacture year.

Table 2-2a. Summary of the Field Survey Results for TRRC District 2

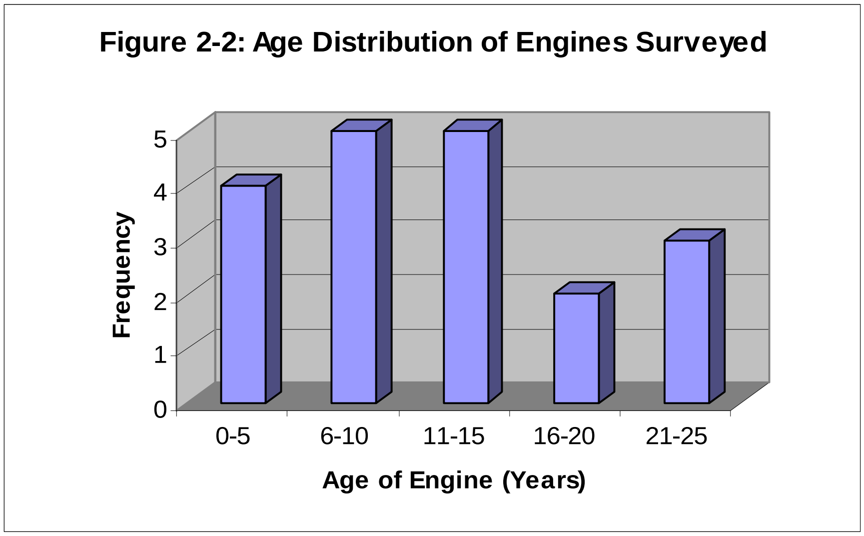
ID	Pressure		Flowrate (mscf/d)	Maint. Sched.		Engine Data				
	Inlet (psig)	Discharge (psig)		Hours	Cycle	Manufacturer	Leased (Y/N)	Leasing Company	Rated Capacity (hp)	Estimated Load (hp)
28A	45	800	45	1	month	Gemini	Y	Universal	26	9
29A	26	860	100	few	month	Caterpillar	Y	Universal	83	22
30A	20	1050	350	few	month	Caterpillar	Y	CSI	194	86
31A	18	795	280	few	3 mo	Caterpillar	Y	CSI	145	64
32A	80	790	385	few	month	Ajax	N		115	58
33A	255	629	499	1 to 2	month	Waukesha	Y	Universal	68	28
34A	90	775	165	few	month	Waukesha	N		35	23
35A	84	1100	60	few	month	Gemini	Y	Flat Rock	26	10
36A	275	600	770	2	month	Ajax	Y	Hanover	115	39
37A	188	600	518	2	month	Ajax	Y	Hanover	140	37
38A	120	850	815	few	month	Ajax	Y	Hanover	180	106
39A	40	900	500	few	month	Waukesha	Y	Gaertner	186	100
40A	27	850	3500	few	month	Caterpillar	Y	CSI	1200	754
41A	45	900	45			Gemini	Y	CSI	26	9
42A	70	900	1400	4	3 mo	Ajax	N		360	236

Table 2-2b. Summary of the Field Survey Results for TRRC District 3

ID	Pressure		Flowrate (mscf/d)	Maint. Sched.		Engine Data				
	Inlet (psig)	Discharge (psig)		Hours	Cycle	Manufacturer	Leased (Y/N)	Leasing Company	Rated Capacity (hp)	Estimated Load (hp)
43A	75	650	677	few	month	Ajax	Y	Hanover	280	95
44A	80	800	1230	few	month	Caterpillar	Y	Hanover	415	185
45A	225	900	600	few	month	Ajax/Cooper	Y	Hanover	140	54
46A	35	650	333	few	month	Caterpillar	Y	Gaertner	120	62
47A	100	650	540	few	month	Caterpillar	Y	J-W	100	67
48A	35	125	200	few	month	Waukesha	Y	Hanover	135	13
49A	45	960	425	4	month	Waukesha	N		165	88
50A	24	715	1181	few	month	Caterpillar	Y	Hanover	600	246
51A	50	675	293	few	month	Ajax	N		80	49
52A	270	800	133	few	month	Ajax	N		140	9
53A	75	150	326	few	month	Ajax	N		80	14
54A	55	680	349	2	month	Caterpillar	Y	Hanover	225	57
55A	155	660	145	2	month	Waukesha	Y	Hanover	68	14
56A	230	685	130	2	month	Caterpillar	Y	Hanover	95	9
57A	60	760	621	few	month	Caterpillar	Y	J-W	150	103
58A	78	720	153	few	month	Caterpillar	Y	J-W	95	22
59A	50	850	50	few	month	Caterpillar	Y	Universal	95	9
60A	20	300	4584	4 to 6	3 mo	Waukesha	Y	CDM	1478	708
60B	20	300	4564	4 to 6	3 mo	Waukesha	Y	CDM	1478	705
60C	20	300	4000	4 to 6	3 mo	Waukesha	Y	CDM	1478	618
61A	16	300	6211	4 to 6	3 mo	Caterpillar	Y	CDM	1340	1020
61B	16	300	5920	4 to 6	3 mo	Caterpillar	Y	CDM	1340	972
61C	16	300	5847	4 to 6	3 mo	Caterpillar	Y	CDM	1340	960
62A	5	60	2916	4 to 6	3 mo	Caterpillar	Y	CDM	637	263

Table 2-2c. Summary of the Field Survey Results for TRRC District 6

ID	Pressure		Flowrate (mscf/d)	Maint. Sched.		Engine Data				
	Inlet (psig)	Discharge (psig)		Hours	Cycle	Manufacturer	Leased (Y/N)	Leasing Company	Rated Capacity (hp)	Estimated Load (hp)
1A	50	480	1404	2	month	Caterpillar	Y	Star	560	199
2A	42.5	500	3033	2	3 mo	Caterpillar	Y	Hanover	945	467
3A	150	464	2928	2	3 mo	Waukesha I- 6	Y	Universal	620	202
4A	70	925	502	2	3 mo	Ajax/Cooper/Penjax	Y	Universal	180	86
5A	35	950	104.2	4	3 mo	Ajax	Y	Universal	60	22
6A	30	820	718	4	3 mo	Caterpillar	Y	Universal	325	149
7A	120	655		3	month	Caterpillar	N		450	
8A	200	700		3	month	Waukesha	N			
9A	110	330		3	month	Waukesha	N			
10A	60	660	650	2	month	Ajax/Cooper	Y	Universal	180	100
11A	60	600	750	4	month	Ajax	Y	Universal	180	110
12A	110	700	1550	4	month	Caterpillar	Y	Hanover	560	190
13A	80	480	85	4	month	Dorman	Y	J-W	50	10
14A	30	485	280	few	month	Caterpillar	Y	J-W	145	48
15A	40	500	380	1	month	Caterpillar	Y	J-W	125	60
16A	65	700	220	1 to 4	month	Caterpillar	Y	Hanover	80	34
17A	30	215	153	1 to 4	month	Waukesha	Y	Hanover	45	18
18A	17	260	192	1 to 4	month	Ford	Y	Compressco	49	29
19A	19	140	338	4	month	Arrow Industries	Y	Lions	65	37
20A	180	590	400	4	month	Arrow Industries	Y	Lions	45	30
21A	22	220	262	4	month	Waukesha	Y	Lions	125	34
22A	183	700	547	2 to 4	2 mo	Ajax	Y	Universal	180	47
23A	35	125	119	2 to 4	1.5 mo	Ariel JCS	Y	Universal	50	8
24A	19	115	220	2 to 4	1.5 mo	Waukesha	Y	Universal	68	20
25A	50	600	2140	few	as need	Waukesha	Y	Universal	530	338
26A	40	275	2099	few	as need	Caterpillar	Y	Universal	500	248
27A	18.5	560	296	few	as need	Ajax	Y	Mustang	230	60



2.2.3 *Engine Sizes*

The engines visited ranged in size from 26 to 1478 horsepower (hp), with a majority of the capacities being between 50 and 200 hp. Figure 2-3 shows the distribution of engine horsepower for 58 of the 66 engines. The horsepower ratings were unavailable for 8 engines. The size distribution of the engines between 1 and 200 hp is presented in greater detail in Figure 2-3a.

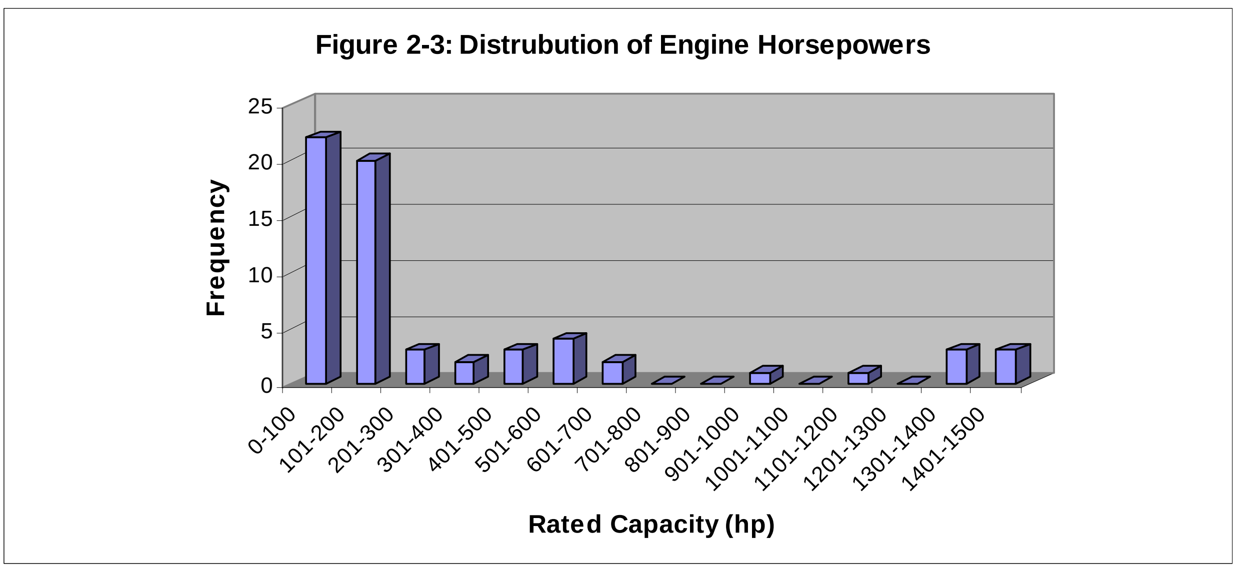
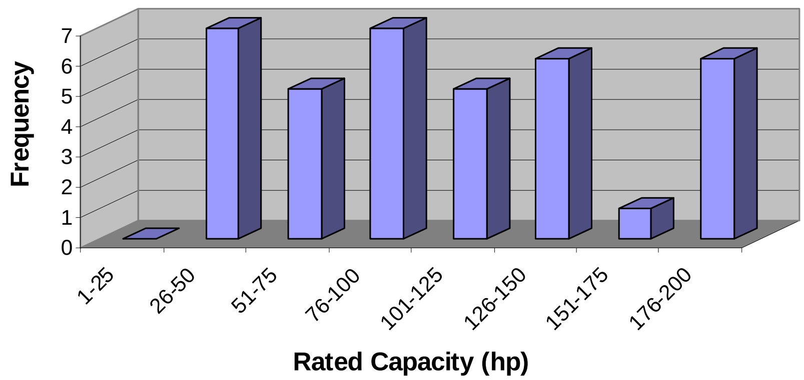


Figure 2-3a: Distrubution of Engine Horsepowers Between 1 and 200 hp



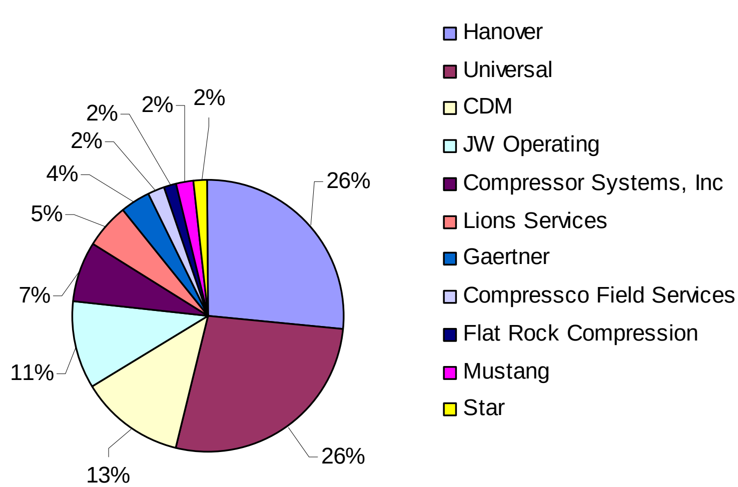
2.2.4 *Engine Designs*

Types of engines were diverse, and ranged from 1 to 16 cylinders. The majority of engines surveyed were 6 cylinder in-line engines, however, a variety of other engine types were represented in the survey, including 4 cylinder in-line engines, 1 and 2 cylinder integral engines, and V-6, V-8, V-12, and V-16 engines.

2.2.5 *Engine Ownership*

Out of the 66 compressors surveyed, 56 were leased and 10 were owned. Universal and Hanover leased the most compressors, at 26% each. CDM and J-W Operating followed with 12 % and 11%, respectively. Figure 2-4 shows the distribution of compressor leasing companies in the survey.

Figure 2-4: Percentage of Compressor Companies Represented



2.2.6 *Engine Load*

Two important parameters for developing an emission inventory are the compressor suction and discharge pressures required to convey the gas from the well head to the gathering lines. Together with the compressor flow-rate, these pressures define the engine load or the amount of mechanical work that is required to compress the natural gas produced by the well. This mechanical work is directly proportional to the volume of fuel that must be burned by the compressor engines, and therefore determines the emissions created by the compressor engines.

The pressures observed at the 66 compressors visited in the 3 districts during the field survey are summarized in Table 2-3. Suction pressures ranged from a minimum of 5 psig to a maximum of 275 psig, and averaged between about 70 and 90 psig. The discharge pressures ranged from a minimum of 115 psig to a maximum of 1100 psig, and averaged between 500 and 800 psig.

Table 2-3. Compressor Suction and Discharge Pressures

TRRC District	Suction Pressures (psig)			Discharge Pressures (psig)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
2	18	275	92	600	1100	827
3	5	270	73	125	960	554
6	17	200	69	115	950	509

The possible impact suction and discharge pressures on the selection of engine type for a given gas field application is analyzed in Table 2-4. The last column of this table presents the compression ratio between the suction and the discharge pressures of the compressor (expressed as a ratio of absolute pressures). This ratio is directly proportional to the mechanical work required by the compressor engine. As show in Table 2-4, 2-stroke engines, which are generally less efficient than 4-stroke engines, are not necessarily selected for the lower compression applications. Based on these observations, there does not appear to be distinction between the applications of 2- and 4-stroke engines based on gas field pressures.

Table 2-4. Compression Requirements by Engine Type

TRRC District	Engine Type	Average Suction Pressure (psig)	Average Discharge Pressure (psig)	Compression Ratio
2	2-stroke	146	748	4.7
	4-stroke	65	865	11
	All	92	827	7.9
3	2-stroke	139	635	4.2
	4-stroke	56	532	7.7
	All	73	554	6.5
6	2-stroke	71	732	8.7
	4-stroke	69	445	5.5
	All	69	509	6.2

The average compression ratios presented in Table 2-4 for the combined set of engines in each district are converted into the mechanical work (or engine load) that is required by the engines. These engine loads are presented in the last column of Table 2-5. The higher engine load required in TRRC District 2 is due predominantly to higher average discharge pressures in this district. The higher discharge pressures indicate that the gathering lines in this district are operated at pressure that are generally 50 to 60% higher than the gathering lines in the other two districts.

Table 2-5. Average Engine Compression Requirements

TRRC District	Inlet Pressure (psig)	Discharge Pressure (psig)	Compression Requirement	
			Ratio	Hp-hr/Mscf
2	92	827	7.9	3.5
3	73	554	6.5	3.1
6	69	509	6.2	3.1

2.2.7 *Seasonality and Operating Schedule*

All sites in the survey reported that there was no seasonality to their gas production. They are obligated to the gas transmission companies to maintain as steady of a gas production rate as possible. For this reason they also have very little down time at the compressor station. If there is a major problem with the compressor or engine, it is replaced immediately with a stand-by unit. All of the leasing companies and the major gas production companies maintain a fleet of stand-by compressor/engine units. These units are mounted on self-contained skids that are easy to drag into place and connect to the suction and discharge lines. The compression site managers consistently reported that their typical site down time is 1 to 4 hours per month. They also report that they see a boost in well flows immediately upon restarting compression activities after a compressor shut-down, thereby resulting in no loss of production for any shut-down of less than 1 to 2 days.

2.3 Field Observations

In addition to collecting the required field survey data, other information helpful to the inventorying of gas compressor engines was collected during the field survey. This information is discussed in this section.

High levels of well drilling were observed throughout the study area. Correspondingly, new pipelines were being installed in all of the three survey districts. In addition, several of the companies visited during the survey reported plans for installing new wells. As a result, there should be a significant growth in compressor use over the next few years.

Site representatives reported that most new wells do not require gas compression until they are 6 months to 2 years old. However, a majority of wells will require compression by the end of their second year of operation and all wells ultimately require compression. The average period that a well operates without a compressor is likely 1 year.

The data reported by the corporate office on the mail-in questionnaire was often inconsistent with the data gathered in the field. The corporate office which provided the questionnaire data was not always well informed about recent changes that had been made in the field, and therefore did not always have the most up-to-date information. This lack of accurate field data was further complicated at many sites because the compressors were owned and maintained by a leasing company.

A broad range of site and equipment conditions were noted among the 62 field survey sites. Some companies were very large with numerous compressors, while others were small with only one or two compressors. The larger companies had compressor sites that were clean and well maintained. The compressors at these companies received daily visits by the pump operators, who inspected them to ensure proper operation. Some smaller companies visited the compressor sites infrequently, often solely when the compressor needed immediate attention.

As noted in the data observations, 55 out of the 66 compressors that were leased. Site representatives reported that the use of leasing companies is becoming the preferred practice, as it eliminates their need to maintain spare parts, backup compressor/engine skids, and engine and compressor mechanics.

The size of a gas compressor engine was not a good indication of engine output. While these engines operate continuously, they seldom operate at full load. The engines in the field survey were operated at loads ranging from about 10 to 70% of full load, and averaged 40% load. There were two primary reasons mentioned by the site representatives for oversizing compressor engines. One reason was that low load operation extends the life of engines that are operated continuously. The second reason was to provide the site with excess compressor capacity so that after a monthly maintenance shutdown, the engine can be operated at full load for a brief period, to make-up the lost production and meet production commitments.

3.0 LEASING COMPANY SURVEY

Most of the gas compressors used in the study area are leased from a limited number of companies. For this reason, it was decided to survey the major leasing companies as a method of obtaining a large amount of compressor engine data from a limited number of contacts.

3.1 Approach

The initial step in the survey of leasing companies was to identify the major leasing companies operating in the study area. An Internet search identified six leasing companies that should be contacted in the survey, and provided their addresses and phone numbers. These companies and their contact information are listed in Table 3-1.

Table 3-1. Major Compressor Leasing Companies in the Study Area

<table>
<tr><th>Leasing Company</th><th colspan="2">Contact Information</th></tr>
<tr><td>1. Hanover Compressor Company</td><td colspan="2">Preston Batula
Environmental Manager
11000 Corporate Centre Drive, Suite 200
Houston, TX 77041
Telephone: 281-854-3183</td></tr>
<tr><td>2. Universal Compression, Inc.</td><td>Kevin Romine
Environmental Manager
4444 Brittmoore Rd.
Houston, TX 77041
Telephone: 713-335-7279</td><td>Tony Zamora
3334 South Southwest Loop
Suite 107
Tyler TX 75701
Telephone: 903-581-3989</td></tr>
<tr><td>3. J-W Operating, Co.</td><td colspan="2">James Barr
Sales Manager
P.O. Box 226406
Dallas, TX 75222
Telephone: 972-233-8191</td></tr>
<tr><td>4. Compressor Systems, Inc.</td><td colspan="2">Doug Lowrie, Corporate Env. Health & Safety Mgr.
Terry Christian, Regional Env. Health & Safety Mgr.
P.O. Box 60760
Midland TX 79711
Telephone: 432-563-1170</td></tr>
<tr><td>5. Mustang Compression</td><td colspan="2">Mike Liner, Leasing Manager
25408 Hwy 59, Suite 100
Porter, TX 77365
Telephone: 281-358-1705</td></tr>
<tr><td>6. Valerus Compression Services</td><td colspan="2">Alan Stults, Fleet Manager
12200 West Little York
Houston, TX 77041
Telephone: 713-983-7500</td></tr>
</table>

The next step was to assemble a list of questions for the leasing survey. Based on guidance provided by HARC and TCEQ, a three page list of questions was prepared for the survey. These questions are provided in Appendix E. A review of the questions led to the conclusion that the best approach to conducting the survey was to ask the simpler questions by telephone, and to request that the companies answer the more detailed questions by submitting a set of data files. All six leasing companies provided answers to the questions in the telephone portion of the survey, and two of the companies, Hanover Compressor and Universal Compression, submitted data files on 1288 compressors their Eastern Texas compressor fleet.

The leasing companies did not have the time and resources to provide a complete data file off all of their compressors in the 110 county study area. To present a representative cross-section of the compressor population in the study area, the leasing companies provided data for the compressors that they leased in selected counties. The data they provided covered 70 of the 110 counties in the study area. For the remaining counties, either data were not readily available from the leasing companies' files or the leasing companies had no compressors leased in those counties, indicating that those counties produce relatively little gas.

To make data submittal more manageable, Universal Compression, the leasing company with the greatest number of compressors in the study area, submitted data for only the counties listed in Table 3-2. These counties are among the top gas producers, but were not among the eight counties visited in the field survey. Freestone County in TRRC District 5 was included because it is the second largest gas-producing county in the study area (behind Panola County). The focus was on large-producing counties because these counties account for a larger fraction of the compressor engines and the emissions.

Table 3-2. Counties for Which Universal Compression Submitted Data

County	TRRC District	Ozone Attainment Status
Goliad	2	Attainment
Live Oak	2	Attainment
Harris	3	Non-attainment
Liberty	3	Non-attainment
Freestone	5	Attainment
Harrison	6	Attainment
Upshur	6	Attainment

3.2 Findings

These findings are based on the interviews with compressor leasing company representatives and are presented in order of the survey questions shown in Appendix E. Quantitative information in this section is based on a database of 1352 compressor engines: data on 1288 engines were provided by the leasing companies and data on 64 compressor engines were provided by the field survey.

3.2.1 Extent of Leasing Activity

The leasing companies estimate that approximately 90% of the compressors used for field compression are leased and that more than 90% of all leased compressors are used for gas field compression. However they are not willing to estimate how many compressors, leased or otherwise, are in the study area. Generally, the leasing companies are not able to readily estimate the number of compressors in this region because it does not correspond to their administrative boundaries for maintaining records, such as sales territories or customer groups.

Each of the compressor leasing companies and the production companies leasing the compressors annually report the quantity and sizes of the leased compressors to the Gas Compressor Association (GCA). The resulting GCA survey quantifies the population and total horsepower capacity of natural gas compressors at the state-level, but does not tabulate the data at the county-level or characterize the distribution of engine sizes. The results of the GCA annual survey are available only to members.

3.2.2 *Compressor Characteristics*

Three types of compressors are commonly used for gas field compression, all of which are designed for long periods of continuous operation with minimal maintenance:

- <u>Separable-engine reciprocating compressors</u>. In separable-engine reciprocating compressors, the thrust of a positive displacement pump, within the cylinder, moves the gas through the system. In general, reciprocating compressors feature low rotational and piston speeds, leading to high reliability.

- <u>Rotary screw compressors</u>. These compact compressors move gas through the system by the positive displacement of two rotating lobes confined in an eccentric cylinder. Rotary screw compressors have the unique ability to load horsepower over a wide range of operating conditions and are often the most cost efficient choice for low pressure applications.

- <u>Integral-engine reciprocating compressors</u>. These compressors are unique in that they are integrated into the engine design, and the engine is not a separate component. Integral-engine compressors use two-stroke, slow-speed (approx. 450 rpm) engines. These compressors, although still available, are an older design that is generally less efficient and more expensive to purchase. However, because the original cost of older units has already been depreciated, they can be leased for a lower fee that allows them to be competitive with separable-engine reciprocating units.

Approximately 45% of compressors in gas field compression service are separable-engine reciprocating compressors and approximately 30% are rotary screw compressors. Both separable-engine reciprocating compressors and rotary screw compressors use four-stroke engines. Therefore, the reciprocating engine emission from these two types of compressors will be similar. Rotary screw compressors are well-suited to high compression ratios while reciprocating compressors are preferred for lower compression ratios.

Integral-engine reciprocating compressors account for the remaining 26% of the leased compressors in the study area. These compressors use two-stroke engines, which have distinctly different emissions characteristics than four stroke engines. These compressors have the advantage of fewer moving parts and operating at very low speeds (450 rpm), resulting in distinctly lower maintenance costs. However, these engines are also less fuel-efficient, so they are generally selected for applications where maintenance costs are of greater concern than fuel costs. Of the more than 300 integral-engine reciprocating compressors encountered in the leasing survey, all of the engines under 500 hp were manufactured by Ajax, a division of Cooper Compression.

Another means to classify compressors is by the number of stages they use for compression. The term “compression ratio” is used to indicate the ratio of a compressor’s discharge pressure to the suction pressure, expressed on an absolute basis. Higher compression ratios require more compression stages. Compressors used in gas field service commonly have from one to three compression stages, with two stages being the most common configuration. One stage is used for compression ratios up to about 5, two stages are used for ratios up to about 17 and three stages are used for ratios up to 100. The average compression ratio observed in the field survey discussed in Section 2 was approximately 8, corresponding to two stages of compression.

3.2.3 *Engine Types and Controls*

The engines used for gas field compression service are classified by both the number of piston strokes in their combustion cycle and by their fuel-to-air ratio. Two-stroke engines complete the combustion cycle in two piston strokes and are designed for lean-burn combustion, which is defined by EPA and TCEQ as having more than 4% excess oxygen in the combustion zone. These engines also operate at very low speeds, about 450 rpm, which contributes to lower maintenance costs. Another advantage of two-stroke engines is that they can tolerate up to 1% sulfur in their fuel. However, one of their disadvantages is that these engines are also less fuel-efficient. Another disadvantage of two-stroke lean-burn engines is that their exhaust emissions cannot be controlled with the most common type of catalytic control, non-selective catalytic reduction (NSCR). The lean combustion conditions results in their exhaust temperature being to cool to promote catalytic reduction of their NO_x emissions.

Four stroke engines complete their combustion cycle in four piston strokes and can be designed for either lean-burn or rich-burn combustion. Rich-burn combustion is defined as having less than 4% oxygen in the combustion zone. The majority of four stroke engines that are under 500 hp are rich burn. In fact, only one of the 1352 engines in the database compiled from the data from Hanover Compressor, Universal Compression, and the field survey was a lean burn engine under 500 hp. During the telephone survey, one other leasing company also reported having a few lean-burn four-stroke engines smaller than 500 hp. Four stroke engines generally operate at speeds between 1200 and 1800 rpm. They also require sulfur levels below 10 ppm. One major advantage of four stroke engines is that they can achieve lower NO_x emissions. The four stroke lean-burn engine naturally emits lower NO_x emissions and the four stroke rich-burn engine can be fitted with NSCR catalyst to achieve even lower NO_x emissions.

Less than 0.2% of gas well compressors are driven by electric motors. Electric motors are sometimes used in residential neighborhoods to reduce noise or where electricity is readily available for less than 7 cents per kWhr.

For the counties which are in attainment with the National Ambient Air Quality Standards (NAAQS), very few engines under 500 hp had NSCR controls. NSCR is commonly referred to as catalytic converter or three-way catalyst because it reduces three pollutants: NO_x, CO, and VOC. Most leasing companies do not note in their central tracking system whether compressors have NSCR. However, leasing company representatives estimate that about 5% of engines under 500 hp have NSCR in attainment areas.

In contrast, almost all natural gas-fired engines under 500 hp in the Houston-Galveston non-attainment area have NSCR controls. These NO_x control requirements for compressor engines have been in-place for many years. The only engines not requiring NO_x controls are two-stroke engines (4% of the total horsepower in this area), engines under 50 hp (less than 0.1% of the total horsepower), and four stroke lean-burn engines which are naturally low in NO_x emissions.

The Dallas/Fort Worth area has recently established NO_x control requirements for compressor engines with capacities greater than 300 hp. These limits can be found in 30 TAC 117.206(b). However these requirements will not be in full effect until 2007. The compliance schedule is in 30 TAC 117.520(b)(2).

3.2.4 *Engine Sizes*

For the entire study area, 83% of the compressor engines have a maximum rating less than 500 hp. However, these engines comprise 40.3% of the total horsepower capacity. The size distribution of two and four stroke engines under 500 hp in attainment counties is shown in Table 3-3, for the database of 1352 engines.

Table 3-3. Distribution of Engine Sizes in Attainment Counties (Engines < 500 hp)

Engine Sizes	< 100 hp	100 – 199 hp	200 – 299 hp	300 – 399 hp	400 – 499 hp
Distribution by Total Horsepower[a]					
4-stroke, rich-burn	16%	27%	13%	5%	6%
2-stroke, lean-burn	4%	11%	7%	10%	0%
4-stroke, rich-burn w/ NSCR	0%	0%	0%	0%	0%
Distribution by Number of Engines[a]					
4-stroke, rich-burn	32%	26%	8%	2%	2%
2-stroke, lean-burn	10%	11%	4%	4%	0%
4-stroke, rich-burn w/ NSCR	0%	0%	0%	0%	0%

[a]The individual numbers have been rounded to whole percentages, thus creating a situation where the total sum of the values in each distribution is 99% and not 100%

The distribution of engine sizes and types is relatively consistent throughout the study area with the exception of the Houston non-attainment area where the fraction of two-stroke engines drops to 8% of the total horsepower among engines under 500 hp. Table 3-4 presents the distribution of engine sizes for the Houston non-attainment area.

Table 3-4. Distribution of Engine Sizes in Houston Non-attainment Area (Engines < 500 hp)

Engine Sizes	< 100 hp	100 – 199 hp	200 – 299 hp	300 – 399 hp	400 – 499 hp
Distribution by Total Horsepower					
4-stroke, lean-burn	0%	0%	0%	1%	0%
2-stroke, lean-burn	1%	4%	0%	4%	0%
4-stroke, rich-burn w/ NSCR	11%	30%	14%	24%	12%
4-stroke, rich burn	0%	0%	0%	0%	0%
Distribution by Number of Engines					
4-stroke, lean-burn	0%	0%	0%	1%	0%
2-stroke, lean-burn	3%	5%	0%	2%	0%
4-stroke, rich-burn w/ NSCR	28%	34%	10%	11%	4%
4-stroke, rich burn	2%	0%	0%	0%	0%

3.2.5 *Engine Fuels*

Most compressor engines are fueled by wellhead gas. If the sulfur content of the gas is too high (greater than 1% for two-stroke engines or 10 ppm for four-stroke engines) low-sulfur natural gas can be piped to the engine or the wellhead gas can be desulfurized using an amine contactor. No engines are fueled with diesel.

3.2.6 *Operating Schedules*

Initially, most newly completed wells do not require a compressor to move the gas from the well head to the gathering line. Some experienced applications engineers estimated that 95% of all wells required no compressor during the first one to eighteen months of operation because the formation pressure exceeds the gathering line pressure. Others estimated that over 75% of new wells needed compressors initially. Overall, it appears that while the leasing companies are extremely knowledgeable about compressors, they are not particularly knowledgeable about the average period of time over which wells do not need a compressor. This is probably due to the fact that the leasing companies may not be involved in the initial phases of a well completion operation.

Once installed, gas well compressors are operated nearly 100% of the time except for a couple of hours per month for routine maintenance. Leasing companies typically guarantee that the compressors will be operable in excess of 98% of the lease period.

3.2.7 *Operating Loads*

Engines are typically not operated at 100% load because, among other reasons, it would reduce the life of the engine. Because operating pressures can change significantly as well as ages, the engine load varies over time. Leasing companies reported that their engines loads were typically about 75% and with some operating as low as 20%.

3.2.8 *Engine Age Distribution*

A detailed distribution of engine ages was not available, but leasing managers estimate that the average age of their gas compressor engines is about 9 years. All leasing managers reported that they overhaul engines every 50,000 hours (about 6 years) of operation. The emissions of a completely overhauled 18-year-old engine, for instance, may match that of a relatively new engine, so an engine's age may be less important than its condition in terms of matching its original emission specifications.

3.2.9 *Catalyst Efficiency*

NSCR catalyst beds can be equipped on any rich burn engine. These catalyst beds can be purchased with NO_x emission limits ranging from less than 0.5 g/bhp-hr to 2 g/bhp-hr, depending on the applicable regulatory limit. To meet lower NO_x levels, the exhaust retention time in the catalyst bed is increased. This added retention is generally achieved by adding a second catalyst bed.

3.2.10 *Engine Instrumentation*

The operating parameters typically monitored on engine-compressor systems include:

- Inlet and outlet gas pressure,
- Gas flow rate,
- Engine speed (rpm), and
- Engine manifold vacuum.

The engine load can be an important parameter when estimating emissions, but engine load is not easily measured. Since the engine manifold vacuum is a qualitative indicator of engine load, most leasing companies periodically calculate the engine load using this parameter.

3.2.11 *Engine Manufacturers and Models*

Table 3-5 presents the estimated compressor engine distribution for leased compressors in the study area, by manufacturer. Approximately 96% of the engines are manufactured by four companies. Table 3-6 presents the estimated compressor engine distribution for leased compressors in the study area, by engine model. The top 10 engine models account for 52% of the engine population. The remaining models individually comprise 1% or less of the engine population.

Table 3-5. Leading Engine Manufacturers

Manufacturer	% of Population
Caterpillar	43%
Waukesha	29%
Ajax (Cooper Compression)	22%
Gemini	2%
Total	96%

Table 3-6. Ten Most Common Engine Models[a]

Manufacturer	Model	Obsolete	Max. hp	Fraction of Population
Caterpillar	G3306 NA		145	12%
Caterpillar	G3304 NA		95	10%
Waukesha	VRG330	yes	75	9%
Caterpillar	G3306 TA		220	5%
Waukesha	F817G		125	4%
Waukesha	F1197G		186	3%
Ajax	DPC-60		58	3%
Ajax	DPC-140		134	2%
Caterpillar	G342 NA	yes	225	2%
Ajax	DPC-115		110	2%
			Total	52%

[a] The remaining models each represent less than 1% of the population.

3.2.12 Summary of Engine Distributions

Table 3-7 provides a breakdown of the net engine capacity (hp), by size range and engine type, for the attainment and non-attainment areas within the study area. Tables showing the population distribution by TRRC District are provided in Appendix F. This information is based on a random sampling of 1352 compressor engines provided by the two largest compressor leasing companies and the field survey.

Table 3-7. Distribution of Compressor Engine Capacities by Engine Size and Type

Engine Category	% of hp	Cumulative Capacity		Net Capacity (hp) in Each Hp Size Range				
		hp	# of engines	0 – 99	100 - 199	200 - 299	300 – 399	400 – 499
Attainment								
Engines ≥ 500 hp[a]	61	214,675	201					
Two-stroke, lean burn, < 500 hp	12	42,627	277	5,787	14,339	8,973	13,528	
Four-stroke, rich burn, < 500 hp	26	91,479	675	21,842	36,887	17,234	6,960	8,556
Electric	0.12	407	3	80	327			
Houston-Galveston Non-attainment								
Engines ≥ 500 hp[a]	49	28,869	28					
Two-stroke, lean burn, < 500 hp	4	2,393	16	200	1,117		1,076	
Four-stroke, rich burn w/NSCR, < 500 hp	46	26,646	147	3,177	8,770	4,125	7,190	3,384
Four-stroke, lean burn, < 500 hp	1	375	1				375	
Four-stroke, rich burn, < 50 hp	0.2	137	4	137				

[a]Engines ≥ 500 hp were not inventoried in this study.

4.0 EMISSION INVENTORY

4.1 Objective

An emission inventory was compiled for gas field compressor engines in the study area (defined in Figure 1-1) from the data collected in the field survey and the leasing company survey, and from activity data available from the TRRC. The scope of the inventory included:

- 110 counties east of I-35 and I-37 (Figure 1-1),
- All gas fired compressor engines <500 hp,
- Annual and ozone season daily emissions,
- Emissions of CO, VOC, NO_x, SO_x and PM2.5,
- Years- 1999, 2002, 2007, and 2010.

This section describes the approach used for conducting the inventory and documents all assumptions used in developing the inventory for the study area.

4.2 Inventory Equation

Equation 4-1 presents the general model or approach used to develop the emission inventory.

Equation 4-1:

$$E_{ijk} = Q_i \text{ x } F_{1i} \text{ x } F_{2j} \text{ x } C_i \text{ x } H_j \text{ x } EF_{jk} \text{ x } 1/2000$$

Where:

E_{ijk}	= Emissions in county i, for engine type j, and pollutant k (tons/yr)
Q_i	= Gas produced in county i (Mscf/yr)
F_{1i}	= Fraction of wells requiring compression in county i
F_{2j}	= Fraction of compression load represented by engines <500 hp, of type j
C_i	= Compression requirements for county i (hp-hr/Mscf)
H_j	= Brake specific fuel consumption for engine type j, (MMBtu/hp-hr)
EF_{jk}	= Emission factor for engine type j, and pollutant k (lb/MMBtu)
1/2000	= Conversion from lbs of emissions to tons of emissions

The source of data for each variable in Equation 4-1 is described in the following sections.

4.3 Gas Production

The annual natural gas production "Q_i" for county "i" was obtained for the years 1999 and 2002 from the TRRC records. These records are available from their web site at:

http://www.rrc.state.tx.us. The forecasted gas production for each county for the years 2007 and 2010 were provided by the TCEQ. They developed the forecasted production rates based on actual 2002 production data from TRRC in combination with DOE's regional forecasts provided by Jonathan Cogan (EIA,DOE). The forecasted productions are presented in Appendix G.

4.4 Wells Requiring Compression

The fraction of gas wells requiring compression "F_{1i}" is based on the fact learned in the field survey, that most wells do not need compression during their first year of production. Ideally, the variable "F_{1i}" would be the fraction of production that is generated from wells greater than 1 year old, and thus, requiring compression. However, the available records from TRRC do not reveal the production from wells greater than 1 year old; they only reveal the fraction of wells that are greater than 1 year old. Therefore, the fraction of wells requiring compression will be used as a surrogate for the fraction of production requiring compression.

The number of wells completed each year and the total number of operating wells are available from the TRRC website: (http://www.rrc.state.tx.us/divisions/og/information-data/wkly-qtry-monthly-reports/prod-drill/ogdc04an.pdf). Because of the small number of wells completed in any one county in any one year, the aggregate well completion data was used for the TRRC district in which the county resides. This information and the resulting values for F_{1i} are presented in Table 4-1. As shown in this table, there is very little difference in fractions between the three TRRC districts.

Table 4-1. Fraction of Wells >1 Year Old in Each District

TRRC Dist	Wells Completed In 2004	Total Wells Jan 2005	Fraction >1 yr Old[a]
2	491	4177	0.88
3	489	3983	0.88
6	1147	12395	0.90

[a]Assumed to be the fraction of wells requiring compression.

4.5 Distribution of Engine Types

The fraction of engines less than 500 hp of type j, "F_{2j}" was determined based on the data obtained from the survey of leasing companies. The leasing company survey data was presented in Tables 3-3 and 3-4. The resulting values of F_{2j} are presented in Table 4-2. Multiple values of F_{2j} were determined based on the county's ambient air quality status. The "attainment" values in Table 4-2 were applied to all counties that were in compliance with national ambient air quality standards (NAAQS). The Houston area was in "non-attainment" of the NAAQS for 1999 and 2002, and was assumed to be in non-attainment for 2007 and 2010. The eight counties in the Houston non-attainment area are: Brazoria, Chambers, Ft Bend, Galveston, Harris, Liberty, Montgomery, and Waller.

The Dallas area counties were in attainment of the NAAQS for 1999 and were assigned the values in the first column. In 2002, the Dallas counties were in non-attainment of the NAAQS and were required to use lower emission engines. In 2005 more stringent engine restrictions were applied. It was assumed that these same engine restrictions would be applied throughout the years of 2007 and 2010. The nine counties in the Dallas non-attainment area include: Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, and Tarrant.

The engine distribution shown in Table 4-2 for the non-attainment counties are based on the engine population distribution information provided by the leasing companies and not on a theoretical analysis of the regulations and assumptions of rule penetration and effectiveness.

Table 4-2. Distribution of Engine Capacity by County NAAQS Status

Engine Type	Fraction of Total Engine Capacity (hp)			
	Attainment (all years)	Houston Non-Attainment '99, '02, '07, '10	Dallas Non-Attainment '02	Dallas Non-Attainment '07, '10
4 stroke, rich	0.25	0	0.23	0.18
4 stroke, lean	0	0.01	0	0
4 stroke, rich w/ NSCF	0.01	0.46	0.03	0.08
2 stroke, lean	0.12	0.04	0.12	0.12
Subtotal engines <500 hp	0.38	0.51	0.38	0.38
Engines ≥500 hp	0.62	0.49	0.62	0.62

4.6 Compression Requirements

The compression requirements for a given county, C_i, are based on the difference between the well pressures and the gathering line pressures. Typical well pressures and gathering line pressures were obtained from the field survey and are discussed in Section 2.2.6 and Table 2-5. Based on these data, average well and gathering line pressures were determined for each TRRC district, and are presented in Table 4-3. A slide rule calculator provided by the Hanover Compressor Company, Houston, Texas, was used to convert the average district inlet and outlet pressures into the average district compression requirements. These average district compression requirements are shown in Table 4-3.

Table 4-3. Average District Compression Requirements

TRRC Dist.	Inlet Pressure (psig)	Discharge Pressure (psig)	Compression Requirement (hp-hr/Mscf)
2	92	827	3.5
3	73	554	3.1
6	69	509	3.1

The Gas Processors Suppliers Association Engineering Data Book Eleventh Edition, FPS Version, 1998, provides Equation 13-4 that can be used to provide a close approximation of the compression requirements:

hp-hr/Mscf = (0.53) x (compression ratio per compressor stage) x (# of Stages) x (F)

Where: F = 1.0 for a single stage, 1.08 for a two-stage and 1.1 for a three-stage compressor. One-stage compression is used for compression ratios between 1 and 6, two-stage compression is used for compression ratios between 5 and 20, and three-stage compression is used for compression ratios between 15 and 100. The compression ratio per compressor stage can be estimated from the overall compression ratio by using the equation:

$$\textit{Compression ratio per stage} = (\textit{overall compression ratio})^{1/S}$$

Where S = the number of compressor stages. In addition to the load of the compressor, the engine also must overcome parasitic loads created by auxiliary equipment on the engine. This parasitic load can range from 6 to 10 percent. Combining the equation for estimating the compression requirement per stage with the adjustment for parasitic load yields Equation 4-2 for estimating the engine compression requirements for compressing natural gas.

Equation 4-2:

$$\textit{hp-hr/Mscf} = (0.57) \times (\textit{overall compression ratio})^{1/S} \times (S) \times (F)$$

4.7 Brake Specific Fuel Consumption

The brake specific fuel consumption, H_j, was determined for the most common engine model in each engine category listed in Table 4-2. The selection of the most common engine model was based on the engine model distributions provided by the engine leasing companies in the leasing company survey. The Caterpillar G3306 NA and the Waukesha F18GL were the most common 4-stroke rich burn and lean burn engines, respectively. The Ajax DPC-180 was selected because it was in the middle of the size range and the fuel consumption range of the Ajax engines used in the study area. The manufacturer of each of these engines was contacted for the break specific fuel consumption specifications of the engine. The brake specific fuel consumption specifications used for the inventory are presented in Table 4-4. The units of break specific fuel consumption are million Btu of natural gas fuel consumed per horsepower-hour of work performed by the engine, expressed in terms of the higher heating value of the fuel (HHV).

Table 4-4. Brake Specific Fuel Consumption for Compressor Engines

Engine Type	Representative Model	Size (hp)	Fuel Consumption $(\mathrm{MMBtu/hp\text{-}hr})_{HHV}$
4 stroke, rich	Caterpillar G3306 NA	145	0.008769
4 stroke, lean	Waukesha F18GL	375	0.008103
4 stroke, rich w/ NSCR	Caterpillar G3306 NA	145	0.008769
2 stroke, lean	Ajax DPC-180	134	0.009324

4.8 Emission Factors

The emission factors for each engine type were obtained from EPA's *Compilation of Air Pollutant Emission Factors, AP-42*, Section 3.2, July, 2000. *AP-42* provides emission factors for 3 types of natural gas-fired reciprocating engines:

- 4-stroke, lean-burn engines,
- 4-stroke, rich-burn engines, and
- 2-stroke, lean-burn engines.

The fourth type of engine contained in the inventory is a 4-stroke rich-burn engine equipped with NSCR technology. *AP-42* recommends applying an efficiency of 90% to the uncontrolled emissions of NO_x, CO, and VOC for engines equipped with NSCR technology. Although most of the engines used for well-head compression are fueled with lease gas, *AP-42* does not have emission factors for lease gas combustion. However, lease gas is un-refined natural gas and is similar in composition. Therefore, the *AP-42* natural gas emission factors listed in Table 4-5 were used for the inventory.

Table 4-5. Engine Emission Factors

	Emission Factors $(lb/MMBtu)_{HHV}$			
Pollutant	**4-stroke lean-burn**	**4 stroke rich-burn**	**4 stroke rich-burn, w/ NSCR**	**2-stroke lean-burn**
$PM_{2.5}$	7.75 E-05	9.50 E-03	9.50 E-03	3.84 E-02
NO_x	0.847	2.27	0.23*	1.94
CO	0.557	3.51	0.351*	0.353
VOC	0.118	2.96 E-02	2.92 E-03*	0.12
SO_x	5.88 E-04	5.88 E-04	5.88 E-04	5.88 E-04

* Assumes 90% reduction

4.9 Ozone Season Day

An ozone season day is defined as a typical day in August. Based on data collected from both the field survey and the leasing company survey, gas production is steady throughout the year in the study area. Therefore, the average emissions on an ozone season day were estimated as $1/365^{th}$ of the annual emissions of each pollutant.

4.10 Inventory Results

The inventory was compiled using the preceding methodology in a MSAccess database. The resulting inventory was then converted into an inventory file using EPA's national inventory file format (NIF). Table 4-6 presents a summary of the annual emissions resulting from the inventory. Overall, these emissions from small engines are additional to the point source emissions from natural gas operations. However, it is possible that an emission source included in the totals below is also reported in the point source inventory, if the site was required to report emissions for reasons other than the small engine.

Table 4-6. Summary of Annual Emissions from Gas Field Compressor Engines < 500 hp, in the Study Area

Pollutant	Emissions in Designated Inventory Year (ton/yr)			
	1999	2002	2007	2010
CO	21,796	23,354	23,113	22,569
NO_x	19,561	20,949	20,786	20,298
VOC	573	613	610	596
$PM_{2.5}$	192	202	202	197
SO_2	6.4	6.6	6.6	6.5

4.11 Example Calculation

The following example calculation estimates the annual NO_x emissions from 4-stroke rich-burn engines in Panola County, Texas in 1999. Equation 4-1 will be used for the estimation:

Equation 4-1:

$$E_{ijk} = Q_i \text{ x } F_{1i} \text{ x } F_{2j} \text{ x } C_i \text{ x } H_j \text{ x } EF_{jk} \text{ x } 1/2000$$

Where:

E_{ijk} = Emissions in county i, for engine type j, and pollutant k (tons/yr)
Q_i = Gas produced in county i (Mscf/yr)
F_{1i} = Fraction of wells requiring compression in county i
F_{2j} = Fraction of compression load represented by engines <500 hp, of type j
C_i = Compression requirements for county i (hp-hr/Mscf)
H_j = Brake specific fuel consumption for engine type j, (MMBtu/hp-hr)
EF_{jk} = Emission factor for engine type j, and pollutant k (lb/MMBtu)
1/2000 = conversion from lbs of emissions to tons of emissions

Q = The natural gas production in 1999 for Panola County. This value was obtained from the TRRC website and is shown in Appendix G as: 253,946,855 Mscf/yr.

F_1 = Fraction of wells requiring compression in Panola County. Panola County is in TRRC District 6. The fraction of wells in District 6 requiring compression is shown in Table 4-1 as 0.9.

F_2 = Fraction of compression load represented by 4-stroke rich-burn engines <500 hp. Panola County is in attainment of NAAQS. The fraction of compression load represented by engines <500 hp in an attainment county is shown in Table 4-2 as 0.25.

C = Compression requirements for Panola County (hp-hr/Mscf). Panola County is in District 6. The compression requirements for compressors in District 6 is shown in Table 4-3 as 3.1 hp-hr/Mscf

H = Brake specific fuel consumption for 4-stroke rich-burn engines (MMBtu/hp-hr). The break specific fuel consumption for 4-stroke rich-burn engines is shown in Table 4-4 as 0.008769 MMBtu/hp-hr.

EF = NO_x emission factor for 4-stroke rich-burn engines (lb/MMBtu). The emission factor for NO_x emissions from 4-stroke rich-burn engines is shown in Table 4-5 as 2.27 lb/MMBtu.

Using Equation 4-1, the NO_X emissions from 4-stroke rich-burn engines in Panola County in 1999 were:

E = (254 x 10^6 Mscf/yr) (0.9) (0.25) (3.1 hp-hr/Mscf) (0.0088 MMBtu/hp-hr) (2.3 lb/MMbtu) (ton/2000lb)
= 1,790 tons/yr

4.12 Uncertainty Analysis

One means to assess the uncertainty in a calculation is to aggregate the uncertainties associated with the various components of the calculation. This aggregation can be achieved by using a method termed: the square-root of the summation of the squares. In this method, an uncertainty is determined for each variable in the inventory equation used to develop the compressor engine inventory. The squared value of each uncertainty is summed and the square root of this summation is an approximate uncertainty for the estimations developed from the inventory equation. Equation 4-1 was used to develop the emission inventory.

Equation 4-1:

$$E_{ijk} = Q_i \text{ x } F_{1i} \text{ x } F_{2j} \text{ x } C_i \text{ x } H_j \text{ x } EF_{jk} \text{ x } 1/2000$$

The estimated uncertainties associated with each variable in Equation 4-1 are discussed below.

Q_i - Gas produced in county i (Mscf/yr):

The TRRC records of gas production in each county are considered relatively accurate. They are measured with very accurate orifice meters that are routinely calibrated. These instruments easily have accuracies of better than 1%.

F_{1i} - Fraction of wells requiring compression in county i:

The fraction of wells requiring compression varied from 0.88 to 0.90 in the three districts surveyed. However, the fraction of wells is being used as a surrogate for the fraction of gas produced from older wells. Since the fraction of gas produced by the older wells may be as low as 0.8, the uncertainty in this value may be +/- 10%.

F_{2j} - Fraction of compression load represented by engines <500 hp, of type j:

Although the surveys revealed no technical reason that the application of engine types would vary between counties, there was nominally a 50% variation in engine type distributions among the various counties.

C_i - Compression requirements for county i (hp-hr/Mscf):

The compression requirements varied between the surveyed counties from 3.1 to 3.5, or 20%. We would expect similar variations between the remaining counties.

H_j - Brake specific fuel consumption for engine type j, (MMBtu/hp-hr):

The break specific horsepower varied between the engines surveyed from 0.008103 to 0.009324 MMBtu/hp-hr. Other common engine models have break specific fuel consumptions ranging from 0.008 to 0.0095, or +/- 9%.

EF_{jk} - Emission factor for engine type j, and pollutant k (lb/MMBtu):

The uncertainty associated with the emission factors is the greatest uncertainty in the emission estimation equation. The Background Document in support of the gas-fired engine section if *AP-42* provided the following information on the uncertainty of the engine emission factors:

Pollutant	Relative Standard Deviation (%)		
	4-stroke, rich-burn	4-stroke, lean-burn	2-stroke, lean-burn
NO_X	20	207	85
CO	74	35	55
TOC	80	27	53

The average relative standard deviation is 70% and the associated 90% confidence level for this standard deviation is +/- 115%.

Square-Root of the Summation of the Squares

The estimated uncertainty based upon the square-root of the summation of the squares for the individual uncertainties listed above is calculated in Table 4-7. The estimated uncertainty of 128% is primarily attributable to the large uncertainty associated with the emission factors used in this study. It was also influenced significantly by the uncertainty in the distribution of engine types. If the emission factors and the engine model distributions were improved to an uncertainty of +/- 20%, the estimated uncertainty in the resulting inventory may be reduced to +/- 35 to 40% for individual counties.

Table 4-7. Uncertainty: Square-Root of the Summation of the Squares

Variable	Uncertainties (U%)	
	U	U^2
Q_i - Gas produced in county i	1	1
F_{1i} - Fraction of wells requiring compression in county i	10	100
F_{2j}- Fraction of compression load for engines <500 hp, of type j	50	2500
C_i- Compression requirements for county i	20	400
H_j- Brake specific fuel consumption for engine type j	9	81
EF_{jk}- Emission factor for engine type j, and pollutant k	115	13225
Summation of U^2		16307
Estimated Resulting Uncertainty (square root of U^2)		128

APPENDIX A

Gas Lease Operator Questionnaire and TCEQ Cover Letter

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

Dear Operator:

The Texas Commission on Environmental Quality (TCEQ) plans to update information for compressor engines operating in the gas fields of Texas located in the area east of Interstate Highway 35. We seek to gain your cooperation in obtaining technical data associated with compressor engines. The data collected will be used to develop a more complete inventory of compressor engines and their emissions.

In this effort the Houston Advanced Research Center and Eastern Research Group (ERG) are working with the TCEQ to conduct a survey of the gas compressor engines operating in Districts 2, 3, and 6 as defined by the Texas Railroad Commission. Representatives from ERG would like to visit one or more of your compressor stations in these districts. During the site visit, information such as name-plate data, fuel consumption and operating schedules pertaining to the compressors will be recorded.

We would be very grateful if you would take the time to complete the attached form for as many as three of your compressor engine stations that are located in the district and county indicated on the form. The ideal compressor station for this study would reasonably represent many of the other stations in your operation, is easily accessible, and is located close to other representative compressor stations.

Please return this form by March 18, 2005. To learn more information about our study, please call Clint Burklin at ERG at (919) 468-7874.

The TCEQ appreciates your assistance in this study.

Sincerely,

Candice Garrett

Candice Garrett, Director
Air Quality Planning and Implementation Division

P.O. Box 13087 • Austin, Texas 78711-3087 • 512/239-1000 • Internet address: www.tceq.state.tx.us

HOUSTON ADVANCED RESEARCH CENTER
SURVEY OF GAS COMPRESSOR ENGINES

Please complete this form for 3 gas compressor stations in ___ ,___ and___Counties. Once completed, please fold the form so that the stamp and return address are outside, tape the form closed and drop in the mail by March 18, 2005. Thank you very much for helping with this study.

This survey is completed by:

Who should we contact for discussing a possible site visit?

Name: ____

Phone numbers: ________________________,_______________________________

E-mail address: ____

Compressor Station Information:

	Station 1	Station 2	Station 3
Station name or other designation:			
Gas field name:			
Lease name:			
Lease number:			
General station location (i.e. nearby town):			
Number of wells actively supplying this station:			
Age of oldest well supplying this station:			
Typical inlet line pressure entering this station (psig):			
Peak outlet line pressure from this station (psig):			
Annual gas production from this station (MMscf/yr):			
Total number of compressors at this station:			
Number of leased compressors at this station:			
Total engine horsepower at this station:			

APPENDIX B

Summary of Questionnaire Responses

Table B-1. Summary of Questionnaire Responses – Technical Data

TRRC Operator ID	Field Survey ID	Lease Operator	Station Name or Designation	No. of Wells At Station	Age of Oldest Well at Station	Typical Line Pressure		Annual Station Gas Production (MMscf/yr)	Number of Compressors at station		Total Engine hp at Station
						Inlet (psig)	Peak Outlet (psig)		Total #	Leased	
168720		Collins Resources, Inc.	n/a	1	25	30	700	77331	1	1	50
467255		Kingwood Resources, Inc.	Cuba Alexander #1	1	unknown	100	900	60	1	0	30
743215	49A	Sage Energy Company	Ramsey B-12	1	21	900	1000	0	1	0	150
003125a	39A	Abraxas Petroleum Corporation	Wagner Gas Unit	1	27	200	820	8.57	1	1	230
003125b	40A	Abraxas Petroleum Corporation	Yoakum Central / Kuester #1H	6	7	100	850	915.5	1	1	1265
027200a		Apache Corporation	McFaddin A Station	14	40	6	460	678535	1	0	800
027200b	42A	Apache Corporation	Gun Point Station	5	20	75	850	148190	2	0	640
040798a		BP America Production Co.	Garrett	18	24	60	485	1700	1	0	750
040798b		BP America Production Co.	Branch	13	24	40		500	1	0	1000
053974c		Basa Resources, Inc.	South Carthage CCF	11	20	20	85	900	1	0	896
148113a	22A	Chevron USA, Inc.	Pruitt Hamilton 1, 2 & 3	3	9	150	750	413	1	0	180
148113b	23A	Chevron USA, Inc.	Blankenship #21	1	25	25	140	54	1	1	50
148113c	24A	Chevron USA, Inc.	Beall - Norman 4	1	29	25	140	68	1	1	68
195834a		Cypress Operating, Inc.	Shiloh CP	11	30	17	600	328500	1	1	600
195903a	57A	Cypress E & P Corp	Rosenbaum Battery	2	1.5 yrs	75-90	675	400	1	1	150
195903b	58A	Cypress E & P Corp	Hitch Battery	1	1.0 yrs	100-400	780	65	1	1	95
224852a		Double Eagle Petroleum Corp.	Stroud	1	24	50	400	25	1	1	40
245649a	36A	EEX Operating, L.P.	E.T. Newhouse	2	3	275	600	285	1	1	115
245649b	37A	EEX Operating, L.P.	F.W. Newhouse	2	3	180	620	203	1	1	140
245649c	38A	EEX Operating, L.P.	NPC Comp	2	4	100	620	220	1	1	180
245649d	43A	EEX Operating, L.P.	Mott Slough Comp	2	4	70	650	475	1	1	525
245649e	44A	EEX Operating, L.P.	Lost Fork Booster	2	4	60	655	365	1	1	250
245649f	45A	EEX Operating, L.P.	Forgason Comp	2	3	350	985	228	1	1	140
252131a		Enervest Operating, LLC	Compressor Station	14	57	42	960	762.8	1	1	950
255130a	59A	Etoco Incorporated	State of Texas Unit	1	4	25	950	81.6	1	1	82
334135a	13A	Grigsby Petroleum Inc.	SL Davis #1	1	-	50	500	20	1	1	50

Table B-1. Summary of Questionnaire Responses – Technical Data (Continued)

TRRC Operator ID	Field Survey ID	Lease Operator	Station Name or Designation	No. of Wells At Station	Age of Oldest Well at Station	Typical Line Pressure		Annual Station Gas Production (MMscf/yr)	Number of Compressors at station		Total Engine hp at Station
						Inlet (psig)	Peak Outlet (psig)		Total #	Leased	
334135b	14A	Grigsby Petroleum Inc.	SL Davis #2	1	3	50	500	97	1	1	149
334135c	15A	Grigsby Petroleum Inc.	SL Davis #3	1	1	50	500	186	1	1	150
350200a	50A	Hamman Oil & Refg. Co.	Krenek Compressor	2	2	35	700	1018	1	1	500
386310a	60A,B,C	Hilcorp Energy Company	BRLD	7	50	18	350	3402348	3	3	4434
386310b	61A,B,C	Hilcorp Energy Company	East	8	50	18	350	3510338	3	3	4020
386310c	62A	Hilcorp Energy Company	#237	1	5	5	75	1446399	1	1	650
411739a	46A	Dan A. Hughes Company	Ilse Miller	1	18	35	635	92	1	1	120
411739b	47A	Dan A. Hughes Company	St. John Catholic Church	1	7	105	635	200	1	1	100
411739c	48A	Dan A. Hughes Company	Naiser-Stovall	1	7	shut down	shut down	35	1	1	110
450175a	51A	Kaiser-Francis Oil Company	Kubala #1	1	2	60	645	106.8	1	0	80
450175b	52A	Kaiser-Francis Oil Company	Roades #1	1	6	150	710	48.5	1	0	140
450175c	53A	Kaiser-Francis Oil Company	Fucik #2	1	2	80	170	119.2	1	0	80
480882a		Lacy Operations, Ltd.	North Panola Station	75	62	30	500	3439	5	1	3507
495689a	16A	Lehnertz-Faulkner, Inc.	Lehnertz	3	30	50	800	72	1	1	80
495689b	17A	Lehnertz-Faulkner, Inc.	Hunt-Bennet	2	60	30	250	100	1	1	45
495689c	18A	Lehnertz-Faulkner, Inc.	Alford #1	1	60	10	250	100	1	1	25
507585a	7A	The Long Trusts	Marwil	1	20	150	750	36.5	1	0	
507585b	8A	The Long Trusts	Hewes	4	20	200	750	365	1	0	
507585c	9A	The Long Trusts	SS Laird	5	20	150	750	557	1	0	
521516a	33A	Magnum Producing & Operating Co.	West #1	1	4 yrs	150	900	100	1	1	60
521516b	34A	Magnum Producing & Operating Co.	Vienna Station	2	60	60	950	35	1	0	50
521516c	35A	Magnum Producing & Operating Co.	Labay #2	1	8	70	1100	10	1	1	26
572550a		Mobil Producing TX & NM, Inc.	Northword	40	27	270-300	1150	3125484	3	0	2595
572550b		Mobil Producing TX & NM, Inc.	Randow-Hoffer	8	27	32	340	769508	1	1	615
572550c		Mobil Producing TX & NM, Inc.	Smolik	19	27	45	330	1908481	1	1	1000
592650a	32A	Mueller Exploration, Inc.	Central Facility	4	6	90	850	190610	2	2	230

Table B-1. Summary of Questionnaire Responses – Technical Data (Continued)

TRRC Operator ID	Field Survey ID	Lease Operator	Station Name or Designation	No. of Wells At Station	Age of Oldest Well at Station	Typical Line Pressure		Annual Station Gas Production (MMscf/yr)	Number of Compressors at station		Total Engine hp at Station
						Inlet (psig)	Peak Outlet (psig)		Total #	Leased	
606617a	10A	Newfield Exploration Company	Pellham Comp	2	7	60	420	256	1	1	180
606617b	11A	Newfield Exploration Company	Adams Comp	4	15	60	600	300	1	1	180
606617c	12A	Newfield Exploration Company	Burton-Minor	12	25	120	700	1278	1	1	550
617512a	19A	O'Benco, Inc.	SE Carthage	3	70	17	650	85141	1	1	68
617512b	20A	O'Benco, Inc.	SE Carthage	1	25	200	650	77304	1	1	68
617512c	21A	O'Benco, Inc.	SE Carthage	7	60	5	450	3968	1	1	150
618230a		Odegard Energy, Inc.	Clark	1	<1	50	550		1	1	
618230b		Odegard Energy, Inc.	Jordan/Wedgeworth	2	<1	50	600	200	1	1	200
618230c		Odegard Energy, Inc.	Brooks	3	3	60	600	300	1	1	
629887a	54A	Owl Creek Production Co., Inc.	Kuehnle Central	5	18	60	750	94	1	1	225
629887b	55A	Owl Creek Production Co., Inc.	Popp #2	1	10	60	750	47	1	1	65
629887c	56A	Owl Creek Production Co., Inc.	Popp #3	1	8	60	750	47	1	1	95
636222a		Palmer Petroleum, Inc.	Laird A	24	23	140-150	600	1490	1	1	950
636222b		Palmer Petroleum, Inc.	Laird B	8	23	100	900	406	1	1	700
636222c		Palmer Petroleum, Inc.	Edom	6	3	110	900	630	1	1	925
683890a	3A	PXP Gulf Coast Inc.	Tompkins #8	9	2	160	450	40	1	1	600
683890b	1A	PXP Gulf Coast Inc.	Mayo Williams	7	24	50	450	42	1	1	400
683890c	2A	PXP Gulf Coast Inc.	Crawford / Tompkins	19	22	70	450	19	1	1	600
741923a	31A	Sabco Operating Company	Borchers	10	30	30	960	110	1	1	145
862520a		Torch Energy Services, Inc.	Merritt Tank Battery	3		60	700	96.3	1	1	125
862520b		Torch Energy Services, Inc.	Weiner-Rudman	25		70	800	1046	1	1	800
862520c		Torch Energy Services, Inc.	Pepper	3		60	360	203.1	1	1	145
881167a	28A	Valence Operating Co.	Leon Barnes	1	20	45	610	12	1	1	26
881167b	29A	Valence Operating Co.	McCollum	1	25	45	800	30	1	1	43
881167c	4A	Valence Operating Co.	Hedge	3	6	75	1000	150	3	1	180
881167d	6A	Valence Operating Co.	Senesac	4	10	30	800	180	1	1	250
881167e	5A	Valence Operating Co.	Rainwater	1	10	65	900	20	1	1	42

Table B-1. Summary of Questionnaire Responses – Technical Data (Continued)

TRRC Operator ID	Field Survey ID	Lease Operator	Station Name or Designation	No. of Wells At Station	Age of Oldest Well at Station	Typical Line Pressure		Annual Station Gas Production (MMscf/yr)	Number of Compressors at station		Total Engine hp at Station
						Inlet (psig)	Peak Outlet (psig)		Total #	Leased	
889600a	41A	Wadi Petroleum, Inc.	Barre #2	1	1 yr	45	900	16.5	1	1	45
920478a	30A	Whiting Oil & Gas Corporation	Holyfield	4	12	40	1000	110	1	1	195
920478b		Whiting Oil & Gas Corporation	Crain #1	1	1977	25	750	15	1	1	145
931352a	25A	Winchester Production Company	Chadwick #1	6	5	60	650	730	1	1	530
931352b	26A	Winchester Production Company	Burnett #4	6	3	20	280	912	1	1	500
931352c	27A	Winchester Production Company	Morelock/Johnson	5	7	30	600	200	1	1	345

Table B-2. Summary of Questionnaire Responses – Site Data

TRRC Operator ID	Gas Field Name	Lease Name	Lease Number	General Station Location	County	TRRC District
168720	Anna Barre	MLM Smith	111795	5 mi Thomaston	Dewitt	2
467255	Pod (Cotton Valley)	Cuba Alexander #1	081249	Henderson	Rusk	6
743215	Lochridge	Ramsey Prison Farm	17186	6 mi W of Rosharon	Brazoria	3
003125a	Kawitt (Edwards)	Wagner Gas Unit	072897	1 mi NE of Nordheim	Dewitt	2
003125b	Yoakum (Edwards)	Kuester Gas Unit #1H	162215	3 mi S of Yoakum	Dewitt	2
027200a	Kay Creek	McFaddin A	07533	McFaddin	Victoria	2
027200b	Gun Point	Sager		Arneckville	Dewitt	2
040798a	Oak Hill (Cotton Valley)	Collie Garrett	114675	Tatum	Rusk	6
040798b	Oak Hill (Cotton Valley)	William Bassett		Henderson	Rusk	6
053974c	Carthage	Ocie Glaspie		Carthage	Panola	6
148113a	Carthage (Cotton Valley)	Pruitt Hamilton	160670, 201716, 205333	Beckville	Panola	6
148113b	Carthage Lower Petit	Blankenship	184730	Beckville	Panola	6
148113c	Carthage Pettit Lower Zone	Beall - Norman	183026	Beckville	Panola	6
195834a	Shiloh	Common Point	1	2 mi NE of Minden	Rusk	6
195903a	N. Beasley (Cook Mountain)	Rosenbaum-Suiter at al Gas Unit	199380	6.2 mi W of Rosenberg	Fort Bend	3
195903b	Rosenberg (Yegua 8120)	Hitch-May et al Gas Unit	200348	4.3 mi SW of Rosenberg	Fort Bend	3
224852a	Deberry	Stroud	X	Deberry	Panola	6
245649a	Provident City	E.T. Newhouse	1	Speaks	Lavaca	2
245649b	Provident City	F.W. Newhouse	8	Speaks	Lavaca	2
245649c	N. Provident City	NPC	2	Speaks	Lavaca	2
245649d	Mott Slough	Naiser	1	El Campo	Wharton	3
245649e	Lost Fork	Fenner	1	El Campo	Wharton	3
245649f	Caney Creek	Forgason	4	Wharton	Wharton	3
252131a	Alibel	Chocolate Bayou	00655	ENE of Alvin approx 5 mi	Brazoria	3
255130a	Sralla Road (Yegua)	State of Texas Deep Unit	24007	1.65 mi W of Highland	Fort Bend	3
334135a	Carthage (Cotton Valley)	SL Davis	092864	Clayton	Panola	6
334135b	Carthage (Cotton Valley)	SL Davis	186992	Clayton	Panola	6
334135c	Carthage (Cotton Valley)	SL Davis	200746	Clayton	Panola	6
350200a	Cooley	Frank Krenek	195280, 202536	Orchard	Fort Bend	3

Table B-2. Summary of Questionnaire Responses – Site Data (Continued)

TRRC Operator ID	Gas Field Name	Lease Name	Lease Number	General Station Location	County	TRRC District
386310a	Old Ocean	Old Ocean Unit		Old Ocean	Brazoria	3
386310b	Old Ocean	Old Ocean Unit		Sweeny	Brazoria	3
386310c	Old Ocean	Old Ocean Unit		Sweeny	Brazoria	3
411739a	Stimmel (Outlar)	Ilse Miller #2	125668	New Taiton	Wharton	3
411739b	Mott Slough (Yegua)	St. John #1	168100	New Taiton	Wharton	3
411739c	Chitland Creek (Yegua 7770)	Naiser-Stovall #1	168196	New Taiton	Wharton	3
450175a	Jones Creek	Kubala #1	180675	El Campo	Wharton	3
450175b	Jones Creek N.	Roades	175109	El Campo	Wharton	3
450175c	Jones Creek	Fucik, George F.	194634	El Campo	Wharton	3
480882a	Carthage (Cotton Valley)			Beckville	Panola	6
495689a	L.C.G. (Page), Darco (CV)	Susan Harris, Hazel Brown		Marshall	Rusk	6
495689b	Henderson, Pettit	Hunt #1, Bennet #1		Henderson	Rusk	6
495689c	Oak Hill S. (Travis Peak)	Alford		Henderson	Rusk	6
507585a	Oak Hill (Cotton Valley)	Marwil	111887	Henderson	Rusk	6
507585b	Oak Hill (Cotton Valley)	Hewes		Tatum	Rusk	6
507585c	Oak Hill (Cotton Valley)	SS Laird		Tatum	Rusk	6
521516a	Vienna	West Lease	187890	Sheridan	Lavaca	2
521516b	Vienna	Vienna	089385	Sheridan	Lavaca	2
521516c	Vienna	Labay Lease	184619	Speaks	Lavaca	2
572550a	Word, N. Word, Hallettsville			Hallettsville	Lavaca	2
572550b	N. Word, Hallettsville			Hallettsville	Lavaca	2
572550c	Word, N. Word			Hallettsville	Lavaca	2
592650a	Joseph P. Mueller	Castellow	184403 & 184656	Sublime	Lavaca	2
606617a	Carthage	Pellham G.U. 1	1	Beckville	Rusk	6
606617b	Carthage	Adams G.U. 1	2	Beckville	Rusk	6
606617c	Oakhill	Burton, Bertha GU 1	3	Kilgore	Rusk	6
617512a	Carthage	Wright Twomey	166997	Old Center	Panola	6
617512b	Carthage	Joe Soaps	193884	Old Center	Panola	6
617512c	Carthage	Biggs	029923	Deadwood	Panola	6
618230a	SE Pinehill (Lo. Petit)	Clark	014350	Pinehill	Panola	6

Table B-2. Summary of Questionnaire Responses – Site Data (Continued)

TRRC Operator ID	Gas Field Name	Lease Name	Lease Number	General Station Location	County	TRRC District
618230b	S. Carthage (Cotton Valley)	Wedgeworth	205278	Dotson	Panola	6
618230c	Beckville (Travis Peak)	Brooks	187611	Fairplay	Panola	6
629887a	El Campo (Yegua)	Kuehnle #4	196721	1 mi east of El Campo	Wharton	3
629887b	El Campo (Yegua)	E.J. Popp #2	163990	1 mi east of El Campo	Wharton	3
629887c	El Campo (Yegua)	E.J. Popp #3	176386	1 mi east of El Campo	Wharton	3
636222a	Oakhill	Faircloth	1	Kilgore	Rusk	6
636222b	Oakhill	Laird	B-3	Kilgore	Rusk	6
636222c	Edom	N/A	N/A	Van	Rusk	6
683890a	Beckville	Tompkins #8	192896	Beckville	Panola	6
683890b	Beckville	Mayo Williams #1	148124	Beckville	Panola	6
683890c	Beckville	Crawford #1	142706	Beckville	Panola	6
741923a	Borchers	Borchers	148640	Yoakum	Lavaca	2
862520a	Oak Hill	Merritt		Tatum	Rusk	6
862520b	Tatum North	Rudman		Tatum	Rusk	6
862520c	Oak Hill	EH Pepper		Tatum	Rusk	6
881167a	Jansky	Leon Barnes	077826	Halletsville	Lavaca	2
881167b	Helen Gohlke	McCollum, E.L.	068157	Victoria	Victoria	2
881167c	Oak Hill (Cotton Valley)	Hedge A	181420	Henderson	Rusk	6
881167d	Oak Hill	Senesac, Nolan	183018, 14194	Tatum	Rusk	6
881167e	Oak Hill (Cotton Valley)	Rainwater A	096513	Henderson	Rusk	6
889600a	**Oil** Field Name: Anna Barre (7900)	Barre #2	08875	Cuero	Dewitt	2
920478a	Holyfield	Baass, Haidusek, Lacey	176317	Halletsville	Lavaca	2
920478b	Meyersville	Crain	075232	Yorktown	Dewitt	2
931352a	South Carthage	Chadwick	182811	Clayton	Panola	6
931352b	North Carthage	Burnett	200133	Deberry	Panola	6
931352c	North Carthage	Morelock/Johnson	Robert Johnson #5	Deberry	Panola	6

Table B-3. Summary of Questionnaire Responses – Site Contact Information

TRRC Operator ID	Contact Name	Contact Address	Contact City	Contact State	Contact Zip Code	Contact Telephone Number
168720	JW Collins	1530 The 600 Bldg	Corpus Chrsti	TX	78473	(361) 882-4404
467255	Joe Gozano	PO Box 5321	Humble	TX	77325-5321	(832) 928-7886
743215	Theresia Smith, CEG, Inc.	100 NE Loop 410, Suite 1300	San Antonio	TX	78216	(281) 872-9300
003125a	Kenny Johnson	PO Box 701007	San Antonio	TX	78270-1007	(210) 490-4788 x 109
003125b	Kenny Johnson	PO Box 701007	San Antonio	TX	78270-1007	(210) 490-4788 x 109
027200a	Calvin Canamore	2000 Post Oak Blvd, Suite 100	Houston	TX	77056-4400	(361) 584-3090
027200b	Calvin Canamore	2000 Post Oak Blvd, Suite 100	Houston	TX	77056-4400	(361) 584-3090
040798a	Michael Sitton	PO Box 3092	Houston	TX	77253	(903) 297-4006
040798b	Michael Sitton	PO Box 3092	Houston	TX	77253	(903) 297-4006
053974c	n/a	4333 N Central Expressway	Dallas	TX	75205	(214) 559-4200
148113a	Blake C. Rhoden	PO Box 36366	Houston	TX	77236	(281) 561-4833
148113b	Blake C. Rhoden	PO Box 36366	Houston	TX	77236	(281) 561-4833
148113c	Blake C. Rhoden	PO Box 36366	Houston	TX	77236	(281) 561-4833
195834a	Ronnie Ebarb	330 Marshall Street, Suite 930	Shreveport	LA	71101	(318) 424-2031 x108
195903a	Donald J. Pfau	12777 Jones Road, Suite 335	Houston	TX	77070	(281) 955-8595
195903b	Donald J. Pfau	12777 Jones Road, Suite 335	Houston	TX	77070	(281) 955-8595
224852a	Jeffrey T. Wilson	11600 German Pines	Evansville	IN	47725	(812) 867-1433
245649a	Lucas Kreitz	363 N Sam Houston Pkwy E	Houston	TX	77060	(361) 935-0465
245649b	Lucas Kreitz	363 N Sam Houston Pkwy E	Houston	TX	77060	(361) 935-0465
245649c	Lucas Kreitz	363 N Sam Houston Pkwy E	Houston	TX	77060	(361) 935-0465
245649d	Lucas Kreitz	363 N Sam Houston Pkwy E	Houston	TX	77060	(361) 935-0465
245649e	Lucas Kreitz	363 N Sam Houston Pkwy E	Houston	TX	77060	(361) 935-0465
245649f	Lucas Kreitz	363 N Sam Houston Pkwy E	Houston	TX	77060	(361) 935-0465
252131a	Elroy L. Ardoin	1001 Fannin Street, Suite 800	Houston	TX	77002	(713) 495-6523
255130a	John Shives	1600 Smith St, Suite 3910	Houston	TX	77002-7348	(713) 654-5010
334135a	Terry Watson	333 Texas Street, Suite 2285	Shreveport	LA	71101	(318) 425-5306
334135b	Terry Watson	333 Texas Street, Suite 2285	Shreveport	LA	71101	(318) 425-5306
334135c	Terry Watson	333 Texas Street, Suite 2285	Shreveport	LA	71101	(318) 425-5306
350200a	Bill Goodwin	PO Box 13028	Houston	TX	77219	(713) 526-7417
386310a	Michael Schoch	PO Box 61229	Houston	TX	77208-1229	(713) 209-2416

Table B-3. Summary of Questionnaire Responses – Site Contact Information (Continued)

TRRC Operator ID	Contact Name	Contact Address	Contact City	Contact State	Contact Zip Code	Contact Telephone Number
386310b	Michael Schoch	PO Box 61229	Houston	TX	77208-1229	(713) 209-2416
386310c	Michael Schoch	PO Box 61229	Houston	TX	77208-1229	(713) 209-2416
411739a	W.E. Horton	PO Drawer 669	Beeville	TX	78104-0669	(361) 358-3782 x 128
411739b	W.E. Horton	PO Drawer 669	Beeville	TX	78104-0669	(361) 358-3782 x 128
411739c	W.E. Horton	PO Drawer 669	Beeville	TX	78104-0669	(361) 358-3782 x 128
450175a	Charles Lock	PO Box 21468	Tulsa	OK	74121-1468	(918) 491-4337
450175b	Charles Lock	PO Box 21468	Tulsa	OK	74121-1468	(918) 491-4337
450175c	Charles Lock	PO Box 21468	Tulsa	OK	74121-1468	(918) 491-4337
480882a	Tim Maggard	PO Box 2146	Longview	TX	75606	(903) 758-8276
495689a	Bruce C. Faulkner	121 S Broadway Ave, Suite 514	Tyler	TX	75702	(903) 592-3311
495689b	Bruce C. Faulkner	121 S Broadway Ave, Suite 514	Tyler	TX	75702	(903) 592-3311
495689c	Bruce C. Faulkner	121 S Broadway Ave, Suite 514	Tyler	TX	75702	(903) 592-3311
507585a	Donnie Jones	PO Box 3096	Kilgore	TX	75663	(903) 984-5017
507585b	Donnie Jones	PO Box 3096	Kilgore	TX	75663	(903) 984-5017
507585c	Donnie Jones	PO Box 3096	Kilgore	TX	75663	(903) 984-5017
521516a	Rajan Ahuja	500 N Shoreline, Suite 322	Corpus Chrsti	TX	78471	(361) 882-3858 x104
521516b	Rajan Ahuja	500 N Shoreline, Suite 322	Corpus Chrsti	TX	78471	(361) 882-3858 x104
521516c	Rajan Ahuja	500 N Shoreline, Suite 322	Corpus Chrsti	TX	78471	(361) 882-3858 x104
572550a	n/a	PO Box 4358	Houston	TX	77210-4358	(281) 654-1244
572550b	n/a	PO Box 4358	Houston	TX	77210-4358	(281) 654-1244
572550c	n/a	PO Box 4358	Houston	TX	77210-4358	(281) 654-1244
592650a	n/a	719 S Shoreline, Suite 600	Corpus Christi	TX	78401	(361) 882-7888
606617a	Chris Mabie	363 N Sam Houston Pkwy E	Houston	TX	77060	(337) 278-9050
606617b	Chris Mabie	363 N Sam Houston Pkwy E	Houston	TX	77060	(337) 278-9050
606617c	Chris Mabie	363 N Sam Houston Pkwy E	Houston	TX	77060	(337) 278-9050
617512a	Steve Harris	PO Box 6149	Shreveport	TX	71136-6149	(318) 865-8568
617512b	Steve Harris	PO Box 6149	Shreveport	TX	71136-6149	(318) 865-8568
617512c	Steve Harris	PO Box 6149	Shreveport	TX	71136-6149	(318) 865-8568
618230a	Christopher Long	2400 Augusta, Suite 212	Houston	TX	77057	(713) 273-4175
618230b	Christopher Long	2400 Augusta, Suite 212	Houston	TX	77057	(713) 273-4175

Table B-3. Summary of Questionnaire Responses – Site Contact Information (Continued)

TRRC Operator ID	Contact Name	Contact Address	Contact City	Contact State	Contact Zip Code	Contact Telephone Number
618230c	Christopher Long	2400 Augusta, Suite 212	Houston	TX	77057	(713) 273-4175
629887a	Ed Ermis	4265 San Felipe, Suite 740	Houston	TX	77027	(979) 332-7716
629887b	Ed Ermis	4265 San Felipe, Suite 740	Houston	TX	77027	(979) 332-7716
629887c	Ed Ermis	4265 San Felipe, Suite 740	Houston	TX	77027	(979) 332-7716
636222a	Terry Valentine	Louisiana Tower 401 Edwards Suite 1400	Shreveport	LA	71101	(318) 222-0517 x 251
636222b	Terry Valentine	Louisiana Tower 401 Edwards Suite 1400	Shreveport	LA	71101	(318) 222-0517 x 251
636222c	Terry Valentine	Louisiana Tower 401 Edwards Suite 1400	Shreveport	LA	71101	(318) 222-0517 x 251
683890a	Dale Roberts	1021 Main Street, Suite 2100	Houston	TX	77002	(903) 680-2202
683890b	Dale Roberts	1021 Main Street, Suite 2100	Houston	TX	77002	(903) 680-2202
683890c	Dale Roberts	1021 Main Street, Suite 2100	Houston	TX	77002	(903) 680-2202
741923a	Rob Pennington	1360 Post Oak Blvd, Suite 2300	Houston	TX	77056	(713) 840-1980 x30
862520a	Dwight D. Serrett	1221 Lamar, Suite 1175	Houston	TX	77010-3051	(713) 756-1621
862520b	Dwight D. Serrett	1221 Lamar, Suite 1175	Houston	TX	77010-3051	(713) 756-1621
862520c	Dwight D. Serrett	1221 Lamar, Suite 1175	Houston	TX	77010-3051	(713) 756-1621
881167a	Jim Sizer	600 Rockmead Dr, Suite 200	Humble	TX	77339-2111	(832) 644-6134
881167b	Jim Sizer	600 Rockmead Dr, Suite 200	Humble	TX	77339-2111	(832) 644-6134
881167c	Jim Sizer	600 Rockmead Dr, Suite 200	Humble	TX	77339-2111	(832) 644-6134
881167d	Jim Sizer	600 Rockmead Dr, Suite 200	Humble	TX	77339-2111	(832) 644-6134
881167e	Jim Sizer	600 Rockmead Dr, Suite 200	Humble	TX	77339-2111	(832) 644-6134
889600a	Ed Riddle,	14405 Walters Rd, Suite 400	Houston	TX	77014	(281) 583-2888
920478a	Richard Fromm, Jack Brown	1700 Broadway, Suite 2300	Denver	CO	80290-2301	(303) 837-1661
920478b	Richard Fromm, Jack Brown	1700 Broadway, Suite 2300	Denver	CO	80290-2301	(303) 837-1661
931352a	Frank Flowers	6007 Financial Plaza, Suite 300	Shreveport	LA	71129	(318) 510-1660
931352b	Frank Flowers	6007 Financial Plaza, Suite 300	Shreveport	LA	71129	(318) 510-1660
931352c	Frank Flowers	6007 Financial Plaza, Suite 300	Shreveport	LA	71129	(318) 510-1660

APPENDIX C

Sample Field Survey Form

Sample Field Survey Form

ERG Survey ID _______________ Questionnaire ID ____________ Page __ of __

Operator ____

Station name ____

Latitude ____________________________ Longitude ___________________________

Site Contact Name _____________________email ______________________________

Phone numbers ____________________________ , _____________________________

TRRC District _________ County _________________

Lease Names and Numbers served by Station:___________________________________

Number of compressors at this station ______ Number of wells at this station ______

Permit types: Std TCEQ Permit / permit-by-rule (Std Exemption) / none

Diagram of well & compressor configuration, transmission distances, and pipe diameters.
Indicate all well ID#s and compressor ID#s

ERG Survey ID _____________ Questionnaire ID _______________ Page __ of __

Company Compressor ID # ________________ ERG Compressor ID_____________

2004 Throughput (MMscf) _________________

	Today	Summer	Winter
Inlet Pressure (psig)			
Discharge Pressure (psig)			
Flowrate (Mscf/min)			

Operating Schedule (hours or months per year)_________________________________

Engine

Mfg. ____ Leased (yes/no)

Model _________________________ Serial Number____________________________

Rated Capacity (hp) ____________ Speed (rpm) ____________ Year Mfg. _________

Integral Engine (yes/no) Type (Lean/Rich Burn) Fuels ___________________

Turbocharger (yes/no) PSC (yes/no) controls (SCR, NSCR, none)

	Today	Summer	Winter
Actual load (bhp)			
Fuel Consumption (scfm)			

Describe any available emission data and who is the contact for the data:

____

____

____

____

____.

ERG Survey ID _________ Questionnaire ID ______ Page __ of __

Gas Field Name ____

Lease Name and Number ____

TRRC Well ID # _______________________ ERG Well ID ______________________

Gas Production – Net to compressors (MMscf) Bypassing Compressors (yes/no)

Annual	June	July	August

TRRC Well ID # ___________________ ERG Well ID __________________

Gas Production – Net to compressors (MMscf) Bypassing Compressors (yes/no)

Annual	June	July	August

TRRC Well ID # ___________________ ERG Well ID __________________

Gas Production – Net to compressors (MMscf) Bypassing Compressors (yes/no)

Annual	June	July	August

TRRC Well ID # ___________________ ERG Well ID __________________

Gas Production – Net to compressors (MMscf) Bypassing Compressors (yes/no)

Annual	June	July	August

TRRC Well ID # ___________________ ERG Well ID __________________

Gas Production – Net to compressors (MMscf) Bypassing Compressors (yes/no)

Annual	June	July	August

APPENDIX D

Field Survey Database

FIELD SURVEY DATABASE

The bold values in Tables D-1 and D-2 were estimated based on information provided by the site.

Table D-1. Compressor Data

Site ID	Comp. ID:	Comp. Line Diam. Suction (in.)	Comp. Line Diam. Discharge (in.)	Today's Pressure Inlet (psig)	Today's Pressure Discharge (psig)	Yesterday's Flowrate (mscf/d)	Typical Values Inlet (psig)	Typical Values Discharge (psig)	Typical Values Flowrate (mcf/d)	Maint. Sched. Hours	Maint. Sched. Cycle
1	1A	3"	3"	50	**480**	1404	50	430-530		2	month
2	2A	4"	4"	**42.5**	**500**	3033	40-45	450-550		2	3 mo
3	3A	4"	4"	150	464	2928	150	400-500	3000	2	3 mo
4	4A	2"	2"	70	925	502			500	2	3 mo
5	5A	2"	2"	35	950	104.2				4	3 mo
6	6A	2"	2"	30	820	718				4	3 mo
7	7A	2"	2"	120	655					3	month
8	8A	2"	2"	200	700					3	month
9	9A	2"	2"	110	330					3	month
10	10A	3"	2"	60	660	650				2	month
11	11A	3"	2"	60	600	750				4	month
12	12A	3"	2"	110	700	**1550**			1200-1900	4	month
13	13A	2"	2"	80	480	85				4	month
14	14A	2"	2"	30	485	**280**			280	few	month
15	15A	2"	2"	40	500	**380**			380	1	month
16	16A	2"	2"	65	700	220				1 to 4	month
17	17A	2"	2"	**30**	**215**	153	30	180-250	168	1 to 4	month
18	18A	2"	2"	17	260	192			194	1 to 4	month
19	19A	2"	2"	19	140	**338**			325-350	4	month
20	20A	2"	2"	180	590	400				4	month
21	21A	2"	2"	22	220	262			260-280	4	month
22	22A	3"	3"	183	700	547			681	2 to 4	2 mo
23	23A	2"	2"	35	125	119				2 to 4	1.5 mo
24	24A	4"	3"	19	115	220			206	2 to 4	1.5 mo
25	25A	3"	3"	50	600	2140			2213	few	as need
26	26A	2"	2"	40	275	2099			2217	few	as need
27	27A	2"	2"	18.5	560	296	27	600	380	few	as need
	Avg for Dist 6 ->			**69**	**509**						
	StdDev ->			**55**	**236**						
28	28A	2"	2"	45	800	45		450-500	15-25	1	month
29	29A	2"	2"	26	860	100				few	month
30	30A	2"	2"	20	1050	350				few	month
31	31A	2"	2"	18	795	**280**			260-300	few	3 mo
32	32A	2"	2"	80	790	385				few	month
33	33A	2"	2"	255	629	499			560	1 to 2	month
34	34A	2"	2"	90	775	**165**			160-170	few	month
35	35A	2"	2"	84	1100	60				few	month
36	36A	3"	2"	275	600	770				2	month
37	37A	3"	3"	188	600	**518**			510-525	2	month
38	38A	3	3	120	850	815				few	month
39	39A	2"	2"	**40**	**900**	**500**	40	900	500	few	month
40	40A	4"	4"	27	850	3500				few	month
41	41A	2"	2"	**45**	**900**	**45**	45	900	45		
42	42A	4"	2"	70	900	**1400**			1400	4	3 mo
	Avg for Dist 2 ->			**92**	**827**						
	StdDev ->			**83**	**144**						

Table D-1. Compressor Data (Continued)

Site ID	Comp. ID:	Comp. Line Diam.		Today's Pressure		Yesterday's Flowrate (mscf/d)	Typical Values			Maint. Sched.	
		Suction (in.)	Discharge (in.)	Inlet (psig)	Discharge (psig)		Inlet (psig)	Discharge (psig)	Flowrate (mcf/d)	Hours	Cycle
43	43A	3"	2"	75	650	677			1200	few	month
44	44A	3"	2"	80	800	1230			1600	few	month
45	45A	4"	4"	225	900	600				few	month
46	46A	2"	2"	35	650	**333**	37		325-340	few	month
47	47A	2"	2"	100	650	540				few	month
48	48A	4"	2"	**35**	**125**	**200**	35	100-150	200	few	month
49	49A	3"	2"	45	960	425				4	month
50	50A	3"	2"	24	715	1181				few	month
51	51A	2"	2"	50	675	**293**			293	few	month
52	52A	2"	2"	270	800	**133**			133	few	month
53	53A	2"	2"	75	150	**326**			326	few	month
54	54A	2"	2"	55	680	349				2	month
55	55A	2"	2"	155	660	145				2	month
56	56A	2"	2"	230	685	130				2	month
57	57A	3	3	60	760	621			583	few	month
58	58A	2"	2"	78	720	153			168	few	month
59	59A	2"	2"	**50**	**850**	**50**	50	850	50	few	month
60	60A	8"	6"	20	300	4584				4 to 6	3 mo
60	60B	8"	6"	20	300	4564				4 to 6	3 mo
60	60C	8"	6"	20	300	4000				4 to 6	3 mo
61	61A	10"	6"	16	300	6211				4 to 6	3 mo
61	61B	10"	6"	16	300	5920				4 to 6	3 mo
61	61C	10"	6"	16	300	5847				4 to 6	3 mo
62	62A	6"	6"	5	60	2916				4 to 6	3 mo
	Avg for Dist 3 ->			**73**	**554**						
	StdDev Dist 3 ->			**74**	**268**						

Table D-2. Engine Data

Comp. ID	Engine Data										
	Manufacturer	Leased (Y/N)	Leasing Company	Model	Serial Number	Rated Capacity (hp)	Rated Speed (rpm)	Year Mfg.	Fuels	Turbochg. (Y/N)	Catalyst (Y/N)
1A	Caterpillar	Y	Star	389 TAW	-	560	1067		lease	Y	Y
2A	Caterpillar	Y	Hanover	35124 SITA	NJ00485	945	1400		lease	Y	N
3A	Waukesha I- 6	Y	Universal	F2895CSI	O-12190/1	620	1200	1996	lease	Y	Y
4A	Ajax/Cooper/Penjax	Y	Universal	16407	75011	180	250-400		lease	N	N
5A	Ajax	Y	Universal		63029	60	250-475		lease	N	N
6A	Caterpillar	Y	Universal	G3406TAW	4FD01976	325	1660	1993	lease	Y	N
7A	Caterpillar	N		RL45CD	701233	450	1500		lease	N	N
8A	Waukesha	N							lease	N	N
9A	Waukesha	N							lease	N	N
10A	Ajax/Cooper	Y	Universal	DPC-180	75865	180	250-400		lease	N	N
11A	Ajax	Y	Universal	DPC-180	81676	180	~360		lease	N	N
12A	Caterpillar	Y	Hanover	G398TA	73BHAN44	**560**	1200	2001	lease	Y	N
13A	Dorman	Y	J-W			50			lease	N	N
14A	Caterpillar	Y	J-W	3306	07Y07711	**145**			lease	N	N
15A	Caterpillar	Y	J-W	9Y7892	7703964	125	1800		lease	Y	N
16A	Caterpillar	Y	Hanover	3304	37YO3349	80	1761		lease	N	N
17A	Waukesha	Y	Hanover	VRC-220	C1037278	45	1800		lease	N	N
18A	Ford	Y	Compressco			49	1800-2000		lease	N	N
19A	Arrow Industries	Y	Lions	VRO-330		65	1500-1600		lease	N	N
20A	Arrow Industries	Y	Lions			45	1478		lease	N	N
21A	Waukesha	Y	Lions	6 WAK	1080195	125	934-1000		lease	N	N
22A	Ajax	Y	Universal	DPC-180	76613	180	250-400		lease	N	N
23A	Ariel JCS	Y	Universal	E-259	E-259	50	1000-1400		lease	N	N
24A	Waukesha	Y	Universal	VRG330	399129	68	1800	2002	lease	N	N
25A	Waukesha	Y	Universal	H24GL	C-12837/2	530	1800	1999	lease	Y	N
26A	Caterpillar	Y	Universal	398NA	13391 (?)	500	1080		lease	N	Y
27A	Ajax	Y	Mustang	DPC-230	72275	230	260-360	1980	lease	N	N

Table D-2. Engine Data (Continued)

Comp. ID	Engine Data										
	Manufacturer	Leased (Y/N)	Leasing Company	Model	Serial Number	Rated Capacity (hp)	Rated Speed (rpm)	Year Mfg.	Fuels	Turbochg. (Y/N)	Catalyst (Y/N)
28A	Gemini	Y	Universal	**G26**	5022	**26**	1600	1991	lease	N	N
29A	Caterpillar	Y	Universal	**3304**		**83**	1800		lease	N	N
30A	Caterpillar	Y	CSI	G3306	007Y05776	194	1800	2002	lease	N	N
31A	Caterpillar	Y	CSI			145	1600-1625		lease	N	N
32A	Ajax	N		DPC-115	66889	115	350		N Gas	N	N
33A	Waukesha	Y	Universal	VRG330	386260	68	1771	2002	lease	N	N
34A	Waukesha	N		VRG265	63368A (?) 1906208	35			N Gas	N	N
35A	Gemini	Y	Flat Rock	G26	E1204	26	1800		lease	N	N
36A	Ajax	Y	Hanover	DPC-115	68428	115	250-360		lease	N	N
37A	Ajax	Y	Hanover	DPC-140	80667	140	250-400		lease	N	N
38A	Ajax	Y	Hanover	DPC-180	75867	180	250-400		lease	N	N
39A	Waukesha	Y	Gaertner	F1197		**186**	1200	~1985	lease	N	N
40A	Caterpillar	Y	CSI	G3516SITA	4EK01695	1200	1170		lease	Y	N
41A	Gemini	Y	CSI	G26 MOC (frame)	E3048	26	1800	late 80's	lease	N	N
42A	Ajax	N		DPC-360	74058	360	360		N Gas	N	N
43A	Ajax	Y	Hanover	DPC 280		280	361		lease	N	N
44A	Caterpillar	Y	Hanover	JGR-2	F-2625	415	1200	1981	lease	Y	N
45A	Ajax/Cooper	Y	Hanover	DPC-140	81896	140	250-400		lease	N	N
46A	Caterpillar	Y	Gaertner	3306	07Y02027	120	1420		lease	N	N
47A	Caterpillar	Y	J-W	CA-117-2	68D2171	**100**	1500		lease	N	N
48A	Waukesha	Y	Hanover	F11G	5367241	135	1800	1998	lease	N	N
49A	Waukesha	N		F1197G		165	1066		N Gas	N	N
50A	Caterpillar	Y	Hanover	33N330	49C0273	600	1200		lease	N	N
51A	Ajax	N		DPC-80A	77920	80	200-400		N Gas	N	N
52A	Ajax	N		DPC-140	78773	140	250-400		N Gas	N	N
53A	Ajax	N		DPC-80A	73347	80	200-400		N Gas	N	N

Table D-2. Engine Data (Continued)

Comp. ID	Engine Data										
	Manufacturer	Leased (Y/N)	Leasing Company	Model	Serial Number	Rated Capacity (hp)	Rated Speed (rpm)	Year Mfg.	Fuels	Turbochg. (Y/N)	Catalyst (Y/N)
54A	Caterpillar	Y	Hanover	342		225	875		lease	N	N
55A	Waukesha	Y	Hanover	330	C799	**68**	940	1998	lease	N	N
56A	Caterpillar	Y	Hanover	37Y	415	95	945		lease	N	N
57A	Caterpillar	Y	J-W	G3306TALCR		150	1400		lease	N	N
58A	Caterpillar	Y	J-W	3304 NA HCR	37Y0377	95	1800		lease	N	N
59A	Caterpillar	Y	Universal		37Y02105	95	1800	1982	lease	N	Y
60A	Waukesha	Y	CDM	7042GL	403597	1478	1200	93-'94	N Gas	Y	Y
60B	Waukesha	Y	CDM	7042GL	399153	1478	1200	93-'94	N Gas	Y	Y
60C	Waukesha	Y	CDM	7042GL	C11090/3	1478	1200	93-'94	N Gas	Y	Y
61A	Caterpillar	Y	CDM	3516	4EK03720	1340	1400		N Gas	Y	Y
61B	Caterpillar	Y	CDM	3516	4EK03719	1340	1400		N Gas	Y	Y
61C	Caterpillar	Y	CDM	3516	4EK03832	1340	1400		N Gas	Y	Y
62A	Caterpillar	Y	CDM	3412	7DB01794	637	1700		N Gas	Y	Y

Table D-3. Comments about Compressor and Engine

Comp. ID	Comments
1A	never been tested / owned by star leasing / person who conducted site visit: Barry Pool (903) 738-2567
2A	Non-catalytic / do have emission tests at PXP Houston office / person who conducted site visit: Barry Pool (903) 738-2567
3A	Emissions tested by Universal (owner), data available from John Rosata in Houston office of PXP / 2 stage compressor / person who conducted site visit: Barry Pool (903) 738-2567
4A	No emissions tests / not known / Person who took us on site visits: Jim Bowman, mobile: (903)658-0240, office: (903)657-0698
5A	No available emissions data / person who took us on site visits: Jim Bowman, 1. (903)658-0240 2. (903)657-0698
6A	No available emissions data / person who took us on site visits: Jim Bowman, 1. (903)658-0240 2. (903)657-0698
7A	Donnie's pager (903)986-7017 / emissions testing unknown / single stage compression / person who accompanied us on our site visit: Buddy Grandstaff
8A	Available emissions data unknown / single stage compression / not able to locate nameplate / person who accompanied us on our site visit: Buddy Grandstaff
9A	Single stage / could not find nameplate / person who accompanied us on our site visit: Buddy Grandstaff
10A	Available emissions data: NOX, SOX / Ajax conducts emissions testing / 2 stage compressor / person that accompanied us on our site visit: Earl Griffin (903)983-9943
11A	No emissions testing / 2 stage compression / person that accompanied us on our site visits: Earl Griffin (903)983-9943
12A	2 stage compressor / 135 mcf/day / Person who accompanied us on site: Earl Griffin (903)983-9943
13A	Only # that could be read off of nameplate was 50 (HP?) / 2 stage compressor / person who accompanied us on our site visits: Jesse Deatin (903)930-7072
14A	2 stage compressor / emissions testing unknown / person who accompanied us on our site visits: Jesse Deatin (903)930-7072
15A	2 stage / Flow rate is estimated - did not come directly from meter / Other possible model #s are 0T9296 / person who accompanied our site visits: Jesse Deaton (903)930-7072
16A	Emission data unknown / 3 stage / other possible model #s: G3304NA also arrangement # 1029431 / person who accompanied our site visit: Bobby Tompkins (903) 918-7007
17A	no testing / one stage compressor / other #s that could be the model #: FAS0004 / person who accompanied us on site visits: Bobby Tompkins (903) 918-2007
18A	assume no testing / one stage compression / person who accompanied us on site visits: Bobby Tompkins (903) 918-2007
19A	Available emissions data unknown / engines are estimated to be ~30yrs or older / 2 stage compressor / person who took us on site visits: Bobby Hales (318)465-1788/6788
20A	Available emissions data unknown / 2 stage compression / Engine estimated to be ~30 yrs or older / person who took us on site visits: Bobby Hales (318) 465-1788/6788
21A	engines are estimated to be ~30 years or older / person who took us on site visits: Bobby Hales (318)465-1788/6788
22A	No testing / 2 cycle - 1 cylinder / 2 stage compression / yesterday's flow reported under summer
23A	No testing / 2 stage compression
24A	No testing / 2 stage compressor / yesterday's flow reported under summer
25A	No testing - Universal would be responsible / 3 stage compressor
26A	unknown / 2 stage compression
27A	No testing / 2 stage compression

Table D-3. Comments about Compressor and Engine (Continued)

Comp. ID	Comments
28A	No testing / Person who conducted site visit: Rudy Mader (713) 248-9061
29A	No testing / person who conducted site visit: Garland Pakebush (361) 319-9144
30A	Emission testing unknown / Person who conducted site visit: Tommy Balusek (979) 541-6219
31A	No emission testing / Nameplate appears to have been removed / Rob Pennington requested copy of report sent to him @ 1360 Post Oak Blvd. Suite 2300, Houston, Tx 77056
32A	No testing / there are 2 compressors onsite but 1 is not in use / Person who conducted site visit: Felix Kuban
33A	No testing / person who conducted site visit: Daryl Bludau (361) 798-6194
34A	No nameplate - took 2#s directly off engine - model number IS correct / person who conducted site visit: Daryl Bludau (361) 798-6194
35A	No testing / person who conducted site visit: Daryl Bludau (361) 798-6194
36A	No testing / person who conducted site visit: Daryl Bludau (361) 798-6194
37A	No testing / person who conducted site visit: Daryl Bludau (361) 798-6194
38A	No testing / person who conducted site visit: Daryl Bludau (361) 798-6194
39A	engine down for the day/ No testing / Gaertner Leasing phone # (361) 289-2894 Ask for Robert / person who conducted site visit: Mike Burn (361) 319-8495
40A	Emissions testing every 15,000 hrs / person who conducted site visit: Mike Burn (361) 319-8495
41A	Unknown emissions data / compressor not running / suction & discharge pressure and flowrate came from questionnaire & confirmed with Ed Riddle via phone / unaccompanied
42A	no testing
43A	compressor has booster compressor, which boosts to 80 lbs / call Hanover @ 1-800-255-8192 for Unit # 71785 / 2 wells down today, so gas production is lower than normal
44A	Flow rate higher typically - missing 400 mcf / 1 well down, did not take down yesterday's flow because well was down
45A	No testing
46A	unknown emissions data / phone # for Gaertner Leasing: 800-272-2894, Robert Lopez / person who conducted site visit: Richard Swanson (no phone #)
47A	no testing / person who conducted site visit: Richard Swanson (no phone #)
48A	currently shut down for 5 days letting pressure build / typical flow and suction & discharge pressures estimated by Richard Swanson (person who conducted site visit)
49A	recent emissions testing by TCEQ / person who conducted site visit: Jim Adams (830) 876-6092
50A	No testing / other info on nameplate: perf spec: OT3965 and AR# 3N3340 / person who conducted site visit: Neal Marek (pumper) (bus card attached to form)
51A	information on questionnaire is correct
52A	information on questionnaire is correct
53A	information on questionnaire is correct
54A	compressor running @ 60% = 96 hp / pressures vary by ~5 psig / unit # is 70791, in case we need to call Hanover / other numbers on engine: 71B2761 & 6L2996
55A	no emissions testing / only using 28hp
56A	no emissions testing / only using 28hp

Table D-3. Comments about Compressor and Engine (Continued)

Comp. ID	Comments
57A	no testing / could not find nameplate / flows were read from a meter / J.W. Operating: 1-800-475-1982
58A	not sure if serial # is correct / "arrangement # 3N4921" - is this a model #?
59A	Yes emissions testing (required) / perf spec: 0T4165, AR# 894921
60A	regular emissions testing required / all #s were read from office computer / person who conducted site visit: David Neel, (979) 490-8214, dneel@hilcorp.com
60B	regular emissions testing required / person who conducted site visit: David Neel, (979) 490-8214, dneel@hilcorp.com
60C	regular emissions testing required / compressor is shut down, all #s are approx / person who conducted site visit: David Neel, (979) 490-8214, dneel@hilcorp.com
61A	emissions testing required / person who conducted site visit: David Neel, (979) 490-8214, dneel@hilcorp.com
61B	emissions testing required / person who conducted site visit: David Neel, (979) 490-8214, dneel@hilcorp.com / AFR controllers
61C	emissions testing required / person who conducted site visit: David Neel, (979) 490-8214, dneel@hilcorp.com
62A	emissions testing required / person who conducted site visit: David Neel, (979) 490-8214, dneel@hilcorp.com

Table D-4. Site Location Data

TRRC ID	Site Survey ID	Operator	Station Name	Lat	Long
683890b	Site1	PXP Gulf Coast, Inc.	Mayo Williams #1 / Beckville Gas Field	32° 14. 008'	94° 28. 578'
683890c	Site2	PXP Gulf Coast, Inc.	Crawford #1 / Beckville Gas Field	32° 13. 839'	94° 29. 724'
683890a	Site3	PXP Gulf Coast, Inc.	Tompkins #1 / Beckville Gas Field	32° 13. 971'	94° 30. 670'
881167c	Site4	Valence Operating Co.	Hedge / Oak Hill Gas Field	32° 16. 024'	94° 41. 598'
881167e	Site5	Valence Operating Co.	Rainwater #2 / Oak Hill Gas Field	32° 15. 827'	94° 39. 178'
881167d	Site6	Valence Operating Co.	Senesac	32° 16. 974'	94° 35. 596'
507585a	Site7	The Long Trusts	Marwil #1 / Oak Hill (Cotton Valley) Gas Field	32° 14. 997'	94° 54. 311'
507585b	Site8	The Long Trusts	Rebecca Hewes / Oak Hill (Cotton Valley) Gas Field	32° 15. 547'	94° 45. 133'
507585c	Site9	The Long Trusts	Maude Laird / Oak Hill (Cotton Valley) Gas Field	32° 15. 697'	94° 40. 253'
606617a	Site10	Newfield Exploration Co.	Pelham Comp / Carthage Gas Field	32° 10. 720'	94° 30. 214'
606617b	Site11	Newfield Exploration Co.	Adams Comp	32° 11. 795'	94° 30. 177'
606617c	Site12	Newfield Exploration Co.	Burtm-Minor	32° 16. 932'	94° 45. 829'
334135a	Site13	Grigsby Petroleum	SL Davis #1	32° 05. 056'	94° 28. 998'
334135b	Site14	Grigsby Petroleum	SL Davis #2	32° 05. 093'	94° 29. 512'
334135c	Site15	Grigsby Petroleum	SL Davis #3	32° 04. 746'	94° 29. 342'
495689a	Site16	Lehnertz Faulkner, Inc.	Lehnertz/ L.C.G (Page), Darco (CV) Gas Field	32° 25. 341'	94° 23. 748'
495689b	Site17	Lehnertz Faulkner, Inc.	Hunt-Bennet	32° 13. 444'	94° 49. 980'
495689c	Site18	Lehnertz Faulkner, Inc.	Alford #1	32° 11. 090'	94° 49. 774'
617512a	Site19	O'Benco, Inc.	SE Carthage / Carthage Gas Field	32° 02. 195'	94° 11. 729'
617512b	Site20	O'Benco, Inc.	SE Carthage / Carthage Gas Field	32° 01. 113'	94° 11. 321'
617512c	Site21	O'Benco, Inc.	SE Carthage / Carthage Gas Field	32° 04. 210'	94° 08. 385'
148113a	Site22	Chevron U.S.A.	Pruitt Hamilton 1, 2, 3 / Carthage (Cotton Valley) Gas Field	32° 17. 736'	94° 26. 139'
148113b	Site23	Chevron U.S.A.	Blankenship #21 / Carthage Lower Petit Gas Field	32° 12. 698'	94° 24. 717'
148113c	Site24	Chevron U.S.A.	Beall-Norman 4 / Carthage Petit Lower Zone (Gas Field)	32° 13. 278'	94° 25. 397'
931352a	Site25	Winchester Production Co.	Chadwick	32° 04. 733'	94° 29. 703'
931352b	Site26	Winchester Production Co.	Burnett	32° 13. 866'	94° 07. 701'
931352c	Site27	Winchester Production Co.	Morelock / Johnson	32° 16. 381'	94° 09. 530'
881167a	Site28	Valence Operating Co.	Leon Barnes (Jansky Gas Field) (Wilcox 10700)	29° 28. 001'	96° 52. 759'
881167b	Site29	Valence Operating Co.	McCollum, EL #1 (Helen Gohlke gas field) (Wilcox Lo)	29° 03. 661'	97° 02. 352'

Table D-4. Site Location Data (Continued)

TRRC ID	Site Survey ID	Operator	Station Name	Lat	Long
920478a	Site30	Whiting Oil and Gas Corporation	Holyfield	29° 21. 028’	96° 49. 279’
741923a	Site31	Sabco Operating Company	Borcher	29° 09. 676’	96° 50. 192’
592650a	Site32	Mueller Exploration	Central Facility	29° 26. 744’	96° 47. 064’
521516a	Site33	Magnum Producing and Operating Co.	West #1	29° 21. 373’	96° 39. 905’
521516b	Site34	Magnum Producing and Operating Co.	Vienna	29° 22. 303’	96° 39. 248’
521516c	Site35	Magnum Producing and Operating Co.	Labay #2	29° 17. 112’	96° 41. 401’
245649a	Site36	EEX Operating Company	E.T. Newhouse	29° 21. 355’	96° 40. 304’
245649b	Site37	EEX Operating Company	F.W. Newhouse	29° 20. 181’	96° 40. 494’
245649c	Site38	EEX Operating Company	NPC Comp	29° 19. 643’	96° 36. 508’
003125a	Site39	Abraxas Petroleum Corp.	Wagner Gas Unit	28° 56. 359’	97° 36. 328’
003125b	Site40	Abraxas Petroleum Corp.	Yoakum Central / Kuester #1H	29° 14. 057’	97° 07. 688’
889600a	Site41	Wadi Petroleum	Barre #2 / Anna Barre Oil Field	28° 58. 775’	97° 13. 589’
027200b	Site42	Apache Corp	Gun Point Station	28° 59. 007’	97° 17. 053’
245649e	Site43	Newfield Exploration Co.	Mott Slough	29° 18. 634’	96° 20. 715’
245649d	Site44	Newfield Exploration Co.	Lost Fork Booster	29° 13. 422’	96° 36. 334’
245649f	Site45	Newfield Exploration Co.	Forgason	29° 22. 306’	96° 13. 150’
411739a	Site46	Dan A. Hughes Co.	Ilse Miller	29° 20. 777’	96° 16. 059’
411739b	Site47	Dan A. Hughes Co.	St. John Catholic Church	29° 18. 394’	96° 20. 386’
411739c	Site48	Dan A. Hughes Co.	Naiser-Stovall	29° 17. 495’	96° 21. 831’
743215	Site49	Sage Energy Co.	Ramsey B-12	29° 18. 968’	95° 34. 217’
350200a	Site50	Hamman Oil and Refg. Co.	Krenek Compressor	29° 37. 030’	95° 59. 744’
450175a	Site51	Kaiser-Francis Oil Co.	Kubala #1 / Jones Creek Gas Field	29° 17. 258’	96° 18. 165’
450175b	Site52	Kaiser-Francis Oil Co.	Roades #1 / Jones Creek N. Gas Field	29° 17. 942’	96° 17. 710’
450175c	Site53	Kaiser-Francis Oil Co.	Fucik #2 / Jones Creek Gas Field	29° 18. 772’	96° 18. 549’
629887a	Site54	Owl Creek Production Co.	Kuehnle Central / El Campo (Yegua) Gas Field	29° 12. 020’	96° 14. 551’
629887b	Site55	Owl Creek Production Co.	Popp #2	29° 12. 420’	96° 13. 920’
629887c	Site56	Owl Creek Production Co.	Popp #3 / El Campo (Yegua) Gas Field	29° 12. 247’	96° 14. 295’

Table D-4. Site Location Data (Continued)

TRRC ID	Site Survey ID	Operator	Station Name	Lat	Long
195903a	Site57	Cypress E&P Corp.	Rosenbaum Battery / N. Beasley (Cook Mtn.) Gas Field	29° 32. 449'	96° 53. 873'
195903b	Site58	Cypress E&P Corp.	Hitch Nattery / Rosenberg (Yegua 8120 Gas Field)	29° 31. 929'	95° 52. 222'
255130a	Site59	Etoco Inc.	State of Texas Unit / Stralla Rd. Gas Field	29° 48. 916'	95° 04. 690'
386310a	Site60	Hilcorp Energy, Inc.	BRLD	29° 02. 781'	95° 45. 087'
386310b	Site61	Hilcorp Energy, Inc.	East	29° 02. 836'	95° 44. 406'
386310c	Site62	Hilcorp Energy, Inc.	Well #237	29° 01. 935'	95° 44. 243'

Table D-5. Site Contact Data

Phone	TRRC District	County	Lease Names and Numbers	Number of Compressors at this Station	Number of Wells at this Station
(903) 680-2202	6	Panola	Mayo Williams #1, 148124	1	7
(903) 680-2202	6	Panola	Crawford #1, 142706	1	19
(903) 680-2202	6	Panola	Tompkins #8, 192896	1	9
(832) 644-6134	6	Rusk	Hedge A #1, 181420	1	3
(832) 644-6134	6	Rusk	Rainwater #2, 096513	1	1
(832) 644-6134	6	Rusk	Senesac, 183018	1	4
(903) 984-5017	6	Rusk	Marwil #1 - R	1	1
(903) 984-5017, (903) 522-0498	6	Rusk	Rebecca Hewes, 100851	1	1
(903) 984-5017, (903) 522-0498	6	Rusk	Maude Laird, 197266	1	1
(337) 278-9050	6	Rusk	Pelham Comp.	1	2
(337) 278-9050	6	Rusk	Adams Comp.	1	4
(337) 278-9050	6	Rusk	Burtm Minor	1	12
(318) 425-5306	6	Panola	SL Davis #1, 092864	1	1
(318) 425-5307	6	Panola	SL Davis #2, 186992	1	1
(318) 425-5306	6	Panola	SL Davis #3, 200746	1	1
(903) 592-3311	6	Rusk	Susan Harris, Hazel Brown	1	3
(903) 592-3311	6	Rusk	Hunt #1, Bennet #1	1	2
(903) 592-3311	6	Rusk	Alford	1	1
(318) 865-8568, (318) 422-6749	6	Panola	Wright Twomey, 166997	1	3
(318) 865-8568, (318) 422-6749	6	Panola	Joe Soaps, 193884	1	1
(318) 865-8568, (318) 422-6750	6	Panola	Briggs, 029923	1	5
(903) 754-4121	6	Panola	Pruitt Hamilton, 205333 / RCC#s 1: 160670, 2: 201716	1	3
(903) 754-4121	6	Panola	Blankenship #21, 184730	1	1
(903) 754-4121	6	Panola	Beall Norman #4, 183026	1	1
(318) 510-1660	6	Panola	Chadwick #1, 182811	1	6
(318) 510-1660	6	Panola	Burnett #4, 200133	1	7 (?)
(318) 510-1660	6	Panola	Robert Johnson #5	1	5 (?)
(832) 644-6134	2	Lavaca	Leon Barnes #1	1	1

Table D-5. Site Contact Data (Continued)

Phone	TRRC District	County	Lease Names and Numbers	Number of Compressors at this Station	Number of Wells at this Station
(832) 644-6134	2	Victoria	McCollum, EL #1, 017181	1	1
(303) 390-4239	2	Lavaca	Holyfield, 176317	1	4
(713) 840-1980 x 30	2	Lavaca	Borchers, 148640	1	10
(361) 772-5630	2	Lavaca	Castellow 184403, 184656	1	4
(361) 882-3858 x 104	2	Lavaca	West #1, 187890	1	1
(361) 882-3858 x 104	2	Lavaca	Vienna, 089385	1	2
(361) 882-3858 x 104	2	Lavaca	Labay, 184619	1	1
(361) 935-0465	2	Lavaca	E.T. Newhouse lease #1	1	2
(361) 935-0465	2	Lavaca	F.W. Newhouse lease #8	1	2
(361) 935-0465	2	Lavaca	NPC #2	1	1
(210) 490-4788	2	Dewitt	Wagner Gas Unit; well # 1h	1	1
(210) 490-4788	2	Dewitt	#1H	1	6
(361) 883-1911	2	Dewitt	Barre #2	1	1
(361) 584-3090	2	Dewitt	Sagel	2 (1 running)	5
(361) 935-0465	3	Wharton	Naiser #1	1	8
(361) 935-0465	3	Wharton	Fenner #1	1	7 (2 shut down)
(361) 935-0465	3	Wharton	Forgason #4, 185831	1	1
(361) 358-3752 x 128	3	Wharton	Ilse Miller #2, 125668	1	1
(361) 358-3752 x 128	3	Wharton	St. John #1, 168100	1	1
(361) 358-3752 x 128	3	Wharton	Naiser Stovall #1, 168196	1	1
(281) 872-9300	3	Brazoria	Ramsey Prison Farm, 17186	1	1
(713) 526-7417	3	Fort Bend	Frank Krenek, 195280, 202536	1	2
(918) 491-4337	3	Wharton	Kubala #1, 180675	1	1
(918) 491-4337	3	Wharton	Roades, 175109	1	1
(918) 491-4337	3	Wharton	Fucik, George F., 194634	1	1
(979) 543-1382	3	Wharton	Kuehnle #4, 196721	1	4
(979) 543-1382	3	Wharton	E.J. Popp #2, 163990	1	1
(979) 543-1382	3	Wharton	E.J. Popp #3, 176386	1	1

Table D-5. Site Contact Data (Continued)

Phone	TRRC District	County	Lease Names and Numbers	Number of Compressors at this Station	Number of Wells at this Station
(281) 955-8595	3	Fort Bend	Rosenbaum - Suiter et al Gas Unit, 199380	1	2
(281) 955-8595	3	Fort Bend	Hitch - May et al Gas Unit, 200348	1	1
(713) 654-5010	3	Fort Bend	State of Texas Deep Unit, 24007	1	1
(713) 209-2416	3	Brazoria	BRLD	3	7
(713) 209-2416	3	Brazoria	East	3	10
(713) 209-2416	3	Brazoria	Well # 247	1	1 well head

Table D-6. Miscellaneous Site Information

Site Survey ID	Comments
Site1	7 wells scattered in area
Site2	
Site3	
Site4	% gas wells that need compression - all after 1st year / *Note: single horizontal cylinder engine
Site5	
Site6	3 stage compressor / in-line engine / Contacts at Universal Compression: Rocky (manager): (903)758-9292; Mark Palasky (Foreman)
Site7	Compressor serial # L72393 / RRC # 11187
Site8	
Site9	6 cylinder in-line / single stage / *Two new wells are bypassing compressor . . . 3 old wells come through compressor (Laird #1, #2, #3).
Site10	single cylinder / Age of wells - 6 years and 2 years
Site11	
Site12	V-engine
Site13	4 cylinder engine
Site14	compressor is down
Site15	in-line, 6 cylinder
Site16	in-line
Site17	
Site18	V-8 engine - 4 cylinder / vacuum - 2-3" water-closer to 3 / Compressco 1-800-259-2714
Site19	in-line 2 stage
Site20	
Site21	6 cylinder in-line / there are 7 wells but two are not producing
Site22	2 cycle / There are going to be 5 compressors - the compressor serves 2 wells - see well #s / card attached to Questionnaire for Don Branton
Site23	4 cycle, 2 cylinder
Site24	6 cylinder in-line
Site25	3" suction & discharge / inline - 8 cylinder
Site26	V-12 / 2" suction & discharge / Tom Hartley, Production Manager (903) 926-3833 / Universal: 1-800-259-6100 / #4523 is unit # on engine
Site27	2" suction & discharge / 2 cylinder / Mustang Compression, Mike @ Rainer - (903) 983-4040 / Pumper was Tom Hartley (903) 926-3833
Site28	2 stage compression / 4 cylinder / 2" suction & discharge
Site29	2 stage compression / 6 cylinder in-line / 2" suction & discharge

Table D-6. Miscellaneous Site Information (Continued)

Site Survey ID	Comments
Site30	2 stage compression / 6 cylinder in-line / 2" suction & discharge
Site31	2 stage compression / 6 cylinder in-line / 2" suction & discharge / 2 stroke engine (not sure about 2 stroke)
Site32	2 stage compression / 1 cylinder / 2" suction & discharge
Site33	2 stage compression (only using 1 stage) / 6 cylinder / 2" suction & discharge
Site34	2 stage compression / 6 cylinder inline / 2" suction & discharge
Site35	2 stage compression / 2 cylinder / 2" suction & discharge
Site36	2 stage compression - only uses 1 stage / 2 cylinder / 3" suction, 2" discharge
Site37	2 stage compression - 1 stage in use/ 2 cylinder - 1 in use / 3" suction, 3" discharge
Site38	2 stage compression / 2 cylinder / 3" suction/ discharge ---> goes to 4"
Site39	2" suction & discharge / 6 cylinder in-line / 2 stage compression / engine is shut down, will be turned on tomorrow or next day
Site40	4" suction & discharge / V-16 engine / 3 stage compression
Site41	1 or 2 stage compression / 2 cylinder? / 2" suction/discharge
Site42	2 stage compression / 2 cylinder / 4" suction / 2" discharge
Site43	2 stage compression / V-8 engine / 3" suction / 2" discharge
Site44	2 stage compression / 2 cylinder / 3" suction / 2" discharge / two of the 7 wells are currently shut down
Site45	2 stage compression (currently using 1 stage) / 1 cylinder / 4" suction & discharge
Site46	2" suction & discharge / 6 cylinder in-line / 2 stage compression
Site47	2" suction & discharge / 6 cylinder in-line / 2 stage compression
Site48	4" suction, 2" discharge / 6 cylinder in-line / 3 stage compression / see photos
Site49	3" suction, 2" discharge / 6 cylinder in-line / 2 stage compression
Site50	3" suction, 2" discharge / V-16 / 3 stage compression
Site51	2" suction & discharge / 1 cylinder / 2 stage compression
Site52	2" suction & discharge / 1 cylinder / 2 stage compression
Site53	2" suction & discharge / 1 cylinder / 2 stage compression
Site54	2" suction & discharge / 6 cylinder in-line / 2 stage compression
Site55	2" suction & discharge / 6 cylinder in-line / 1 stage compression
Site56	2" suction & discharge / 4 cylinder in-line / 2 stage compression ; using only 1 stage right now
Site57	2.875" suction & discharge / 6 cylinder in-line / 2 stage compression
Site58	2" suction & discharge / 4 cylinder in-line / 2 stage compression / 3/12 wells require compression
Site59	2" suction & discharge / 4 cylinder in-line / 2 stage compression / catalyst

Table D-6. Miscellaneous Site Information (Continued)

Site Survey ID	Comments
Site60	8" suction, 6" discharge / V-12 / 2 stage compression / catalyst / all Hilcorp wells and compressors operate on a loop
Site61	10" suction, 6" discharge / V-16 / 3 stage compression / catalyst
Site62	6" suction & discharge / V-12 "screw" - non-reciprocating

APPENDIX E

Leasing Company Interview Questions

Leasing Company Interview Questions

1. In general, what types of compressors are leased rather than purchased? Are there parts of the state or sizes of compressors that are leased in disproportionately high numbers?

2. What is the total number of compressors you lease to natural gas wells in Texas? What fraction of the compressors are east of I-35 & north of I-37?

3. What is your estimate of the total number of compressors at natural gas wells in East Texas, both industry-owned and leased?

4. Of the compressors you lease, what % are:
    - Reciprocating ____
    - Integral-engine____
    - Rotary screw ____
    - Others ____

5. What % of the wells in East Texas would you estimate have no compressor? How does this vary among the districts in East Texas?

6. Of the compressors you lease in East Texas, what % have engines:
    - > 500 bhp ____
    - 400 to 500 bhp ____
    - 300 to 400 bhp ____
    - 200 to 300 bhp ____
    - 100 to 200 bhp ____
    - under 100 bhp ____

   How does this vary by region or district?

7. What % of engines use the following types of fuel?
    - Raw gas _____
    - Pipeline gas _____
    - Waste gas _____
    - Diesel _____
    - Electricity _____

   How does this vary by region or district?

8. What is the age distribution of compressor engines?
    - % that are 0 to 5 years _____
    - % that are 6 to 10 years _____
    - % that are 10 to 20 years _____
    - % that are 20 to 30 years _____
    - % that are over 30 years _____

9. What fraction of the engines are lean burn? PSC or ultra-lean burn? How does this vary by region or district? How is it possible to tell in the field if an engine is configured as lean burn?

10. Based on your maintenance records, what is the typical operating schedule or what % of a typical engine's operating hours are during the following periods:

    Dec – Feb ____
    Mar – May ____
    Jun – Aug ____
    Sep – Nov ____

    Does this vary by size? Or by region?

11. What is a typical engine's load %? How is load % measured? What is the typical engine's load % during summer months? Does this vary by region?

12. What instrumentation do you typically provide with your engines?
    - Fuel feed rate?
    - Inlet gas pressure?
    - Outlet gas pressure?
    - Gas flow rate?
    - Engine rpm?
    - Engine load?

13. What % of the engines have air pollution control technologies such as SCR or NSCR? What are typical efficiencies for these controls? How does this vary by region?

We would like to receive a file containing the following information on each piece of leased equipment in TRRC districts 2, 3, and 6:

Engine description-

manufacturer	
model	
shaft speed	rpm
engine type	lean/rich/PSC
strokes	2 or 4
controls	none/ SCR/ NSCR
control efficiency	%
engine age	years
fuel type	raw gas/ pipeline gas/ waste gas/electricity/ diesel
fuel consumption @100% load	Btu/bhp-hr
NO_x emissions	g/bhp

Compressor description

type	reciprocal/integral engine/rotary screw/other
stages	

Design Parameters

power	bhp
inlet pressure	psig
outlet pressure	psig
flow	MMscf/day
engine load	%
runtime	hr/yr

APPENDIX F

Distribution of Compressor Engine Capacities by TRRC District

District	Number of Engines	Total hp	Horsepower range					
			< 100	100 - 199	200 - 299	300 - 399	400 - 499	Total
District 2								
2-stroke, lean-burn	70	12,545	3%	11%	8%	15%	0%	37%
4-stroke, rich-burn	162	20,921	16%	25%	9%	7%	5%	63%
District 3 (attainment area only)								
2-stroke, lean-burn	40	5,112	2%	7%	3%	2%	0%	13%
4-stroke, rich-burn	251	32,809	23%	40%	15%	4%	4%	87%
District 5								
2-stroke, lean-burn	97	14,483	9%	13%	13%	18%	0%	54%
4-stroke, rich-burn	91	12,481	11%	15%	13%	5%	2%	46%
District 6								
2-stroke, lean-burn	70	10,487	4%	12%	5%	8%	0%	29%
4-stroke, rich-burn	171	25,268	14%	25%	14%	5%	13%	71%

APPENDIX G

Natural Gas Production by County

Natural Gas Production by County

County	District	Gas Production (Mscf/yr)			
		1999	2002	2007	2010
ANDERSON	6	7,031,213	9,205,850	13,618,125	13,331,428
ANGELINA	6	601,992	518,755	525,855	514,785
ARANSAS	2	5,425,138	7,362,587	7,482,005	7,324,489
ATASCOSA	2	13,205,367	7,722,975	7,556,072	7,396,997
AUSTIN	3	36,932,075	9,665,711	9,198,340	9,004,691
BASTROP	3	568,434	287,887	533,533	522,301
BEE	2	18,802,857	37,659,716	35,967,090	35,209,888
BELL	2	0	0	0	0
BEXAR	3	240	240	816	798
BOSQUE	6	0	0	0	0
BOWIE	6	80,669	195,067	263,459	257,913
BRAZORIA	3	35,850,585	35,621,586	35,439,666	34,693,568
BRAZOS	3	21,817,768	17,680,373	23,840,907	23,338,993
BURLESON	3	3,661,300	5,058,998	18,948,610	18,549,692
CALDWELL	3	14,145	21,230	452,583	443,055
CALHOUN	2	9,144,617	7,213,734	7,275,337	7,122,172
CAMP	6	318,756	808,295	809,207	792,171
CASS	6	10,989,609	5,714,543	5,827,521	5,704,837
CHAMBERS	3	39,050,011	26,436,974	27,224,885	26,651,730
CHEROKEE	6	15,365,032	13,621,979	13,262,568	12,983,356
COLLIN	6	0	0	0	0
COLORADO	2	86,664,804	49,521,700	25,996,381	25,449,089
COMAL	2	0	0	0	0
COOKE	6	123,970	120,847	581,672	569,426
DALLAS	6	29,965	1,457	1,379	1,350
DE WITT	2	17,618,705	13,733,962	0	0
DELTA	6	0	0	0	0
DENTON	6	12,464,494	104,260,674	98,717,416	96,639,155
ELLIS	6	0	0	0	0
FALLS	6	14,019	0	11	11
FANNIN	6	0	0	0	0
FAYETTE	3	39,815,326	19,054,931	32,839,712	32,148,349
FORT BEND	3	31,088,149	45,586,251	44,224,091	43,293,057
FRANKLIN	6	6,438,518	5,084,404	4,992,153	4,887,055
FREESTONE	6	80,803,620	217,431,645	205,516,985	201,190,312
GALVESTON	3	45,108,089	33,899,790	30,235,868	29,599,323
GOLIAD	2	29,615,277	37,866,089	36,391,365	35,625,231
GONZALES	3	1,373,097	1,503,461	1,632,166	1,597,805
GRAYSON	6	2,881,312	3,128,752	6,534,606	6,397,036
GREGG	6	50,250,606	55,070,069	55,112,693	53,952,426
GRIMES	3	54,569,537	21,233,035	20,678,585	20,243,246
GUADALUPE	2	0	14,288	114,127	111,724

Natural Gas Production by County (Continued)

County	District	Gas Production (Mscf/yr)			
		1999	2002	2007	2010
HARDIN	3	12,040,417	17,755,547	17,443,824	17,076,586
HARRIS	3	85,330,284	32,144,930	33,041,751	32,346,135
HARRISON	6	57,062,350	56,188,323	55,219,374	54,056,860
HAYS	3	0	0	0	0
HENDERSON	6	19,305,989	23,480,955	39,607,509	38,773,667
HILL	6	0	0	0	0
HOOD	6	1,372,788	1,063,800	1,030,636	971,555
HOPKINS	6	1,599,448	1,135,541	1,215,969	1,190,369
HOUSTON	6	3,730,628	2,523,058	2,708,638	2,651,614
HUNT	6	0	0	0	0
JACKSON	2	16,974,062	16,578,258	17,263,328	16,899,890
JASPER	6	3,118,639	9,685,946	10,230,596	10,015,215
JEFFERSON	3	34,693,556	28,543,053	28,336,267	27,739,714
JOHNSON	6	27,629	27,881	26,381	25,826
KARNES	2	9,500,306	8,260,003	8,126,216	7,955,138
KAUFMAN	6	0	0	20,795	20,357
LAMAR	6	0	0	0	0
LAVACA	2	141,798,151	94,170,620	87,768,123	85,920,373
LEE	3	8,810,681	4,731,664	16,455,688	16,109,253
LEON	6	32,747,529	20,786,975	22,042,801	21,578,742
LIBERTY	3	8,738,718	32,722,809	32,072,877	31,397,659
LIMESTONE	6	44,561,155	42,555,881	40,305,243	39,456,712
LIVE OAK	2	26,360,202	28,564,640	27,563,372	26,983,090
MADISON	3	4,035,743	5,488,017	5,744,712	5,623,770
MARION	6	226,988	5,138,155	4,933,868	4,829,997
MATAGORDA	3	59,994,556	55,360,639	54,774,954	53,621,797
MCLENNAN	6	0	0	47	46
MILAM	3	24,456	31,028	436,730	427,536
MONTAGUE	6	413,923	371,712	1,852,731	1,746,523
MONTGOMERY	3	38,652,007	21,146,204	21,017,396	20,574,924
MORRIS	6	4,642,197	0	0	0
NACOGDOCHES	6	26,202,590	28,971,371	27,455,788	26,877,772
NAVARRO	6	538,475	447,752	486,186	475,951
NEWTON	6	3,489,232	2,078,125	4,614,594	4,517,444
NUECES	2	36,461,269	57,499,773	56,206,068	55,022,782
ORANGE	3	9,437,097	13,509,712	13,173,885	12,896,540
PANOLA	6	253,946,855	237,091,000	228,627,384	223,814,176
PARKER	6	7,498,437	6,697,185	6,537,844	6,163,064
POLK	3	47,366,796	31,683,037	30,177,903	29,542,579
RAINS	6	7,898,530	7,899,271	7,474,410	7,317,054
RED RIVER	6	0	0	41,089	40,224
REFUGIO	2	26,307,573	21,019,303	36,021,351	35,263,006
ROBERTSON	3	23,826,384	50,086,743	47,024,195	46,034,212

Natural Gas Production by County (Continued)

County	District	Gas Production (Mscf/yr)			
		1999	2002	2007	2010
ROCKWALL	6	0	0	0	0
RUSK	6	73,703,936	76,878,087	74,418,209	72,851,510
SABINE	6	138,030	24,269	134,678	131,842
SAN AUGUSTINE	6	224,433	122,616	170,925	167,327
SAN JACINTO	3	6,467,599	5,499,122	5,258,573	5,147,866
SAN PATRICIO	2	14,272,743	12,496,716	12,976,583	12,703,392
SHELBY	6	9,496,664	25,726,551	24,326,127	23,813,998
SMITH	6	6,891,415	13,481,408	14,509,546	14,204,082
SOMERVELL	6	18,767	17,578	0	0
TARRANT	6	529,528	17,889,766	16,824,740	16,470,535
TITUS	6	205,373	201	2,722	2,665
TRAVIS	3	0	0	11	11
TRINITY	3	106,262	42,367	255,450	250,072
TYLER	3	770,070	2,194,376	3,638,867	3,562,259
UPSHUR	6	56,186,773	62,997,744	59,631,155	58,375,762
VAN ZANDT	6	9,333,345	7,000,611	8,633,228	8,451,476
VICTORIA	2	16,793,670	23,219,917	22,456,266	21,983,502
WALKER	3	1,457,519	2,584,520	2,490,805	2,438,367
WALLER	3	7,524,942	7,099,287	6,832,749	6,688,902
WASHINGTON	3	75,866,143	42,034,396	43,431,956	42,517,599
WHARTON	3	60,177,806	62,035,488	59,421,829	58,170,843
WILLIAMSON	3	14,384	14,306	12,457	12,195
WILSON	2	5,982	11,525	54,634	53,483
WISE	6	67,390,710	129,241,470	130,990,484	123,481,475
WOOD	6	11,364,074	9,898,297	12,294,394	12,035,564

APPENDIX H

Quality Assurance Project Plan

NATURAL GAS COMPRESSOR ENGINE SURVEY AND ENGINE NO_x EMISSIONS AT GAS PRODUCTION FACILITIES

Quality Assurance Project Plan

Prepared by
Eastern Research Group, Inc.
Morrisville, NC

March 30, 2005

Clint Burklin, ERG Project Manager: ____

Ray Merrill, ERG QA Manager: ____

Alex Cuclis, HARC Project Manager: ____

Bertie Fernando, TCEQ Technical Liaison: ____

A2. Table of Contents

A3. Distribution List

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Regi Oommen	ERG	regi.oommen@erg.com	919-468-7829
Jennifer O'Neil	ERG	Jennifer.oneil@erg.com	919-468-7811
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Charlie Rubic	TCEQ	crubic@tceq.state.tx.us	512-239-1478

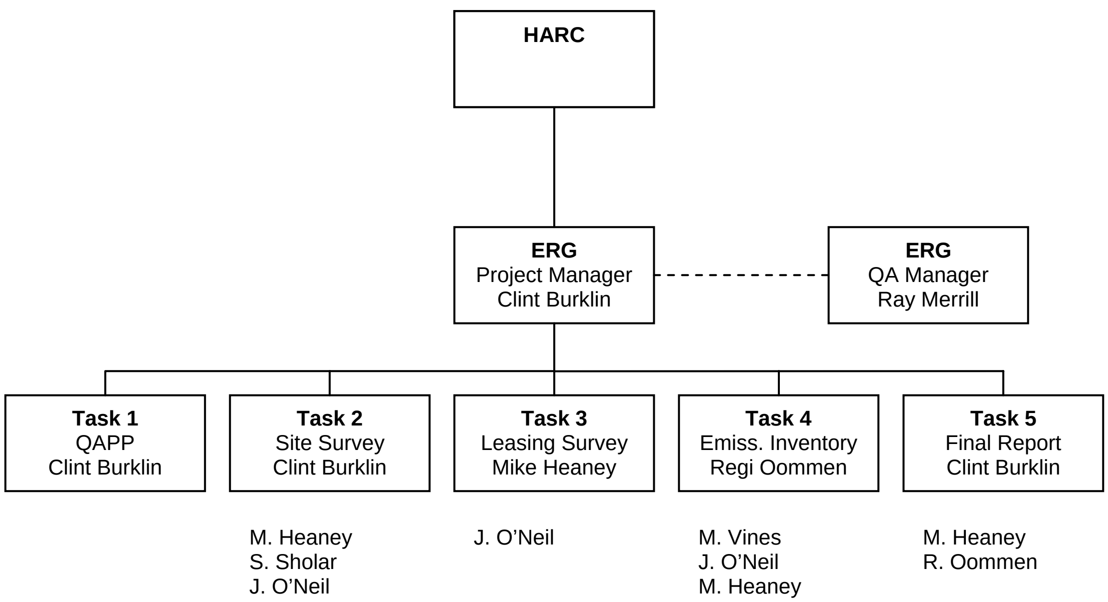
A4. Project Organization

A4.1 Purpose of Study

The purpose of this project is to collect relevant technical information to estimate the distribution of compressor engines associated with natural gas wells. The information will be collected from gas production operations that are located in the counties bisected by and east of Texas Interstate Highways 35 and 37 (IH-35 & 37). The technical data collected under the scope of work will be used by the Texas Commission on Environmental Quality (TCEQ) to compare equipment parameters and equipment usage, to quantify accurately nitrogen oxide (NOx) emissions and to perform control strategy analyses on compressor engine emissions associated with gas producing operations in eastern Texas.

A4.2 Roles and Responsibilities

The project organization is presented in the figure below. The responsibilities of each staff are listed following the figure.



Clint Burklin:

Task 1: Quality Assurance Project Plan
- Develop QAPP
- Provide audit materials to QA Manager
- Respond to corrective action requests from QA Manager

Task 2: Survey of Gas Well Compressor Sites
- Provide technical direction to technical team
- Develop the criteria for selecting questionnaire recipients
- Prepare cover letter for questionnaire
- Manage selection of producers for site visits
- Train field survey team

Task 3: Survey of Leasing Companies
- Peer review questionnaire for Leasing companies
- Peer review list of leasing companies for survey

Task 4: Develop Emission Inventory
- Peer review inventory factors
- Peer review inventory algorithms and results
- Peer review projection factors for 2007

Task 5: Final Report
- Prepare monthly progress reports
- Manage preparation of final report

Mike Heaney

Task 2: Survey of Gas Well Compressor Sites
- Identify all descriptive well and compressor data at TRRC
- Assemble questionnaire
- Assemble field survey forms
- Design database

Task 3: Survey of Leasing Companies
- Develop survey form
- Conduct leasing survey
- Develop inventory factors from field survey and leasing survey

Task 4: Develop Emission Inventory

- Implement inventory using TRRC data, inventory factors, *AP-42* factors
- Identify available TRRC data for projecting activity in 2007

Task 5: Final Report

- Report on field and lease survey findings
- Report on development of inventory factors, activity data, emission factors
- Report on projecting 2007 emissions

Regi Oommen

Task 4: Develop Emission Inventory

- Manage inventory development
- Direct development of emission inventory database
- Direct development of NEI database
- Establish criteria for modeling ozone season day

Task 5: Final Report

- Report on development of emission inventory database
- Report on developing NEI database

Ray Merrill

Task 1: Quality Assurance Project Plan

- Review QAPP
- Execute QA activities throughout project
- Monitor response to corrective action requests

Jennifer O'Neil

Task 2: Survey of Gas Well Compressor Sites

- Obtain addresses and contact information for 50-80 gas producers
- Coordinate mail-out of questionnaires
- Enter data from questionnaire respondents into database
- Schedule site visits
- Enter site survey data into database

Task 3: Survey of Leasing Companies

- Enter leasing survey data into database

Task 4: Develop Emission Inventory

- Enter TRRC data into inventory database

Scott Sholar

Task 2: Survey of Gas Well Compressor Sites

- Conduct site surveys
- Complete site survey forms

Melodie Vines

Task 4: Develop Emission Inventory

- Code NEI Database using the Emission Inventory Database

A5. Project Definition and Background

The purpose of this project is to collect relevant technical information to estimate the distribution of compressor engines associated with natural gas wells. The information will be collected from gas production operations that are located in 115 counties bisected by and east of Texas Interstate Highways 35 and 37 (IH-35 & 37). The development of emission estimates for gas compressor engines will require detailed information of actual activity data as well as the engines distribution and population in a number of selected representative gas producing counties. The compressor engine data that is currently available does not meet the requirements needed to perform emissions estimations for compressor engines. The project activities will collect data that will be used to estimate and allocate compressor emissions by identifying the distribution of compressor engines, their capacities, fuel type and usage, operating parameters, and the spatial allocation of the engines and temporal allocation of the engines' operations. The database containing this information will be used in conjunction with *AP-42* emission factors and TRRC activity data to develop the county level inventory of criteria pollutants.

A6. Project Description

Task 1: Quality Assurance/Quality Control (QA/QC) Procedures

ERG will develop a draft and final Quality Assurance Project Plan (QAPP), with a discussion of the quality assurance/quality control procedures to be followed by the ERG staff. The QAPP will meet Environmental Protection Agency (EPA) QAPP requirements found in EPA/240/B-01/-003. All work will be completed in accordance with the QA/QC procedures specified in the QAPP. Within 10 days of receiving HARC comments, ERG will finalize the QAPP. The final QAPP must be approved before Task 2, 3, 4, and 5 are conducted.

Task 1 Deliverables: A draft and final QAPP.

Deliverables Dates: Draft QAPP due January 17, 2005
Final QAPP due February 7, 2005

Task 2: Survey of Gas Well Compressor Sites

A field survey will be conducted for 45 representative gas well compressor sites owned or operated by 30 different companies. The 45 gas well compression sites for the field survey will be from counties located east of IH-35 and 37, or transected by IH-35 and 37. A minimum of 10 representative gas well companies will be selected from each of the three Texas Railroad Commissions (TRRC) gas districts # 2, 3 and 6. The following items will be identified and agreed upon in consultation with the HARC Project Manager prior to the survey activity begins:

- Selection of representative survey sites
- Development of survey forms and planning of the field surveys
- All other activities related to the Compressor field survey

Initially, 200 or more different gas producing or operating companies will be selected and survey questionnaires will be mailed to the selected producers or operators, based on gas production capacities. Based on their response, 45 gas compressor sites will be chosen from 30 companies for field surveys, 15 gas compressor sites in each of three TRCC districts. The chosen gas well compressor sites will be representative of the range of compressors operating in the counties east of Texas IH-35 & 37. A wide range of gas well owners or operators will be selected such that in a given TRRC gas district there shall be no more than two sites that will be owned or operated by the same company. However, if more than two compressor sites are located in the same vicinity which are owned or operated by the same company, then ERG will collect as much survey data on the additional compressor sites as practical (on the day of the initially planned survey of two sites). This additional data will be in addition to the minimum number of 45 survey data sets required. This effort will maximize the collection of data from a wide range of gas wells using a variety of equipment and also cover a wide range of equipment usage in the field, based on the well operator's equipment requirements, and experience. The selection of counties and associated gas well compression sites will be made with the consultation and approval of the HARC Project Manager. The initial well information and well identifications will be obtained from the TRRC well information database. The questionnaires mailed to the gas well producers or operators will include the following information requests:

1. Identification of recommended representative compressors to be surveyed,
2. The gas well(s) TRRC ID number(s), and the TRRC site location data for the gas wells that supply gas to the recommended compressor,
3. Information that can be used to assess the accessibility of compressor sites prior to the survey, and
4. The names and points of contact for the producers/operators.

The sites will be moderately accessible. Appropriate permissions from the owner/operator will be obtained prior to the survey activities. The gas wells will be selected to encompass a spectrum of production and operating parameters to provide representative characteristics of the selected sites. ERG will document that the selected wells are representative of other gas wells based on available TRRC parameters such as well head pressures, gas chemical composition, production rates, production activities and the equipment size/usage as compared to those of the other wells in the same production or reservoir area.

ERG will identify the name and gas capacity of the reservoir which supplies the candidate compressor's feed using TRRC information. We will identify low and high pressure wellhead values of the gas wells selected. If necessary to complete a questionnaire, ERG will follow-up the questionnaires mailed to the gas well producers or operators and the resulting response information by interviewing the producers or operators.

The HARC project manager must approve the selected sites.

The field survey visits will collect the information required to estimate the criteria pollutant emissions from the compressor engines, and to model the emissions from all engines east of IH-35 & 37. A field survey form will be developed by ERG and approved by HARC prior to conducting the fields survey. Example information for the survey form includes:

1. Total number of compressor engines at a site, the engine heat input, the estimated engine design horse power and brake horse power, the engine manufacturer, and the engine model number as it may appear on the engine for each engine,
2. Number of each engine type (4-stroke, 2-stroke, . . .),
3. Rate and type of fuel burned for each engine,
4. Burn type: rich/medium/lean for each engine,

5. Natural gas throughput (by hour and estimated by month and year), flow rate and/or meter readings (use flow meter readings), inlet and outlet compressor pressures (use gauge values), and pipe diameters for each engine,
6. Estimated number of hours of engine operation per month and per year for each engine,
7. The number of wells that are supplying gas to each compressor,
8. The identification of the well(s) supplying gas to each compressor. (Identification numbers of each of the gas wells connected to the compressor shall follow the TRRC system of well identifications.),
9. The actual compressor location (latitude and longitude) shall be identified by using GPS or other means as approved by HARC so that the well(s) locations can be referenced to the TRRC data,
10. Crank RPMs (to be used to estimate load factor),
11. Well location (with RRC references and measured GIS data) and a “plan” sketch of the well sites, including the gathering pipes and compressor locations,
12. Gas wellhead pressure,
13. Indicate if compressor engines selected are operating under TCEQ permit or under Permit by Rule requirements and document all relevant permit and operating data,
14. Air pollution controls used (if any),
15. Any other supporting data that will help develop a comprehensive database to prepare information on the distribution of compressor engine horse power ratings, operating parameters, and their distribution,
16. Typical compressor engine load profile (percent time @ 100, 90, 80, 70, . . . percent full load) or simply the typical compressor engine load (running at steady state), and
17. Date of compressor engine manufacture.

The field data sheets will be recorded clearly and legibly, and will be entered into a spreadsheet database immediately following the field trip. All field data will be available for HARC to review as needed.

Task 2 Deliverables: Deliverables will include the survey plans for site visits to 45 or more sites, locations visited, the methods and information used to make the site selections, and all essential data required to be collected as indicated above. The questionnaires mailed to the gas well producers or operators and the resulting response information, the methods and information used to make the site selections, the survey plan, and the field survey data collected will be documented in electronic format, such as Excel spreadsheets and will be delivered to the HARC project representative for HARC review and comments. If additional site visits are planned, ERG will provide the reasons for having to perform additional visits.

Deliverables Dates:	Draft questionnaire, survey form, recipient list	January 31, 2005
	Final questionnaire, survey form, recipient list	February 14, 2005
	Mail questionnaires,	February 14, 2005
	Submit survey database structure	February 28, 2005
	Receive questionnaires	March 7, 2005
	Submit proposed survey sites	March 21, 2005
	Complete site visits	May 6, 2005
	Submit completed survey database	May 16, 2005

Task 3: Survey of Leasing Companies, Data Analysis, and hp-hr/MCF Factors Estimation Methodology Development

Under this task, ERG will develop a survey form and perform a survey of 6 to 10 compressor leasing companies that offer the potential for obtaining information on compressor engines. The leasing company survey form will be approved by the HARC project manager before the survey is started. Accurate data may be obtained on the size of engines and the compressors, throughput and other "essential information" used in the field in this manner. The leasing companies will be surveyed to collect the following data on their leased fleet of compressors/engines by county (or region):

14. The total number of compressor engines they have in service,
15. An estimate of the total number of gas line compressor engines in service in addition to the ones they supply,
16. Estimation of the total horsepower all companies currently having to operate in each county they serve (> 500 hp and < 500 hp),
17. The ratio of the number of compressor engines with less than 500 hp to engines to the number of compressor engines with greater than 500 hp engines,
18. Of the engines < 500 hp, what percentage are < 400 hp, < 300 hp, < 200 hp, and < 100 hp,

For the remainder of the list, the leasing companies survey will also collect data on compressor engines in the ranges from 500 to 401 hp, 400 to 301 hp, 300 to 201 hp, 200 to 101 hp, and 100 to 0 hp, by county (or region).

19. Typical compressor engine hp requirements to compress million cubic feet of natural gas per day within a typical operating pressure range (for different hp ranges),
20. Estimated typical compressor operating gas throughput profile (mcf/hr, day, week, month, and/or year),
21. Estimate of percent of engine types (2 cycle, 4 cycle, and any other type),
22. Estimate of age distribution of compressor engines,
23. Typical number of stages of the compressors,
24. Estimate of typical compressor engine burn type (i.e. rich, medium, or lean),
25. Estimate of typical fuel used by the engines,

26. Typical compressor engine load profile (percent time @ 100, 90, 80, 70, . . . percent full load) or simply the typical compressor engine load (running at steady state),
27. Typical inlet and the outlet gas pressures and pipe diameters of the compressors,
28. Typical Number of wells and gas flows serviced,
29. Air pollution control technology type, if any,
30. Estimated pollution control efficiency (if any), by control technology type,
31. Estimated percentage of time the compressor engines operate in the field (monthly, annually),
32. Estimated percentage of time engines in the above stated ranges of hp operate in the field (monthly, annually),
33. Estimated range of gas well-head pressures with respect to the gas field and/or gas reservoirs,
34. Estimated range of gas pipe line sizes and their operating pressures, and
35. Date of compressor engine manufacture.

The field survey data, the leasing company's data, and the relevant TRRC data will be compared to flag any errors or inconsistencies that need to be resolved before developing emission factors and emissions estimates for gas compressor engines.

Based on the data collected from the field survey and the leasing company survey, ERG will develop hp-hr/MCF factors for engines in the ranges from 500 to 401 hp, 400 to 301 hp, 300 to 201 hp, 200 to 101 hp, and 100 to 0 hp. The hp-hr/MCF factors, will be a function of variables such as engines hp ranges, throughput, fuel type, engine age, engine type, engine burn type, load profiles, percentage of engines in operation per month. Using the total county monthly gas production rates, ERG will estimate what percentage of the gas is compressed by the compressor engines covered in the survey.

The HARC project manager will approve the methodologies and hp-hr/MCF factors developed before Task 4 can begin.

Task 3 Deliverables: The leasing companies survey form, the survey information and data collected, the relevant TRRC data, documentation of the analysis the data, documentation of the development of the new methodology for developing emission factors and emissions estimates for gas compressor engines, the new hp-hr/MCF factors, and estimates will be submitted in electronic format, such as Excel spreadsheets and etc. If needed, HARC will request the contractor to submit original data or document colleted in the survey.

Deliverable Date:	Draft lease survey form and list of recipients	February 28, 2005
	Final lease survey from and list of recipients	March 15, 2005
	Complete lease survey	March 28, 2005
	Enter lease survey into database	April 11, 2005
	Submit *AP-42* factors and TRRC activity data	May 2, 2005
	Submit Emission factors and activity factors	May 30, 2005

Task 4: Develop an Emissions Inventory

ERG will use TRRC data, TCEQ information on gas compressor engines, the survey data collected, the ERG derived correlations of hp-hr/MCF, EPA traceable emission factors, and projections of future gas production to estimate ozone season day and annual total emissions for each pollutant (NOx, VOC, SO2, CO2, and PM 2.5) from compressor engines for each Texas county east of HI 35 & 37 (This area is inclusive of counties IH-35 and 37 pass through.) for the years 1999, 2002, and 2007. The total annual emissions will be in tons per year for each pollutant and also daily emissions will be in tons per day for each pollutant.

Task 4 Deliverables: Emission inventory information as detailed in Task 4 and the data will be submitted in hard copies and in electronic format, such as Excel spreadsheets. In addition the data will be submitted in the EPA's National Emissions Inventory format.

Deliverable Date:	Draft inventory	July 1, 2005
	Final Inventory	July 29, 2005

Task 5: Final Report

At the conclusion of the study ERG will prepare a final report that includes all relevant documents, and all relevant data, including the information collected in the surveys, the results of all derived data and correlations with reference to each county surveyed, and technical discussions of the patterns of the compressor engine distributions in terms of variables such as their capacities, hp ranges, throughputs, and other operating parameters. All other data collected in this study will be documented with the supporting data in the final report. The emissions inventory will be included in the final report with estimates of the uncertainty of the emissions estimates. The final report will make recommendations for improving the inventory for this category of sources and potential practical control strategies.

Under the reporting task, monthly progress reports will be submitted at the beginning of each month. Monthly reports will follow the format provided by HARC. These monthly reports will include information on any deliverables that have been completed

Task 5 Deliverables: Deliverables will be a draft final and a final report and spreadsheets listing all data collected including the survey information. The final report will be comprehensive and will include the methodologies used in obtaining all information and producing all correlations and emissions estimates.

Deliverable Date:	Draft Final Report	July 11, 2005
	Final Report	July 29, 2005

A7. Quality Objectives and Criteria

The objective of this study is to develop an accurate county level inventory of natural gas fired compressor engines east of IH-35 & 37. County level gas well activity data will be obtained from TRRC, for the specific years of the inventory. Emission factors for gas fired engines will be obtained from *AP-42*. The field and lease survey data collected in this study will be used to relate the TRRC activity data and the *AP-42* emission factors to yield a county level emission inventory. Therefore the activity-engine relationships developed in this study must be representative of the engines used in eastern Texas, considering variables such as:

- Leased and owned engines,
- High and low volume gas wells,
- High and low pressure gas fields,
- Sparse and compacted well densities.

We will select 45 compressor sites from 30 operators and at least 6 leasing companies to collect the required data. No more than two sites will be selected from any one operator and the 30 operators will be selected equally from three separate TRRC districts with the greatest activity (# 2, 3, and 6).

The databases developed in this study must be well organized, well labeled, and well documented, so that a third party researcher can utilize the data, and reproduce the factors and relationships developed from the database.

A8. Special Training and Certifications

There will be no special training or certifications required for the staff conducting this study. The staff that are developing the activity relationships have more than 25 years experience, each, in emission estimation for engines and similar equipment. The staff that are responsible for compiling the inventory and the NEI database have been performing inventory and NEI quality audits for EPA's Office of Air Quality Planning and Standards for the last 5 years.

A9. Documents and Records

A9.1. Information Included in the Reporting Package

The following documents and records will be developed and maintained by ERG in the conduct of this study. Each item will be submitted to HARC and its designees as a draft for review before being submitted in final form.

Questionnaire and Field Survey Database

A Microsoft Excel 2003 spreadsheet will be developed to store the data collected with the questionnaires and the field surveys. All information in the forms collected by ERG will be entered into the spreadsheet. The database will be submitted to HARC in electronic form. A numeric label will be assigned to each questionnaire and survey form collected in this study and cross referenced to the database entry. At the conclusion of this study the questionnaires and survey forms will be submitted to HARC for documentation.

Leasing Company Database

A Microsoft Excel 2003 spreadsheet will be developed to store the data collected from the leasing company surveys. All information in the survey forms completed by ERG will be entered into the spreadsheet. The database will be submitted to HARC in electronic form. A numeric label will be assigned to each survey form collected in this study and cross referenced to the database entry. At the conclusion of this study the survey forms will be submitted to HARC for documentation.

Compressor Engine Inventory

A Microsoft Excel 2003 spreadsheet will be developed to provide a county level inventory of gas-field compressor engine emissions in eastern Texas. The spreadsheet will contain activity data from TRRC and emission factors from *AP-42*. These data will be compartmentalized such that newer data can be substituted at any time to update the inventory. The specific references for all data used in the spreadsheet will be footnoted on the sheet where it appears. The activity relationships developed by ERG will be used in the spreadsheet to estimate the annual tons/yr and the tons/ozone-day county-wide emissions of: NOx, VOC, SO2, CO2, and PM 2.5.

NEI Files

A Microsoft Access 2003 database containing the above compressor inventory will be submitted in NEI 3.0 format to HARC. The *NIF 3.0 Users Guide and Specifications* provided at: http://www.epa.gov/ttn/chief/nif/index.html will be used to format and QA/QC the NIF files.

Final Report

The final report in Microsoft Word format will be submitted to HARC at the conclusion of this study. The report will summarize the information collected in the surveys, the derivation of correlations used in the inventory, and technical discussions of the patterns of the compressor engine distributions in terms of variables such as their capacities, hp ranges, throughputs, and other operating parameters. A summary of the emissions inventory will be included in the final report with estimates of the uncertainty of the emissions estimates. The final report will make recommendations for improving the inventory for this category of sources and potential practical control strategies.

A9.2. References

There are several references that we will require to conduct this study. These references include:

1. The TRRC Database of gas well information,
2. The TCEQ inventory of Gas Engine Permits,
3. EPA's compilation of Air Pollutant Emission Factors, *AP-42*
4. EPA's Guidelines for Submitting data to the National Emissions Inventory.

Since no environmental samples or analysis will be collected on this project the majority of Section B is not applicable. Section B5 will address quality control of data collection.

B5. Quality Control

It is important that the field survey sites and the leasing companies selected for this study are representative of the activities east of IH-35 & 37 and yield the best inventory possible. When selecting the field survey sites, we will identify sites that represent the range of gas producing sites in eastern Texas. The parameters that will be varied when selecting the survey sites are:

- High and low volume gas wells,
- High and low pressure gas fields,
- Sparse and compacted well densities, and

We will select 45 compressor sites from 30 operators to collect the required data. No more than two sites will be selected from any one operator and the 30 operators will be selected equally from three separate TRRC districts with the greatest activity (# 2, 3, and 6). The list of selected survey sites will be submitted to HARC, along with supporting rationale, for their review and approval.

Since there are relatively few large leasing companies, we will attempt to survey all of the major companies. It is possible that 6 to 8 companies will represent 90% or more of the leased compressor engines and almost 50% of total engines in the gas fields. Therefore a list of at least 6 leasing companies will be submitted to HARC, along with supporting rationale, for their review and approval.

B9. Non-Direct Measurements

The following method will be used to inventory emissions for a given county:

Preliminary talks with engine leasing companies determined that the compression requirements at a site are not predictable based on field characteristics. This is because so many other variables come into play, including age of well, formation porosity, depth, pressure of local gathering lines, etc. However, we may find that there are similarities of compression requirements and compressor station designs between the various TRRC districts.

$$\mathbf{E} = \mathbf{\Sigma_i}\ \mathbf{Q} \times \mathbf{F_i} \times \mathbf{H_i} \times \mathbf{EF_i} \times \mathbf{C}$$

Where:

E = annual emissions for the county (Ton/yr)
Q = annual gas production for the county (MMscf/yr)
F_i = fraction of compressors using engine type "i"
H_i = heat rate for engine type "i" (mscf of gas/hp-hr of compression)
EF_i = emission factor for engine type "i" (lb/mscf of gas burned)
C = compression requirements of the district (hp-hr/MMscf gas produced)

Factors "F" and "C" will vary by TRRC district, and will be derived from our survey of the compressor station designs used in each district. "EF" will come from *AP-42*, U.S. EPA's emission factor manual. "H" is available from engine performance data available from each manufacturer. "Q" is available from the TRRC database of Texas gas wells.

C1. Assessments and Response Action

The following table presents the review responsibilities under this project.

Deliverable	Developer	Reviewer
Field survey spreadsheet	J. O'Neil	M. Vines
Lease survey spreadsheet	J. O'Neil	M. Vines
Emission Inventory Spreadsheet	M. Heaney	C. Burklin
NEI Database	M. Vines	R. Oommen
Calculation of Inventory Factors	M Heaney	C. Burklin

The reviewer will note all required corrections on the product, along with their name and the review date. A copy will be returned to the product developer, a copy will be provided to Clint Burklin and a copy will be kept on file. When the corrections are made by the developer, the corrections will be verified by the original reviewer and the name of the reviewer and the date of the "final review" will be placed on the final product.

C2. Reports to Management

Copies of all interim and final reviewed versions of the products listed in Section C2 containing the notes on the correction requirements will be sent to Clint Burklin upon completing each review. A copy of each review iteration will also be kept on file for review by Ray Merrill, the QA Manager and by HARC representatives.

D1. Data Review, Verification and Validation

All spreadsheets and databases will be created with Microsoft Office 2003 products. All columns and rows will have full labels. Footnotes will be provided for each data range in the spreadsheets to indicate the source of the data. All data entered by the ERG will be fully checked by a second team member. All algorithms entered into the software will be checked through manual calculation by a second team member. The staff conducting data entry and the staff conducting reviews will be designated on each page of the software with the date of their activity. The name of each file will include a version number or version date. All versions will be kept for quality control until the completion of the project.

D3. Reconciliation with User Requirements

A memorandum will be prepared for HARC that documents the methodology that will be used to inventory the compressor engines east if IH-35 & 37. The methodology will develop the most accurate county level inventory possible, within the constraints of the *AP-42* emission factors and the TRRC activity database. The methodology memorandum will define the available activity data from TRRC, and how it will be used with the results of the survey to estimate the quantity and type of compressor engines used in each county. Supporting documentation will also be submitted with the memorandum for HARC review.