TYLER/LONGVIEW/MARSHALL FLEXIBLE ATTAINMENT REGION

SPECIAL STUDY RELATING TO OIL AND GAS PRODUCTION

2005 and 2007 EMISSIONS FROM COMPRESSOR ENGINES WITH CONSIDERATION FOR LOAD FACTOR

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SUMMARY

Emissions from gas compressor engines are an important component of the Northeast Texas emission inventory. In order to estimate emissions from compressor engines, it is necessary to calculate the load on the engines. Engine load is the ratio of the average actual engine horsepower to the engine's rated horsepower. The purpose of the East Texas Compressor Study was to determine the appropriate load factor when estimating engine horsepower for compressor engines used in natural gas production in the five Northeast Texas Air Care (NETAC) counties and Panola County. Average load factors were determined for three engine categories. For engines less than 240 hp, the load factor was 70%. For engines between 240-500 hp, the load factor was 69%. For engines greater than 500 hp, the load factor was 58%. There was a wide variability in load factors, which ranged from approximately 0% to 102 %. Variability occurs across different wells, but an individual well may also experience wide load variations over time. This report analyzes the underlying causes of this variability. The above load factors were used to estimate 2007 emissions of Nitrogen Oxides (NOx), Volatile Organic Compounds (VOC), and Carbon Monoxide (CO) from gas compressor engines in the five NETAC counties as well as in neighboring Panola County. The number of gas wells and the emissions from natural gas production in Panola County are large, and it can act as an upwind source to the Tyler/Longview/Marshall five county area, therefore it is included in this inventory.

In a previous study, Pollution Solutions inventoried gas compressor engine emissions for the year 2005 using an assumed load factor of 100%. Applying the load factors determined in the present study reduces the estimated 2005 emissions of NOx by 34%. Similar reductions are seen for VOC and CO. Previous studies have overestimated the contribution of NOx, VOC, and CO from compressors because these estimates assumed that the engines were operating under full load (installed horsepower). Table 1 is a summary of emissions that were calculated for 2005 and 2007.

TABLE 1
SUMMARY OF COMPRESSOR ENGINE EMISSIONS

2005

Total tons of emissions for 5 County area for all engines at 100% Load

	ton/yr
NOX	18427.783
VOC	1194.6861
CO	11762.49

2005

Total tons of emissions for 5 County area for all engines at reduced load

	ton/yr
NOX	12180.46
VOC	748.05
CO	6974.13

2007

Total tons of emissions for 5 County area for all engines at reduced load

	ton/yr
NOX	15756.309
VOC	967.65749
CO	9021.5405

2007

Emissions for Panola County from compressor engines at reduced load

	ton/yr
NOX	12059.814
VOC	740.64107
CO	6905.0501

INTRODUCTION

Pollution Solutions was engaged by Northeast Texas Air Care (NETAC) to do a special study of emissions from gas compressor engines used in natural gas production. The study area was the five NETAC counties of Gregg, Smith, Harrison, Rusk, and Upshur as well as Panola County, which contains a large number of gas compressor engines and is adjacent to the NETAC area. The overall objective was to determine the load factor of natural gas compressor engines in these counties and use those load factors to calculate emissions from the compressor engines. After determination of the appropriate load factor, emissions from compressed natural gas production were calculated. For the purposes of this study, compressor emissions consist of NOx, VOC, and CO.

Previous studies developed an emission estimation methodology based on installed engine horsepower. Engine emissions depend not only on the engine's installed horsepower, but also on the load factor or working horsepower. For compressor engines used in natural gas production, the load factor (determined by dividing the average engine operating rpm by the rated rpm) is influenced by compression adjustments in the engine setup and well conditions including water loading in the well bore. The purpose of this study was to develop a survey technique and analysis method in order to determine this average load factor.

There are several information sources that were utilized to extract different pieces of the data. The Texas Railroad Commission keeps production information by well site and by county. Various engine manufacturers have web pages where some, but not all of the engines are listed with the corresponding emissions information. There are engine lease companies, which provide compressors to the various production companies. There are engine maintenance shops, which specialize in compressor engines. There are the compressor sites which have operating engines.

For those engines which are leased, there is the setup information. The lease company and/or maintenance shop may adjust the operating parameters such as the cylinder compression, engine operating rpm, single acting versus double acting compressors and other parameters to better adjust the engine and compressor while optimizing well performance. This is performed prior to compressor siting or at start up and may assist in the sizing of the engine for that well site. This may include the use of a larger engine, which must be down rated or used at a low rpm. For those sites which request a specific size, but ultimately accept a larger engine, there is information as to the intended load factor and the actual load factor. For those engines which are currently sited, it is possible to determine operating rpm versus engine rating rpm, engine setup and gas production data. Some engines transmit their load information through satellite links to the engine lease company. This study utilizes information from satellite and on-site analysis.

Manufacturing emission data was researched to determine the influence of load factors on emission factors. The data available for changes in emission factors at reduced load was very limited and for the few cases where the information was published, a change in the load caused only a small change in the emission factor. For the engines included in the field study, emissions were adjusted only to reflect changes in the engine loads, and the effect of changing loads on the emission factors was assumed to be insignificant and was neglected.

The leasing companies have the most information and the largest number of engines available for comparison. However, this must be related to the total population of engines and the operating practices of field personnel. The information from the leasing companies, maintenance shops and field production sites, in aggregate, was used to arrive at an average load factor. The total project consisted of 153 data points. A data point is a point in time when the load factor is determined for an engine. In some cases one engine provided multiple data points.

SURVEY OF MAINTENANCE SHOPS AND LEASING COMPANIES

The survey of maintenance facilities and leasing companies provided the opportunity to get information on many engines without the time, expense and difficulty of visiting each well site. Because engine leasing is the predominant method of acquiring production equipment in the NETAC counties, surveying the leasing companies allowed an opportunity to interview people familiar with the all of the different engine types and sizes used in the NETAC area. The various leasing companies did share this information, and a very accurate breakout by engine type and size that are being used was obtained. Engine manufacturing data provides horsepower available at different rpms. The engine manufacturing data also provides the emissions at maximum horsepower. Engine leasing companies were asked to provide the actual horsepower for the various engines and the maximum horsepower. Leasing companies supplied data for 132 data points. The leasing companies, through use of their proprietary software, calculated the working horsepower. The working horsepower is calculated from the compression, engine rpm, single acting versus double acting compressors, and measured pressures of gas entering and exiting the system.

SURVEY OF PRODUCTION SITES

To validate and expand on information from leasing companies, 5 well sites were surveyed by visiting the site, reviewing engine set up and operating parameters. This data was consistent with data from engines in similar horsepower ranges. While at the well site measurements of engine rpm versus rated rpm were obtained. Additional engine setup information was obtained such as 1^{st} stage an 2^{nd} stage single or double acting cylinders, inlet and outlet pressure, manifold pressure, engine nameplate information, volume of gas through the sales meter, and whether head spacers were added. The actual production per well is not always available. This is due to manifolding of multiple wells to the sales meter. With the assistance of the well operators/leasing company, the actual load factor was determined for each well site. To determine load factor, engine set up information and well information were input into a proprietary computer program. To go to a site and determine the operating horsepower of an engine from just observation is very difficult unless you are an expert with that engine. While a proprietary program was used, there is a similar program (Ariel; available at Arielcorp.com) that could be used if the observer had information such as 1^{st} stage an 2^{nd} stage single or double acting cylinders, inlet and outlet pressure, manifold pressure, engine nameplate information, volume of gas through sales meter, and whether head spacers were added. Use of computer software to determine the load factor requires knowledge of all the input parameters as well as their application on a particular engine.

This study accounted for the fact that some wells operate without a compressor engine. Previous studies have assumed that the wells without a compressor were a small fraction of the total and on average were insignificant. It was determined through our interviews of engine leasing company staff that wells are immediately put on a compressor to enhance the well production. This is an economic decision based on the current market conditions for natural gas.

Load factors were also obtained from a study entitled "2006 Update on a Pilot Project to Assess the Effectiveness of an Emission Control System for Gas Compressor Engines in Northeast Texas" prepared by Environ International Corporation. During the course of that study, load factors were obtained as part of emissions testing on 5 different engines at 16 separate times. These load factors were used along with data collected in the present study to determine the average load factor for the NETAC counties.

DATA ANALYSIS

Generally, the load is a function of down hole conditions and the overall productivity of the well. Initially a compressor engine assigned to a well or group of wells will have a load of close to 100%. As the well or wells age, there is a downward trend in production and the load factor is reduced. Often, the original engine/compressor is left in place even if the reduced demands on the engine mean that it is no longer correctly sized for the well. Availability of compressors is also a factor, such that a smaller engine may not be available to replace an engine that is larger than required for a well with decreasing production.

An important down hole factor is the water balance in the gas field and in the well bore. The use of compressors induces a vacuum and pulls water and gas up the pipe. The water is heavier and forms a lens of liquid on the sidewall of the pipe allowing gas to travel through the center and be produced. Occasionally, the water collapses and the gas is trapped under the water until the bubble is broken and the lens reforms. When the gas is trapped, the gas production slows, and the load on the engine is reduced. The well is described as waterlogged when this happens. Therefore, the load factor for an individual well measured on a given day is just a snapshot that may not accurately represent the long term average load on the engine. The load factor for that well and for the total gas field is an average of conditions over time.

The load factor for 3 categories of engines was calculated. The categories were for engines less than 240 horsepower, engines between 240 horsepower and 500 horsepower and engines greater than 500 horsepower. The size distribution of engines was determined based on how the engines are regulated by the TCEQ. Engine categories are based on installed horsepower. The regulation does not change based on load factor. Engines with horsepower less than 240 hp are unregulated, while engines with horsepower between 240 hp and 500 hp must be registered with TCEQ, although their emissions are unregulated. Engines with horsepower greater than 500 hp must be registered, and their emissions are regulated by TCEQ. For engines less than 240 horsepower, the average load factor was 70%. For engines between 240 horsepower and

500 horsepower the average load factor was 69%. For engines greater than 500 horsepower the average load factor was 58%.

For the greater than 500 horsepower category, there were 113 data points. In this category, there was one engine operating at 0 % of its rated horsepower and another engine operating at 102 % of its rated horsepower. The sum of the operating horsepower for these 113 engines was obtained. The sum of operating horsepower was divided by the number of engines in this category to determine the average operating horsepower. For these engines greater than 500 horsepower, the average engine was operating at 58% of its rated horsepower. The load factor is 58% for this category. Tables 2, 3 and 4 provide the information of how the load factor was calculated for each category.

TABLE 2
LOAD FACTOR CALCULATION FOR ENGINES LESS THAN 240 HP

Rated HP	Operating HP	Description (eng model)	% Load
95	95.0	CAT 3304 NA	100.0%
95	67.5	CAT 3304 NA	71.0%
95	90.3	CAT 3304 NA	95.0%
95	79.8	CAT 3304 NA	84.0%
95	91.2	CAT 3304 NA	96.0%
95	83.6	CAT 3304 NA	88.0%
195	146.3	CAT 3306 TA	75.0%
195	183.3	CAT 3306 TA	94.0%
195	158.0	CAT 3306 TA	81.0%
195	134.6	CAT 3306 TA	69.0%
195	146.3	CAT 3306 TA	75.0%
195	150.2	CAT 3306 TA	77.0%
195	163.8	CAT 3306 TA	84.0%
95	95.0	CAT 3304 NA	100.0%
195	157.2	CAT 3306 TA	80.6%
225	137.3	CAT 342 NA	61.0%
220	57.2	CAT 3306 TA	26.0%
220	125.4	CAT 3306 TA	57.0%
145	95.7	CAT 3300 NA	66.0%
225	117.0	CAT 342 NA	52.0%
220	121.0	CAT 3306 TA	55.0%
220	125.4	CAT 3306 TA	57.0%
145	95.7	CAT 3300 NA	66.0%
225	144.0	CAT 342 NA	64.0%
120	120.0	CAT 3306 TA	100.0%
225	121.5	CAT 342 NA	54.0%
220	83.6	CAT 3306 TA	38.0%
225	87.8	CAT 342 NA	39.0%
220	59.4	CAT 3306 TA	27.0%
		Sum of %	2031.6%
		Total engines	29
		AVERAGE LOAD FACTOR	70.1%

TABLE 3
LOAD FACTOR CALCULATION FOR ENGINES BETWEEN 240 HP TO 500 HP

HP	Operating HP	Description (eng model)	% Load
400	364.0	Waukesha F18GL	91.0%
400	300.0	Waukesha F18GL	75.0%
400	212.0	Waukesha F18GL	53.0%
400	328.8	Waukesha F18GL	82.2%
265	241.2	Cummins KTA19	91.0%
265	172.3	Cummins KTA19	65.0%
265	257.1	Cummins KTA19	97.0%
265	192.4	Cummins KTA19	72.6%
265	129.9	Cat 342 TA	49.0%
265	143.1	Cat 342 TA	54.0%
400	124.4	F18GLLCR/JGJ2-3	31.1%
		Sum of %	760.9%
		Total engines	11
		AVERAGE LOAD FACTOR	69.2%

TABLE 4
LOAD FACTOR CALCULATION FOR ENGINES GREATER THAN 500 HP

HP	Operating HP	Description (eng Model)	% Load
633	196.9	G3508TALEPC\JGE2	31.1%
633	351.7	G3508TALEPC\JGE2	55.6%
633	182.9	G3508TALE\JGE2-3	28.9%
1340	595.6	G3516TALEAFR\JGE4-2	44.4%
1005	469.0	G3512TALEAFR\JGE4-2	46.7%
790	333.6	G3512TAHCR/JGE4	42.2%
633	0.0	G3508TALE/JGE2	0.0%
1340	387.1	G3516TALE/JGE4	28.9%
1340	268.0	G3516TALE/JGE4	20.0%
1340	655.1	G3516TALE/JGT4	48.9%
1340	268.0	G3516TALE/JGE4	20.0%
1340	893.3	G3516TALE/JGE4	66.7%
1340	1286.0	G3516/JGT4-2/3	96.0%
633	424.6	G3508/JGE2-3	67.1%
1340	1256.3	G3516TALE/JGT4-2\3	93.8%
1340	595.6	G3516TALE/JGE4	44.4%
1340	595.6	G3516TALE/JGE4	44.4%
1340	625.3	G3516TALE/JGE4	46.7%
1340	1131.6	G3516TALE/JGE4-3	84.4%
1340	839.4	G3516TALE/JGE4-3	62.6%
633	129.2	G3508TALE/JGE2-3	20.4%
633	84.4	G3508TALEPC\JGE2	13.3%
633	182.9	G3508TALE\JGE2-3	28.9%
1340	982.7	G3516TALEAFR\JGE4-2	73.3%
1005	357.3	G3512TALEAFR\JGE4-2	35.6%
790	210.7	G3512TAHCR/JGE4	26.7%
633	196.9	G3508TALE/JGE2	31.1%
1340	774.2	G3516TALE/JGE4	57.8%
1340	268.0	G3516TALE/JGE4	20.0%
1340	506.2	G3516TALE/JGT4	37.8%
1340	297.8	G3516TALE/JGE4	22.2%
1340	1036.3	G3516TALE/JGE4	77.3%
1340	1369.8	G3516TALE/JGE4	102.2%
1340	1274.5	G3516TALE/JGE4	95.1%
1340	1274.5	G3516/JGT4-2/3	95.1%
1340	1155.4	G3516/JGT4-2/3	86.2%
633	419.2	G3508/JGE2-3	66.2%
633	433.3	G3508/JGE2-3	68.4%
633	419.2	G3508/JGE2-3	66.2%
1340	1185.2	G3516TALE/JGT4-2\3	88.4%
1340	1244.7	G3516TALE/JGT4-2\3	92.9%
1340	684.9	G3516TALE/JGE4	51.1%
1340	416.9	G3516TALE/JGE4	31.1%
1340	804.0	G3516TALE/JGE4	60.0%
1340	1101.8	G3516TALE/JGE4-3	82.2%
1340	1244.7	G3516TALE/JGE4-3	92.9%
633	194.1	G3508TALE/JGE2-3	30.7%
1340	500.3	G3516TALE/JGT4-2\3	37.3%

TABLE 4
LOAD FACTOR CALCULATION FOR ENGINES GREATER THAN 500 HP

HP	Operating HP	Description (eng Model)	% Load
633	182.9	G3508TALE\JGE2-3	28.9%
1340	1042.2	G3516TALEAFR\JGE4-2	77.8%
1005	245.7	G3512TALEAFR\JGE4-2	24.4%
790	210.7	G3512TAHCR/JGE4 (R burn)	26.7%
633	28.1	G3508TALE/JGE2	4.4%
1340	595.6	G3516TALE/JGE4	44.4%
1340	327.6	G3516TALE/JGE4	24.4%
1340	625.3	G3516TALE/JGT4	46.7%
1005	402.0	G3512TALE/JGE4	40.0%
1340	297.8	G3516TALE/JGE4	22.2%
1340	1340.0	G3516TALE/JGE4	100.0%
1340	1263.7	G3516TALE/JGE4	94.3%
633	329.7	G3508TALE/JGE2	52.1%
1340	1204.1	G3516/JGT4-2/3	89.9%
633	343.8	G3508/JGE2-3	54.3%
633	386.0	G3508/JGE2-3	61.0%
633	259.4	G3508/JGE2-2	41.0%
1340	1263.7	G3516TALE/JGT4-2\3	94.3%
1340	1204.1	G3516TALE/JGT4-2\3	89.9%
1340	995.7	G3516TALE\JGE4-2	74.3%
1340	774.2	G3516TALE/JGE4	57.8%
1340	446.7	G3516TALE/JGE4	33.3%
1340	982.7	G3516TALE/JGE4	73.3%
1340	1072.0	G3516TALE/JGE4-3	80.0%
1340	608.6	G3516TALE/JGT4-2\3	45.4%
633	112.5	G3508TALE\JGE2-3	17.8%
1340	923.1	G3516TALEAFR\JGE4-2	68.9%
1005	335.0	G3512TALEAFR\JGE4-2	33.3%
790	228.2	G3512TAHCR/JGE4	28.9%
633	267.3	G3508TALE/JGE2	42.2%
1340	416.9	G3516TALE/JGE4	31.1%
1340	297.8	G3516TALE/JGE4	22.2%
1340	446.7	G3516TALE/JGT4	33.3%
1340	297.8	G3516TALE/JGE4	22.2%
1340	1280.4	G3516TALE/JGE4	95.6%
1340	1268.5	G3516TALE/JGE4	94.7%
633	458.6	G3508TALE/JGE2	72.4%
1340	1268.5	G3516/JGT4-2/3	94.7%
1340	1179.2	G3516/JGT4-2/3	88.0%
633	163.2	G3508/JGE2-3	25.8%
633	444.5	G3508/JGE2-3	70.2%
633	360.1	G3508/JGE2-3	56.9%
633	374.2	G3508/JGE2-3	59.1%
1340	1268.5	G3516TALE/JGT4-2\3	94.7%
1340	1149.4	G3516TALE/JGT4-2\3	85.8%
1340	911.2	G3516TALE\JGE4-2	68.0%
1340	655.1	G3516TALE/JGE4	48.9%
1340	416.9	G3516TALE/JGE4	31.1%

TABLE 4
LOAD FACTOR CALCULATION FOR ENGINES GREATER THAN 500 HP

HP	Operating HP	Description (eng Model)	% Load
1340	982.7	G3516TALE/JGE4	73.3%
1340	833.8	G3516TALE/JGE4-3	62.2%
1340	1089.9	G3516TALE/JGE4-3	81.3%
1340	583.6	G3516TALE/JGT4-2\3	43.6%
630	491.4	Cat G3508	78.0%
630	516.6	Cat G3508	82.0%
630	579.6	Cat G3508	92.0%
630	567.0	Cat G3508	90.0%
630	598.5	Cat G3508	95.0%
630	611.1	Cat G3508	97.0%
630	535.5	Cat G3508	85.0%
630	604.8	Cat G3508	96.0%
630	535.5	Cat G3508	85.0%
630	504.0	Cat G3508	80.0%
630	472.5	Cat G3508	75.0%
630	535.5	Cat G3508	85.0%
630	386.2	Cat G3508	61.3%
		Sum of %	6591.8%
		Total engines	113
		AVERAGE LOAD FACTOR	58.3%

LOAD FACTOR VERSUS TIME

The information in Table 5 is summary of load factors versus time. This information was obtained from Compressor Systems, Inc., a compressor engine leasing company. Compressor Systems maintains information through a satellite system on selected engines that are in the study area. The information provided is a load factor of unit identified engines at 4 specific times (snapshots) over a period of 6 months. Unit refers to the number assigned by the leasing company or nameplate of the engine. The actual load varied from a low of 0% to a high of 102%. Individual compressors tend to stay in the same load range, but 30% swings in the load are not uncommon.

TABLE 5
% LOAD VARIATION BY DATE
Compressor Systems Engines

Unit	HP	Description (eng model)	% Load 1/26/08	% Load 4/26/08	% Load 7/9/08	% Load 7/31/08
404456	633	G3508TALEPC\JGE2	31.1%	13.3%		
404648	633	G3508TALEPC\JGE2	55.6%			
410391	633	G3508TALE\JGE2-3	28.9%	28.9%	28.9%	17.78%
410395	1340	G3516TALEAFR\JGE4-2	44.4%	73.3%	77.8%	68.89%
410406	1005	G3512TALEAFR\JGE4-2	46.7%	35.6%	24.4%	33.33%
410814	790	G3512TAHCR/JGE4	42.2%	26.7%	26.7%	28.89%
410887	633	G3508TALE/JGE2	0.0%	31.1%	4.4%	42.22%
410963	1340	G3516TALE/JGE4	28.9%	57.8%	44.4%	31.11%
411033	1340	G3516TALE/JGE4	20.0%	20.0%	24.4%	22.22%
411036	1340	G3516TALE/JGT4	48.9%	37.8%	46.7%	33.33%
411116	1005	G3512TALE/JGE4			40.0%	
411134	1340	G3516TALE/JGE4	20.0%	22.2%	22.2%	22.22%
411138	1340	G3516TALE/JGE4		77.3%		
411157	1340	G3516TALE/JGE4	66.7%	102.2%	100.0%	95.56%
411160	1340	G3516TALE/JGE4		95.1%	94.3%	94.67%
411167	633	G3508TALE/JGE2			52.1%	72.44%
411209	1340	G3516/JGT4-2/3	96.0%	95.1%	0.0%	94.67%
411211	1340	G3516/JGT4-2/3		86.2%	89.9%	88.00%
411214	633	G3508/JGE2-3				25.78%
411216	633	G3508/JGE2-3		66.2%		70.22%
411217	633	G3508/JGE2-3	67.1%	68.4%	54.3%	56.89%
411219	633	G3508/JGE2-3		66.2%	61.0%	59.11%
411223	633	G3508/JGE2-2			41.0%	
411264	400	F18GLLCR/JGJ2-3				31.11%
411330	1340	G3516TALE/JGT4-2\3	93.8%	88.4%	94.3%	94.67%
411334	1340	G3516TALE/JGT4-2\3		92.9%	89.9%	85.78%
411366	1340	G3516TALE\JGE4-2			74.3%	68.00%
810069	1340	G3516TALE/JGE4	44.4%	51.1%	57.8%	48.89%
810070	1340	G3516TALE/JGE4	44.4%	31.1%	33.3%	31.11%
810072	1340	G3516TALE/JGE4	46.7%	60.0%	73.3%	73.33%
810456	1340	G3516TALE/JGE4-3	84.4%	82.2%	80.0%	62.22%
810469	1340	G3516TALE/JGE4-3	62.6%	92.9%		81.33%
810490	633	G3508TALE/JGE2-3	20.4%	30.7%		
810636	1340	G3516TALE/JGT4-2\3		37.3%	45.4%	43.56%

DISCUSSION OF EFFECTS OF LOAD FACTOR ON EMISSIONS

Emissions for the five county area were obtained by summing the number of operating gas wells and multiplying this total by the average installed horsepower per well. The load factor (percent of rated horsepower) was multiplied by the estimated horsepower for each horsepower range. This reduces the total horsepower in each engine size range by the percent load (load factor). Emissions for a given pollutant equal engine horsepower times the emission factor for that pollutant (in grams per horsepower hour) times 8760 hours per year divided by 454 grams per pound divided by 2000 pound per ton. This yields total tons per year for the five counties, and includes the effect of the load factor. We assume that the engine operates continuously for the entire year. The equation below shows a sample calculation of NOx emissions:

$$NOx\ Emissions = \#Wells \times \frac{Avg\ Installed\ HP}{Well} \times Load \times NOx\ Emission\ Factor \times Hours\ Operating \times \frac{1lb}{454g} \times \frac{1ton}{2000lbs}$$

Emissions are distributed to each county based on the number of gas wells in that county. The effect of applying the load factor to the estimation process is a linear reduction in emissions for each horsepower range. NOx emissions for 2005 for the five NETAC counties were originally estimated at 18,427 tons/yr. The horsepower for each category was reduced by the load factor. Recalculating emissions based on working horsepower resulted in a reduced NOx estimate of 12,180 tons/yr in 2005. This is a 34% reduction in emissions. While this is a significant reduction in emissions it is somewhat offset by the continuing increase in number of operating gas wells. Table 6 is the calculation of emissions that was done for the 2005 emissions that assumed a load factor of 100%. Table 7 shows the 2005 emissions that included the load factor calculated in this study.

TABLE 6
EMISSIONS FROM COMPRESSOR ENGINES IN THE TYLER-LONGVIEW-MARSHAL AREA
Year 2005

Emission Factors		
	gm/hp-hr	
500 HP plus	3.42	NOX
	0.43	VOC
	6.21	CO
240 HP to 500 HP	17.3	NOX
	0.7	VOC
	1.11	CO
Less than 240 HP	15.45	NOX
	0.52	VOC
	1.38	CO

Gas wells	County
643	Upshur
413	Smith
1489	Rusk
1358	Harrison
842	Gregg
TOTAL 4745	GAS WELL COUNT
54.86	HP/WELL
260311	Total HP for 5 county area

HP/ engine size range		
Size HP	Total HP	% of Total HP
500 plus	179488	68.95%
240-500	25696	9.87%
less 240	55127	21.18%

Emissions equal HP times gm/hp-hr times 8760 hrs divided by 454gm/lb divided by2000 lb/ton

Engine Category	Emissions Tons/yr		hrs/yr	lb/ton	gm/lb	gm/hp-hr	hp
500 HP plus	5922.15	NOX	8760	2000	454	3.42	179488
500 HP plus	744.60	VOC	8760	2000	454	0.43	179488
500 HP plus	10753.38	CO	8760	2000	454	6.21	179488
240 HP to 500 HP	4288.71	NOX	8760	2000	454	17.3	25696
240 HP to 500 HP	173.53	VOC	8760	2000	454	0.7	25696
240 HP to 500 HP	275.17	CO	8760	2000	454	1.11	25696
Less than 240 HP	8216.93	NOX	8760	2000	454	15.45	55127
Less than 240 HP	276.56	VOC	8760	2000	454	0.52	55127
Less than 240 HP	733.94	CO	8760	2000	454	1.38	55127

Total tons of emissions for 5 County area for all engines

	ton/yr
NOX	18427.78
VOC	1194.69
CO	11762.49

Emissions for each County from compressor engines

	Upshur	**Smith**	**Rusk**	**Harrison**	**Gregg**
NOX T/Y	2497.17	1603.94	5782.71	5273.96	3270.01
VOC T/Y	161.89	103.98	374.90	341.91	212.00
CO T/Y	1593.95	1023.80	3691.12	3366.38	2087.25

NOX T/DAY	6.8416	4.3943	15.8430	14.4492	8.9589
VOC T/ DAY	0.4435	0.2849	1.0271	0.9368	0.5808
CO T/DAY	4.3670	2.8049	10.1126	9.2230	5.7185

TABLE 7
EMISSIONS FROM COMPRESSOR ENGINES IN THE TYLER-LONGVIEW-MARSHAL AREA REDUCED LOAD
Year 2005

Emission Factors	gm/hp-hr	
500 HP plus	3.42	NOX
	0.43	VOC
	6.21	CO
240 HP to 500 HP	17.3	NOX
	0.7	VOC
	1.11	CO
Less than 240 HP	15.45	NOX
	0.52	VOC
	1.38	CO

	Gas wells	County
	643	Upshur
	413	Smith
	1489	Rusk
	1358	Harrison
	842	Gregg
TOTAL	4745	GAS WELL COUNT
	54.86	HP/WELL
	260311	Total HP for 5 county area @ 100% Load

HP/ engine size range		
100% load		
Size HP	Total HP	% of Total HP
500 plus	179488	68.95%
240-500	25696	9.87%
less 240	55127	21.18%

Emissions equal HP times load factor
times gm/hp-hr
times 8760 hrs divided by 454gm/lb
divided by2000 lb/ton

eng size range HP	Load Factor
500 Plus	58.3%
240-500	69.2%
less 240	70.1%

Engine Category	Emissions Tons/yr		hrs/yr	lb/ton	gm/lb	gm/hp-hr	hp at reduced load
500 HP plus	3452.61	NOX	8760	2000	454	3.42	104641
500 HP plus	434.10	VOC	8760	2000	454	0.43	104641
500 HP plus	6269.22	CO	8760	2000	454	6.21	104641
240 HP to 500 HP	2967.78	NOX	8760	2000	454	17.3	17781
240 HP to 500 HP	120.08	VOC	8760	2000	454	0.7	17781
240 HP to 500 HP	190.42	CO	8760	2000	454	1.11	17781
Less than 240 HP	5760.06	NOX	8760	2000	454	15.45	38644
Less than 240 HP	193.87	VOC	8760	2000	454	0.52	38644
Less than 240 HP	514.49	CO	8760	2000	454	1.38	38644

Total tons of emissions for 5 County area for all engines at reduced load

	ton/yr
NOX	12180.46
VOC	748.05
CO	6974.13

Emissions for each County from compressor engines at reduced load

	Upshur	**Smith**	**Rusk**	**Harrison**	**Gregg**
NOX T/Y	1650.59	1060.18	3822.28	3486.00	2161.42
VOC T/Y	101.37	65.11	234.74	214.09	132.74
CO T/Y	945.07	607.02	2188.51	1995.97	1237.56

NOX T/DAY	4.5222	2.9046	10.4720	9.5507	5.9217
VOC T/ DAY	0.2777	0.1784	0.6431	0.5865	0.3637
CO T/DAY	2.5892	1.6631	5.9959	5.4684	3.3906

DISCUSSION OF THE EFFECTS OF GROWTH

As shown in Table 8, the Tyler/Longview/Marshall area is experiencing rapid growth in the number of productive gas wells. From 2005 to 2007, there was a 23 % increase in number of operating wells. Emissions for the five county area were obtained by: 1) Summing the number of operating gas wells; 2) Multiplying the number of total gas wells by the average installed horsepower per well (from previous study) to determine horsepower; 3) Multiplying horsepower by the appropriate emission factor for NOx, VOC or CO.

The NOx emissions are 15,756 tons per year for 2007 with the increase in wells. This means that even with a more accurate representation of emissions utilizing the working horsepower, NOx from gas well compressors is a significant factor and growing by more than 10% per year. Table 9 is the calculation of emissions for the 5 county area for 2007 that includes the well count for 2007 and the calculated load factors.

TABLE 8
GAS WELL COUNT 2005 & 2007

COUNTY	**Number of Gas wells**	
	2005	2007
UPSHUR	643	729
SMITH	413	600
RUSK	1489	2022
HARRISON	1358	1849
GREGG	842	938
TOTAL	4745	6138
PANOLA		4698

TABLE 9

EMISSIONS FROM COMPRESSOR ENGINES IN THE TYLER-LONGVIEW-MARSHAL AREA REDUCED LOAD

Year 2007

Emission Factors	gm/hp-hr	
500 HP plus	3.42	NOX
	0.43	VOC
	6.21	CO
240 HP to 500 HP	17.3	NOX
	0.7	VOC
	1.11	CO
Less than 240 HP	15.45	NOX
	0.52	VOC
	1.38	CO

Gas wells	County
729	Upshur
600	Smith
2022	Rusk
1849	Harrison
938	Gregg
TOTAL 6138	GAS WELL COUNT
54.86	HP/WELL
336731	Total HP for 5 county area @ 100% Load

HP/ engine size range		
100% load		
Size HP	Total HP	% of Total HP
500 plus	232181	68.95%
240-500	33239	9.87%
less 240	71310	21.18%

Emissions equal HP times load factor
times gm/hp-hr
times 8760 hrs divided by 454gm/lb
divided by2000 lb/ton

eng size range HP	Load Factor
500 Plus	58.3%
240-500	69.2%
less 240	70.1%

Engine Category	Emissions Tons/yr		hrs/yr	lb/ton	gm/lb	gm/hp-hr	hp at reduced load
500 HP plus	4466.21	NOX	8760	2000	454	3.42	135361
500 HP plus	561.54	VOC	8760	2000	454	0.43	135361
500 HP plus	8109.69	CO	8760	2000	454	6.21	135361
240 HP to 500 HP	3839.04	NOX	8760	2000	454	17.3	23002
240 HP to 500 HP	155.34	VOC	8760	2000	454	0.7	23002
240 HP to 500 HP	246.32	CO	8760	2000	454	1.11	23002
Less than 240 HP	7451.06	NOX	8760	2000	454	15.45	49989
Less than 240 HP	250.78	VOC	8760	2000	454	0.52	49989
Less than 240 HP	665.53	CO	8760	2000	454	1.38	49989

Total tons of emissions for 5 County area for all engines at reduced load

	ton/yr
NOX	15756.31
VOC	967.66
CO	9021.54

Emissions for each County from compressor engines at reduced load

	Upshur	**Smith**	**Rusk**	**Harrison**	**Gregg**
NOX T/Y	1871.35	1540.21	5190.49	4746.40	2407.86
VOC T/Y	114.93	94.59	318.77	291.50	147.88
CO T/Y	1071.47	881.87	2971.91	2717.63	1378.66

NOX T/DAY	5.1270	4.2197	14.2205	13.0038	6.5969
VOC T/ DAY	0.3149	0.2592	0.8733	0.7986	0.4051
CO T/DAY	2.9355	2.4161	8.1422	7.4456	3.7771

ADJOINING COUNTIES

Emissions from gas production in the Tyler/Longview/Marshall Area are significant in their own right. When the emissions from an adjoining county (Panola) are added the effect is large. Panola has 4,698 wells. This compares to the five county total of 6,138 wells. Panola County had estimated emissions of 12,060 ton/yr of NOx for 2007. Because Panola is adjacent to and can be upwind of the 5 Tyler/Longview/Marshall counties represented by NETAC it may be of interest in any future control plan for Tyler/Longview/Marshall. Table 10 is the 2007 emission calculation for Panola County using the load factor.

TABLE 10
EMISSIONS FROM COMPRESSOR ENGINES IN PANOLA COUNTY
Year 2007

Emission Factors	gm/hp-hr	
500 HP plus	3.42	NOX
	0.43	VOC
	6.21	CO
240 HP to 500 HP	17.3	NOX
	0.7	VOC
	1.11	CO
Less than 240 HP	15.45	NOX
	0.52	VOC
	1.38	CO

Gas wells	County
4698	Panola
4698	TOTAL GAS WELL COUNT
54.86	HP/WELL
257732	Total HP for Panola county @ 100% Load

HP/ engine size range		
100% load		
Size HP	Total HP	% of Total HP
500 plus	177710	68.95%
240-500	25441	9.87%
less 240	54581	21.18%

Emissions equal HP times load factor times gm/hp-hr times 8760 hrs divided by 454gm/lb divided by2000 lb/ton

eng size range HP	Load Factor
500 Plus	58.3%
240-500	69.2%
less 240	70.1%

Engine Category	Emissions Tons/yr		hrs/yr	lb/ton	gm/lb	gm/hp-hr	hp at reduced load
500 HP plus	3418.42	NOX	8760	2000	454	3.42	103605
500 HP plus	429.80	VOC	8760	2000	454	0.43	103605
500 HP plus	6207.12	CO	8760	2000	454	6.21	103605
240 HP to 500 HP	2938.39	NOX	8760	2000	454	17.3	17605
240 HP to 500 HP	118.89	VOC	8760	2000	454	0.7	17605
240 HP to 500 HP	188.53	CO	8760	2000	454	1.11	17605
Less than 240 HP	5703.01	NOX	8760	2000	454	15.45	38261
Less than 240 HP	191.95	VOC	8760	2000	454	0.52	38261
Less than 240 HP	509.40	CO	8760	2000	454	1.38	38261

Emissions for Panola County from compressor engines at reduced load

	Panola
NOX T/Y	12059.81
VOC T/Y	740.64
CO T/Y	6905.05

NOX T/DAY	33.0406
VOC T/ DAY	2.0292
CO T/DAY	18.9179

Information Sources

This report could not have been completed without the information and help from Compressor Systems and JW Operating compressor leasing companies. Additional information sources were a report entitled “2006 Update on a Pilot Project to Assess the Effectiveness of an Emission Control System for Gas Compressor Engines in Northeast Texas” prepared by Environ International Corporation, a report entitled “Tyler/Longview/Marshall Flexible Attainment Region, Special Study Relating to Oil and Gas Production, 2005 Emissions from Compressor Engines” prepared by Pollution Solutions , and the Railroad Commission of Texas which provided information on gas wells in production.