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National Estimate of Methane Emissions from Compressors in the U.S. Natural Gas Industry

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INTRODUCTION

The combustion of natural gas emits much less carbon dioxide per unit of energy generated than other fossil fuels. For this reason, one strategy that has been suggested for reducing global warming is to encourage switching from other fossil fuels to natural gas. However, methane is currently thought to be a more potent greenhouse gas than carbon dioxide; if so, leakage of natural gas (which is approximately 90 percent methane) could reduce or eliminate the advantage of using natural gas because of its lower carbon dioxide emissions.

Two major issues must be addressed before the consequences of the fuel switching strategy can be evaluated. First, there is a need to better define the impact of methane relative to carbon dioxide on global warming. Second, it is important to better define methane emissions from the gas industry. Because of the latter issue, the Gas Research Institute (GRI) and the U.S. Environmental Protection Agency (EPA) have developed a cooperative program to quantify methane emissions from U.S. gas operations. Currently, estimates of methane emissions from the gas industry range from 0.5 to 4.0 percent of production. The GRI/EPA program is a comprehensive program to determine methane emissions from the wellhead to the customer's meter. The goal is to determine emissions to within approximately 3 billion cubic meters (m^3), or 100 billion standard cubic feet (scf), which is approximately 0.5 percent of U.S. production. To achieve this overall accuracy, an accuracy target has been established for each source category in the natural gas industry.

One source category is the exhaust from compressor engines that are used to move the gas through the system. Compressors are located in production fields, processing plants, gas storage facilities, and along transmission lines. A preliminary study indicated that the exhaust from compressor engines might account for more than 50 percent of the industry's methane emissions. Because the uncertainty in this early estimate was quite large, Radian Corporation conducted a study to determine methane emissions from both reciprocating and turbine compressor engines. The accuracy target established by the GRI/EPA program was to determine the emissions for this source category within 30 billion scf.

In this study, methane emissions were estimated by multiplying the methane emission rate of the unit by the activity of the unit. The emission rate expresses the amount of emissions per operating characteristic, independent of the other features of the unit. The activity expresses the operating characteristic of the unit which was, in this case, either a reciprocating engine or gas turbine. For example, when the operating characteristic is fuel usage, the activity is annual fuel used by compressors. When the operating characteristic is operating time, the activity is hours of operation (per year).

The emission rates used in this study were in the form of methane emissions per hour. The activity of each unit was the annual operating hours for that unit. A national estimate of annual methane emissions was determined from emissions estimates using available data for compressors in the natural gas industry.

APPROACHES

The Ideal Emission Estimate

Ideally, the annual methane emissions from compressors in the natural gas industry would be determined from the sum of the annual emissions from each unit in the industry, where the emission rate may vary over time and from unit to unit. This relationship is expressed by:

$$\text{Emissions} = \sum_{i=1}^{N} \int [ER_i(t) \times A_i(t)]\, dt \tag{1}$$

where $ER_i(t)$ is the instantaneous emission rate at time (t) for compressor_i, $A_i(t)$ is the instantaneous activity at time (t) for compressor_i, and N is the total number of compressor units in the industry. To reflect annual emissions, the integral in Equation (1) is evaluated over the time interval t_1 to t_2, where $t_2 - t_1$ is equal to 1 year. This approach produces no uncertainty in annual emissions.

Emission Estimate Using Test Data

The ideal approach was considered impractical because it would require a massive data-gathering effort by the industry. Fortunately, a substantial amount of data was available for both the emission rates and activity factors of compressor engines. For the emission rates, data for reciprocating engines and gas turbines were available for a number of models that were tested during relatively short time periods. Values for the annual activity of compressors, in terms of operating hours, were also available for some models. If data for all compressors in the industry were available, the following equation could be used to estimate methane emissions:

$$\text{Emissions} = \sum_{i=1}^{N} [ER_i|_{\Delta t=\text{test}} \times A_i(t)|_{\Delta t=\text{1year}}] \tag{2}$$

where ER_i is the emission rate of compressor_i (in grams of methane per hour) evaluated over the time period of the test; where the activity, A_i, of compressor_i corresponds to the annual operating hours of compressor_i; and where N is the total number of compressor units in the industry. This equation assumes that the emission rate of the compressors during the test period represents the emission rate of the compressors during the year, on the average.

Methane emissions from compressors will vary from manufacturer to manufacturer and model to model. Assuming that the compressors are properly maintained, differences in methane emissions, even for the same model, also will be caused by operating the compressors at different horsepower levels or speeds, or for longer or shorter periods of time in order to satisfy the operational needs of the system.

Figure 1 illustrates the relationship between operating load and emissions for a Cooper Bessemer two-cycle engine.[1] The figure shows the total hydrocarbon emission rate at varying loads, where speed is used to lower horsepower. Total hydrocarbon emissions can be considered a surrogate for methane emissions, since methane is expected to comprise a large portion (over 90 percent) of total hydrocarbon emissions from compressors. The data show that the emission rate for a Cooper Bessemer engine increased at lower loads, with a 40 percent increase in emissions at 50 percent of rated horsepower (full load), and a possible 100 percent increase if loads close to 30 percent of full load are used. A similar increase in methane emissions can be expected for other engine and turbine models, although the magnitude of the increase for other models is not known at this time.

The emission rate of any compressor, then, is a function of the rated horsepower and operating horsepower. The equation below summarizes this relationship:

$$ER_i = f(ER_i^{\circ}, Hp_i^{\circ}, Hp_i) \tag{3}$$

where ER_i is the operating emission rate of compressor_i; ER_i° is the emission rate of compressor_i at the rated horsepower, Hp_i°; and Hp_i is the operating horsepower. The data from the Cooper Bessemer illustrate that a linear relationship can be used to represent emissions for this engine as a function of horsepower, within 3 percent accuracy, over the range of horsepower from 50 to 100 percent of rated horsepower. In this situation, the average horsepower at which the engine operates over the year [as in Equation (2)] could be used to evaluate the integral in Equation (1) without any loss of accuracy.

If the information needed to develop Equation (3) was known for all engines and the relationship between horsepower and emissions for each engine was linear, the following equation could be used to more accurately estimate annual methane emissions from compressor engines from test data:

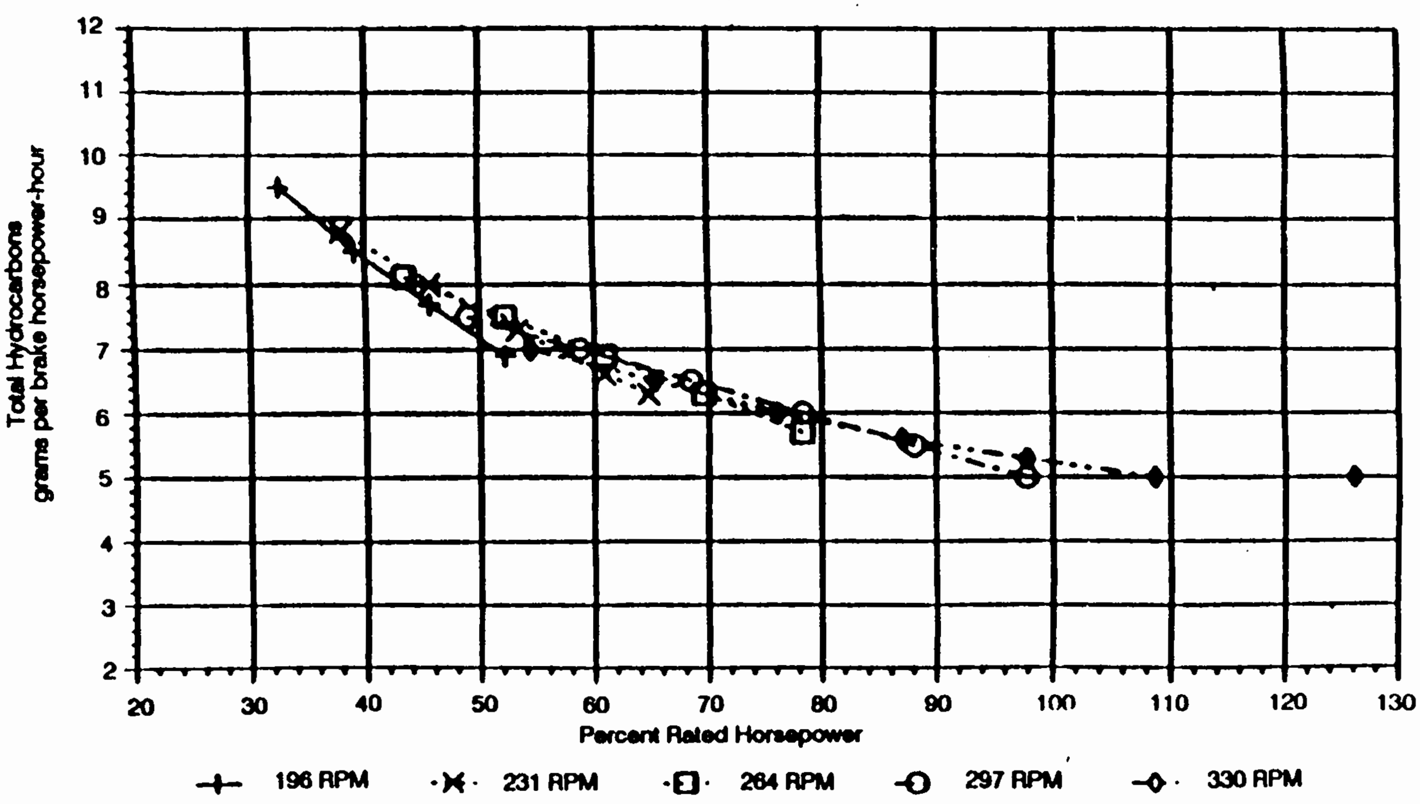

Figure 1. Effect of horsepower and speed on total hydrocarbon emissions for a Cooper Bessemer 2 cycle engine[1]

$$\underset{\text{(grams)}}{\text{Annual Emissions}} = \sum_{i=1}^{N} [\text{ER (Hp)}_i \times \text{Annual Hours (Hp)}_i] \quad (4)$$

where ER $(Hp)_i$ is the emission rate of $compressor_i$ as a function of horsepower (in grams of methane per hour); Annual Hours $(Hp)_i$ are the annual operating hours of $compressor_i$ at a specified horsepower; and N is the total number of compressor units in the industry.

Scaled-up Emission Estimate Using Test Data

Although emission and activity data for all compressors in the industry were not known, an estimate of methane emissions for the industry was made by proportioning the emissions for a subset of the industry (with known emission and activity data) according to the proportion of horsepower contributed by this subset. This approach assumes that the emission rates for the test engines during the test period and the operating hours estimated for the subset represent the average operation of compressors in the industry. A more detailed description of this approach is found in the Method section of this paper.

It was found that for the emission test data, on the average, the compressor emission rates were measured at virtually the same horsepower as the operating horsepower that was recorded for the compressors with the activity data (where the average horsepower of the compressors for the test data was equal to 0.985 times the average of the horsepower for the activity data). Therefore, knowledge of the relationship between horsepower and emissions was not needed for the analysis presented here.

An estimate of methane emissions using test data for a subset of the industry may underestimate actual industry emissions if many compressors are operated at lower loads for a significant period of time, since methane emissions are likely to increase when compressors are operated at less than full load. Future work in this area should include an analysis of the relationship between horsepower and methane emissions, so that individual compressor emission rates can be estimated with more accuracy.

DATABASES

Description of the Databases

A number of databases were obtained for this study, that provided information on compressor emissions and operations. The databases were part of GRI's TRANSDAT compressor module.[2] Two databases in the compressor module contain information about the distribution of compressors in the natural gas industry. One of the databases is an almost complete listing of engines and turbines in the gas industry, accounting for 16.2 million out of the 16.7 million total horsepower that was reported by the American Gas Association (AGA) for this industry in 1989.[3] This "Industry Database" contains information concerning 8,282 compressors in the natural gas industry. However, individual compressor horsepower is not reported in the database; only the total horsepower for all compressors of a specific type is reported for each gas company.

A second smaller database in the compressor module (the "Operating Database") is a subset of the Industry Database (with 1,515 units) corresponding to 3.2 million total horsepower. The Operating Database is the only database in TRANSDAT that contains information on annual operating hours for each unit. The operating horsepower of each compressor is also recorded in the database. The data in the Operating Database were obtained from an AGA survey of 112 companies in ozone nonattainment areas, where nitrogen oxides (NO_x) emissions were minimized. Because emissions of NO_x and hydrocarbons are inversely related, the operation of compressors to minimize NO_x will likely increase emissions of hydrocarbons and, hence, of methane. Consequently, the data in the Operating Database, such as the operating horsepower, may represent maximum methane emission conditions. The use of these data, then, presents a conservative estimate of industry emissions, if the data are representative of the industry as a whole.

Data from emissions tests performed by Southwest Research Institute are contained in a third database in TRANSDAT (the "Test Database"). During the emission tests, the compressors were operated at close to full load (rated horsepower). Methane emissions, fuel use, fuel use rate, and horsepower were recorded for each emissions test for 241 models of engines and turbines. Since there was some variation in horsepower in the multiple emissions tests for the same compressor, it may be possible to define the relationship between horsepower and methane emission rate for the 241 models of compressors in this database. With this information, it would be possible to extrapolate from the test conditions to actual operating conditions at lower horsepower levels. Because of the limitations of this study, an analysis of this type was not performed.

Because the Test Database contains only emission data and the other databases contain only operating data, a fourth database was developed that contains data for compressors for which information was found in both the Operating Database and Test Database. This fourth database was called the "Emissions Database." A total of 775 reciprocating engines and 86 gas turbines (out of 1,515 units in the Operating Database) fit the criteria and were included.

Table 1 describes the contents of each of the four databases.

Model-Matching Hierarchy

A model-matching schema was designed to maximize the amount of correlation between the Test Database data and the Industry and Operating Databases. Originally, when the compressors were matched according to exact model names, the Test Database accounted for only 38 percent of the units

TABLE 1. DESCRIPTION OF THE DATABASES

	Industry Database			Operating Database			Test Database			Emissions Database		
Data	Engines	Turbines	Total	Engines	Turbines	Total	Engines	Turbines	Total	Engines	Turbines	Total
Total Units	7,489	793	8,282	1,385	130	1,515	NA	NA	NA	775	86	861
Manuf/Model[a]	922	144	1,066	318	31	349	229	12	241	120	7	127
Total hp (MM)	11.2	5.0	16.2	2.4	0.8	3.2	NA	NA	NA	1.3	0.4	1.7
Total Hours (MM)	NA[b]	NA	NA	4.6	0.3	4.9	NA	NA	NA	0.2	0.2	3.1

[a] Number of unique compressor models in the database.

[b] Not applicable.

in the Operating Database and only 7 percent of the Industry Database. Through consultations with experts in the field of compressor emissions, a three-step hierarchy was designed to match more data in the Industry and Operating Databases to the Test Database.

The first step, therefore, in the hierarchy was based on an exact match. For instance, an Ajax DPC-360 engine in the Industry or Operating Database was identified with data from the Test Database for an Ajax DPC-360 in the first step of the hierarchy.

The second step in the matching procedure matched compressors by substring name, where the horsepower of both compressors was within ± 20 percent. An example of the second step in the hierarchy was a match of a Clark BA8T engine with a Clark HBA8T engine (common substring of BA8T), where the horsepower for the Clark HBA8T engine in the Emissions Database was 1,911, and was 2,050 for the Clark BA8T engine in the Industry Database. The third step in the hierarchy consisted of matching the rated horsepower per cylinder (± 20 percent) in compressors with similar initial names (manufacturer) but with varying substrings. An example of the third step is a match of a Clark BA5 engine, with 248 horsepower per cylinder (total horsepower = 1,242) and a Clark BA8 engine, with 211 horsepower per cylinder (total horsepower = 1,000).

Following the execution of the three steps in the model-matching hierarchy, 37 percent of the models and 57 percent of the units in the Operating Database (and 23 and 55 percent, respectively, in the Industry Database) were matched to emissions data. The execution of the three-step hierarchy also increased the amount of data in the Emissions Database to a total of 1.7 million horsepower, from the previous total of 1.3 million horsepower after the first step only, and accounting for over half of the horsepower in the Operating Database and Industry Database.

METHOD TO ESTIMATE METHANE EMISSIONS

The Emissions Database was used to estimate methane emissions from compressors in the natural gas industry. The method used to calculate emissions is described below.

Equations

An average emission rate was obtained for each model of compressor engine and turbine in the Emissions Database from the average of all methane emission tests in the Test Database for that model. Since the time period in which each test was conducted was not given, the emission rates, in units of grams of methane per hour, were calculated from the reported methane emissions per unit of fuel (in grams per m^3) and the reported fuel use rate (in m^3 per hour) for each compressor:

$$\underset{(g/hr)}{\text{Emission Rate}_i} = \underset{(g/m^3)}{\text{Average Emission Rate}_i} \times \underset{(m^3/hr)}{\text{FUR}_i} \qquad (5)$$

where FUR_i was the average fuel use rate for compressor_i.

The total annual methane emissions for each compressor were then calculated as in Equation (6):

$$\underset{(\text{grams})}{\text{Emissions}_i} = \text{ER}_i \times \text{Annual Operating Hours}_i \qquad (6)$$

where ER_i was the methane emission rate of compressor_i calculated with Equation (5), and Annual Operating Hours_i were obtained from the data for compressor_i in the Emissions Database.

The total methane emissions for the compressors in the Emissions Database were determined using:

$$\underset{(\text{grams})}{\text{Annual Emissions}} = \sum_{i=1}^{N} [\text{ER}_i \times \text{Annual Operating Hours}_i] \qquad (7)$$

where the emissions from each unit were calculated as in Equation (6), and N was the total number of compressors in the database.

Estimate of National Emissions

If data for all compressors in the industry were available, a national estimate could be calculated using Equation (7). Since the compressors in the Emissions Database were only a subset of the compressors in the natural gas industry, a procedure was necessary to relate the methane emissions calculated using Equation (7) to a national estimate.

The ratio of the total horsepower from compressors in the industry (16.7 million horsepower) to the total horsepower of the compressors in the Emissions Database (1.7 million horsepower) was used to scale up the methane emissions calculated in Equation (7) by a factor of (16.7/1.7), or 9.8, to estimate national emissions. This relationship is shown by:

$$\begin{array}{c}\text{National Methane}\\ \text{Emissions}\end{array} = \begin{array}{c}\text{Methane Emissions for}\\ \text{Emissions Database}\end{array} \times \overset{\text{Scaling Factor}}{\frac{Hp_I}{Hp_{ED}}} \qquad (8)$$

where Hp_I is the total horsepower in the industry[3] and Hp_{ED} is the total horsepower in the Emissions Database, which produce a scaling factor of 9.8.

RESULTS

National Emission Estimate

An estimate of national methane emissions from compressors using the approach discussed above was 0.22 teragrams (Tg) of methane. Over 99 percent of the emissions were estimated to be from reciprocating engines and less than 1 percent from gas turbines. This estimate was based on the assumption that the compressors in the Emission Database represent compressors used in the natural gas industry, on the average. If the industry compressors are operated at horsepower levels much less than the rated horsepower, the methane emissions estimated here could underestimate the industry emissions, since methane emissions are thought to vary inversely with horsepower.

Field, Plant, and Pipeline Compressor Emissions

Compressors are used in field and plant operations as well as in transmission activities. The emission estimate above does not apportion methane emissions among the segments of the natural gas industry that use compressors. The U.S. Department of Energy (DOE) provides estimates of the amount of fuel used in field (lease), plant, and pipeline applications, and these estimates were used to apportion methane emission estimates among the sources.[4] The methane emission estimates were based on the assumption that all the fuel reported for field and plant purposes was used by compressors. This assumption is likely to be an overestimate, because fuel is known to be used for field and plant purposes by equipment other than compressors. Although the portion of lease and plant fuel used for other purposes was not known, estimates of the fuel used by these sources served as rough estimates of fuel used by compressors in field, plant, and pipeline operations.

The result of using DOE estimates of fuel use was that 39 percent of total compressor fuel was attributed to field compressors, 26 percent to plant compressors, and 35 percent to pipeline. It is likely, however, that a higher percentage of total compressor fuel is used for pipeline, and that lower portions are used for field and plant. The AGA estimated that 84 percent of total compressor horsepower was used for the pipeline[3]; if fuel use can be assumed to be proportional to horsepower, the percent of fuel used by pipeline compressors could be over twice as high as the estimate based on the DOE information.

Since methane emissions were assumed to be proportional to fuel use, the DOE breakdown in fuel between the three sources of compressor emissions in the natural gas industry was used to apportion the national estimate of 0.22 Tg of methane emissions between the three sources. The results were that, of the total 220 megagrams (Mg) of annual methane emissions estimated for compressors in the industry, 86 Mg of methane was estimated to be emitted from field compressors, 57 Mg from plant compressors, and 77 Mg from pipeline compressors. As discussed above for apportioning fuel use between these three sources, the emissions from pipeline compressors were probably underestimated, and the portions for the other two sources were overestimated. Another possible error in the breakdown of emissions was the assumption that the emission rate and operating characteristics of compressors in field, plant, and pipeline applications were similar.

UNCERTAINTY IN EMISSION ESTIMATES

Since the true value of methane emissions from compressors in the natural gas industry is not known, the accuracy of the estimate of 0.22 Tg of methane emissions cannot be assessed. However, the data can be used to produce an approximation of the uncertainty in the emission estimate. Like confidence intervals, the uncertainty estimated for a value can describe, with a high degree of confidence, the range in which the true value lies.

The target uncertainty for the total estimate of methane emissions from all sources in the natural gas industry was close to 3 billion m^3 (100 billion scf). Because many segments in the natural gas industry emit methane that are part of the overall methane emission estimate in the GRI/EPA project, the goal for each segment was to produce a methane estimate with as little uncertainty as possible. The target uncertainty for compressors was approximately 800 million m^3 (30 billion scf).

The following explains the procedure used to estimate the uncertainty in the annual methane emission estimate from compressors and the results of this estimate.

Basis of Uncertainty in the Compressor Emission Estimate

The only sources of uncertainty in the approach described above that could be estimated were the analytical error associated with the test data used to calculate the methane emission rates and the scale-up to national emissions based on the ratio of the horsepower in the Emissions Database to the estimate of compressor horsepower in the industry.

The uncertainty in the hydrocarbon analysis was estimated to be ± 10 percent, based on the expected gas chromatograph (with a flame ionization detector) capabilities. Likewise, the uncertainty associated with fuel flow measurements was estimated to be ± 2.5 percent. The uncertainty associated with the scale-up between the Emissions Database and total industry horsepower was more difficult to quantify. Two indirect assessments of this uncertainty are discussed below, using comparisons between the Emissions Database and the Industry Database, which was taken to be a fairly good representation of the industry as a whole. The uncertainty for the scale-up to nationwide emissions was estimated to be approximately 1 percent, based on estimated significant figures in total horsepower. For an estimated industry horsepower of 16.7 million, the uncertainty was estimated to be 0.17 million horsepower; for the Emissions Database, with 1.7 million horsepower, the uncertainty was estimated to be 0.017 million horsepower.

Procedure to Calculate Uncertainty

The software "@Risk"[5] was used to estimate the uncertainty in the estimate of methane emissions from compressors. The variables of uncertainty were entered into the program along with the values discussed above. The "@Risk" uncertainty estimating procedure recalculated the total methane emission estimate using Latin Hypercube sampling at normally distributed intervals along the range of each variable, defined by the expected value and the (estimated) standard deviation of that value. In the case where the standard deviation was estimated from significant figures, a uniform interval (as opposed to a normally distributed interval) was used for the Latin Hypercube sampling.

In the "@Risk" program, the recalculation was performed 500 times, each time using a different value in the interval of each variable in the emission equations. The results of the 500 calculations, excluding values below zero, were analyzed for variation about the mean. The uncertainty was reported as the coefficient of variation, or the standard deviation divided by the mean, as a percent.

Estimates of Uncertainty

The uncertainty for the estimate of methane emissions from compressor engines and turbines, at 0.22 Tg (11.5 billion scf), was estimated to be approximately 1 percent, or 4.3 million m^3 (0.15 billion scf). This value is well below the 800 million m^3 target for compressor engines and turbines.

Comparison of the Database

One component of uncertainty in the methane emission estimate that could not be quantified for the uncertainty analysis was the degree to which the compressors in the Emissions Database represented the compressors in the industry. The Emissions Database was compared with the Industry Database in two procedures that were designed to assess the representativeness of the Emissions Database for compressors in the industry and, indirectly, the uncertainty associated with the scaling factor.

Figures 2 and 3 are plots for engines and turbines, respectively, showing the total horsepower for each model in the Industry Database versus the total horsepower of that model in the Emissions Database. The line formed from the relationship between the total horsepower for each database was plotted on each graph. For engines, a line through 11.2 million and 1.3 million, the total horsepower for engines in the Industry and Emissions Databases, respectively, constituted the ideal relationship between the total horsepower for each type of engine in the two databases. Similarly, for turbines, a line through 5 million and 0.4 million produced the ideal relationship for the total horsepower for each type of turbine in the two databases. The figures show that the horsepower contribution of the compressors in the Emissions Database was higher than the horsepower

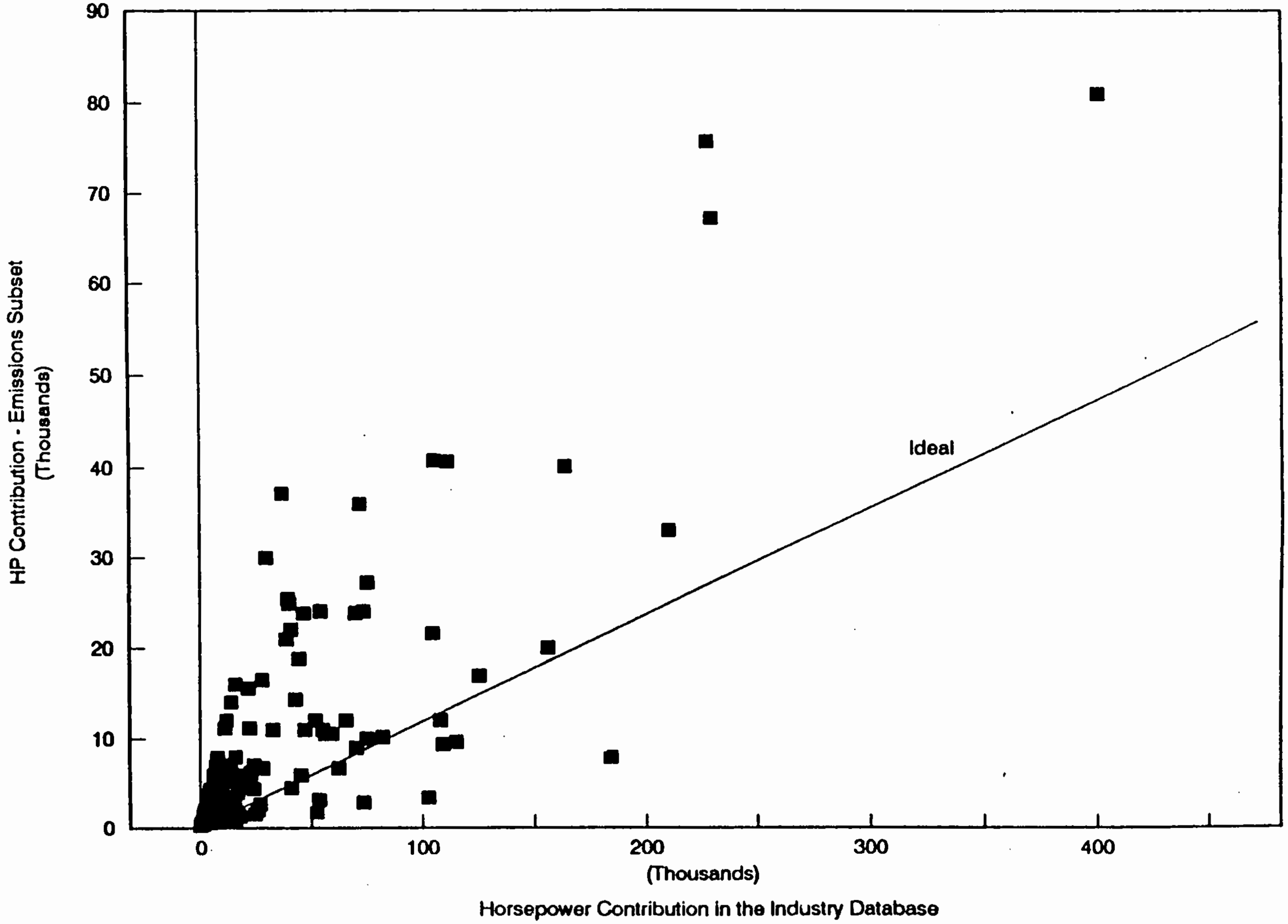

Figure 2. Relative horsepower contribution of each engine model in the Emissions and Industry Databases

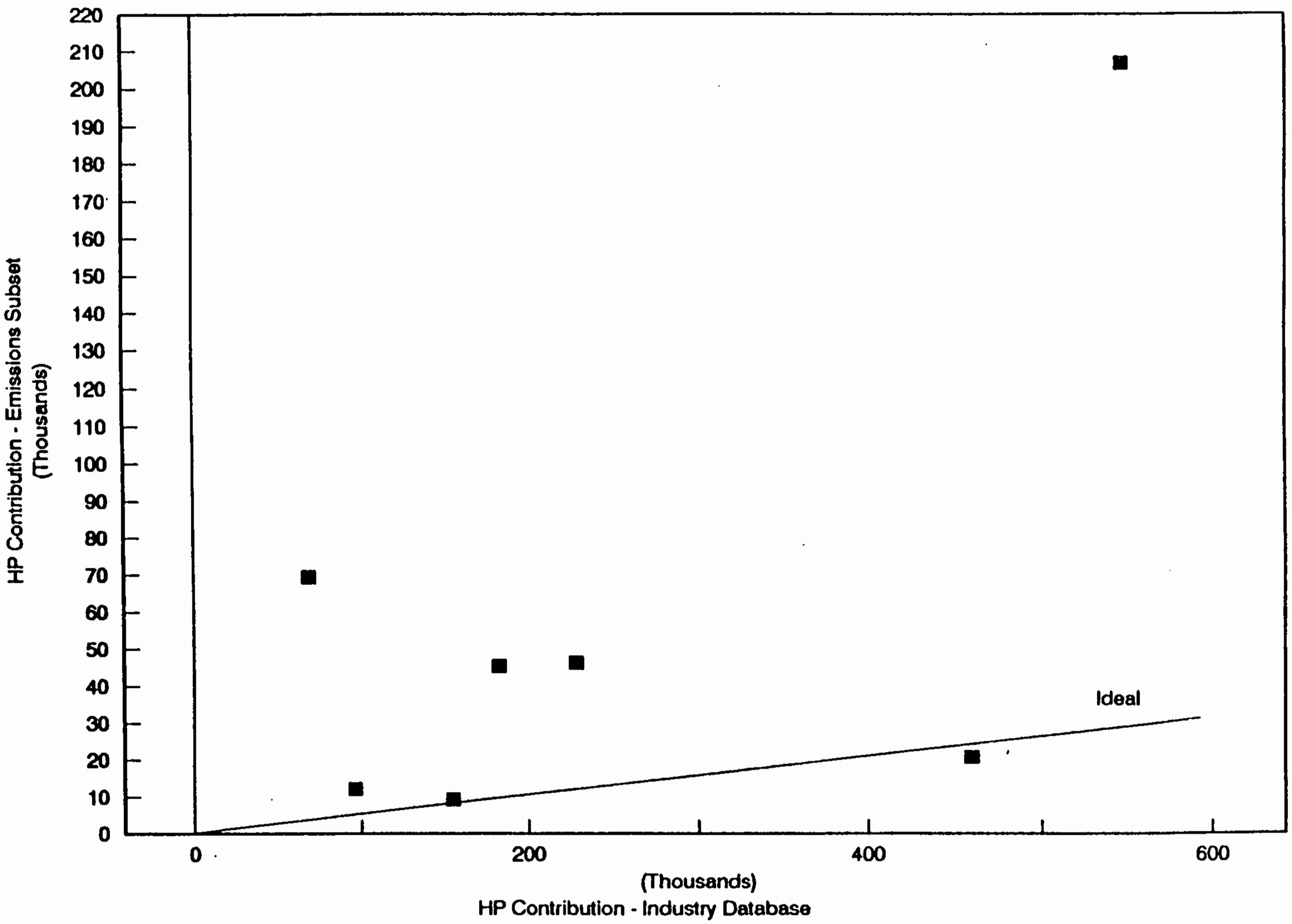

Figure 3. Relative horsepower contribution of each turbine model in the Emissions and Industry Databases

contribution in the Industry Database. However, the trend in general is in a positive direction for both databases, showing that compressors that contribute a large amount of horsepower to the total in one database also contribute significantly to the other. Conversely, compressors that are small contributors in one database are of similar ranking in the other. This comparison presents a qualitative assessment of the representativeness of the Emissions Database for the industry's compressors.

A more quantitative assessment of how well the Emissions Database represents industry compressors was performed using a comparison between the emission factors derived from the Emissions Database and the Industry Database, with the Industry Database used as a close approximation of compressors in the natural gas industry. To determine the emission factors for the Emissions Database, an overall average emission factor was calculated for engines and turbines, separately, after Step 1 in the hierarchy, where only the data that were exact matches with the compressors in the Test Database were included. Overall average emission factors were calculated for engines and turbines, weighting the model-specific emission factors for each engine and turbine, respectively, by the horsepower contribution of that model in the Emissions Database.

To determine the emission factors for the Industry Database, model-specific emission factors were developed after Step III in the hierarchy, and overall average emission factors were calculated for engines and turbines, weighted by the horsepower contribution of the engine and turbine models, respectively, in the Industry Database. The results were that the overall average emission factors calculated for the Emissions Database were 18 grams of methane emitted per m^3 of fuel for engines, and 0.16 grams of methane emitted per m^3 of fuel for turbines. The overall average emission factors calculated for the Industry Database were 20 grams of methane emitted per m^3 of fuel for engines, and 0.17 grams of methane emitted per m^3 of fuel for turbines. This analysis showed quantitatively that the Emissions Database was a fairly good representation of the Industry Database and, therefore, the industry.

CONCLUSIONS AND RECOMMENDATIONS

The annual methane emissions estimate of 0.22 Tg for compressors in the natural gas industry was less than the previous estimate of 2.2 Tg by a power of 10. Although compressors are still a significant source of methane emissions, this estimate reduces the importance of compressors in the assessment of the natural gas industry's contribution to global warming.

The uncertainty for the estimate, at 4.3 million m^3 of methane (0.15 billion scf), was much less than the portion of total industry methane emissions contributed by compressors, and was 0.15 percent of the target uncertainty (100 billion scf) for the industry.

Future work in this area could include an assessment of the effect of compressor operation, in terms of horsepower, on the methane emission rate.

On the basis of the data on this subject, the annual methane emissions could be higher than the current estimate by a factor of 2, if compressor operation is at horsepower levels significantly lower than compressors' rated horsepower.

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16. ABSTRACT The paper discusses a cofunded Gas Research Institute/EPA program to evaluate methane emissions from the natural gas industry in the U.S. The program consists of an emission testing program and an engineering assessment program for the major methane emission sources within the natural gas industry. One methane emission source is reciprocating engines and turbines that are used to drive compressors in the natural gas industry. In the study, the evaluation of methane emissions from the natural gas industry had a target uncertainty of 2,841 million standard cubic meters (100 billion standard cubic feet). The methane emissions estimate of 0.22 Tg for compressors in the natural gas industry is much less than the previous estimate of 2.2 Tg, by a power of 10. Although compressors are still a significant source of methane emissions, this estimate reduces the importance of compressors in the assessment of the natural gas industry's contribution to global warming. The uncertainty for the estimate, at 0.003 Tg (0.15 billion scf), is much less than the portion of the total industry methane emissions contributed by compressors, and is 0.15% of the target uncertainty (100 billion scf) for the industry.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Methane Emission Compressors Natural Gas Production Distribution	Pollution Control Stationary Sources Global Warming	13B 07C 14G 13G 21D

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