United States
Environmental Protection
Agency

GRI-94 / 0257.27
EPA - 600/R-96-080j
June 1996

Research and Development

METHANE EMISSIONS FROM THE NATURAL GAS INDUSTRY

Volume 10: Metering and Pressure Regulating Stations in Natural Gas Transmission and Distribution

Prepared for

Energy Information Administration (U. S. DOE)

Prepared by

National Risk Management
Research Laboratory
Research Triangle Park, NC 27711

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GRI-94/0257.27

EPA-600/R-96-080j
June 1996

METHANE EMISSIONS FROM THE NATURAL GAS INDUSTRY, VOLUME 10: METERING AND PRESSURE REGULATING STATIONS IN NATURAL GAS TRANSMISSION AND DISTRIBUTION

FINAL REPORT

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For

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DISCLAIMER

NOTE: EPA's Office of Research and Development quality assurance/quality control (QA/QC) requirements are applicable to some of the count data generated by this project. Emission data and additional count data are from industry or literature sources, and are not subject to EPA/ORD's QA/QC policies. In all cases, data and results were reviewed by the panel of experts listed in Appendix D of Volume 2.

RESEARCH SUMMARY

Title	Methane Emissions from the Natural Gas Industry, Volume 10: Metering and Pressure Regulating Stations in Natural Gas Transmission and Distribution Final Report
Contractor	Radian International LLC GRI Contract Number 5091-251-2171 EPA Contract Number 68-D1-0031
Principal Investigators	Lisa M. Campbell Blake E. Stapper
Report Period	March 1991 - June 1996 Final Report
Objective	This report describes a study to quantify the annual methane emissions from metering and pressure regulating stations in natural gas transmission and distribution.
Technical Perspective	The increased use of natural gas has been suggested as a strategy for reducing the potential for global warming. During combustion, natural gas generates less carbon dioxide (CO_2) per unit of energy produced than either coal or oil. On the basis of the amount of CO_2 emitted, the potential for global warming could be reduced by substituting natural gas for coal or oil. However, since natural gas is primarily methane, a potent greenhouse gas, losses of natural gas during production, processing, transmission, and distribution could reduce the inherent advantage of its lower CO_2 emissions. To investigate this, Gas Research Institute (GRI) and the U.S. Environmental Protection Agency's Office of Research and Development (EPA/ORD) cofunded a major study to quantify methane emissions from U.S. natural gas operations for the 1992 base year. The results of this study can be used to construct global methane budgets and to determine the relative impact on global warming of natural gas versus coal and oil.
Results	The national annual emissions from metering/pressure regulating stations are 27 Bscf ± 85% and 4.5 Bscf ± 835% for distribution and transmission, respectively.

Based on data from the entire program, methane emissions from natural gas operations are estimated to be 314 ± 105 Bscf for the 1992 base year. This is about 1.4 ± 0.5% of gross natural gas production. The overall program also showed that the percentage of methane emitted for an incremental increase in natural gas sales would be significantly lower than the baseline case.

The program reached its accuracy goal and provides an accurate estimate of methane emissions that can be used to construct U.S. methane inventories and analyze fuel switching strategies.

Technical Approach

Metering/pressure regulating stations in gas distribution include both transmission-to-distribution custody transfer and the downstream pressure reduction stations. The primary losses from these stations include fugitive emissions and emissions from pneumatic devices. The emissions from these stations are dependent upon the type of station, inlet pressure of the station, and whether the station is located in a vault or above-ground. Annual emissions were determined by developing emission factors and extrapolating these data based on activity factors, where the national annual emissions are the product of the emission factor and activity factor.

A total of 95 metering/pressure regulating facilities were measured at 13 different distribution and transmission companies using a tracer gas technique. The emissions data for the distribution stations were stratified into categories to account for differences between station characteristics and to minimize bias from a disproportionate sampling approach. The emission factors derived from the tracer measurement data were stratified into station type, inlet pressure, and location categories.

Activity factors for the distribution metering/pressure regulating stations were developed from demographic information provided by 12 distribution companies. The station counts provided by the companies were disaggregated by station type and inlet pressure range. The miles of main pipeline were used to extrapolate the individual company data to a national estimate of the number of stations in each category. To disaggregate the regulating stations into location categories (i.e., vaults versus above-ground), data were obtained from five distribution companies and the averages applied to the national extrapolation.

Transmission metering/pressure regulating stations include transmission-to-transmission custody transfer and transmission-to-customer transfer (i.e., farm taps and direct industrial sales). Emission factors for the transmission segment were derived from the tracer measurement database for metering/pressure regulating stations, and the activity factors were based on site survey data from six transmission companies. The emission and activity factors were subdivided into transmission interconnects, farm taps, and direct industrial sales categories.

Project Implications

For the 1992 base year the annual methane emissions for the U.S. natural gas industry are 314 Bscf ± 105 Bscf (± 34%). This is equivalent to 1.4% ± 0.5% of gross natural gas production. Results from this program were used to compare greenhouse gas emissions from the fuel cycle for natural gas, oil, and coal using the global warming potentials (GWPs) recently published by the Intergovernmental Panel on Climate Change (IPCC). The analysis showed that natural gas contributes less to potential global warming than coal or oil, which supports the fuel switching strategy suggested by IPCC and others.

In addition, results from this study are being used by the natural gas industry to reduce operating costs while reducing emissions. Some companies are also participating in the Natural Gas-Star program, a voluntary program sponsored by EPA's Office of Air and Radiation in cooperation with the American Gas Association to implement cost-effective emission reductions and to report reductions to the EPA. Since this program was begun after the 1992 baseline year, any reductions in methane emissions from this program are not reflected in this study's total emissions.

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1.0 SUMMARY

This report is one of several volumes that provide background information supporting the Gas Research Institute (GRI) and U.S. Environmental Protection Agency Office of Research and Development (EPA/ORD) methane emissions project. The objective of this comprehensive program is to quantify the methane emissions from the gas industry for the 1992 base year to within ± 0.5% of natural gas production starting at the wellhead and ending immediately downstream of the customer's meter.

This report documents the approach used to quantify methane emissions from metering and pressure regulating facilities in natural gas transmission and distribution. A tracer measurement technique was developed and used as the method to quantify methane emissions from metering and pressure regulation facilities. A total of 95 tracer measurements were used to derive the emission factors for determining emissions from metering/pressure regulating stations in both the transmission and distribution segments of the gas industry. The total emissions are a product of the emission factor and activity factor, which were stratified into inlet pressure and location (above-ground versus in a vault) categories to improve the precision of the emissions estimate.

Metering/pressure regulating stations in the distribution segment include both transmission-to-distribution custody transfer points and the downstream pressure reduction stations. The emission factors for distribution are based on the average measured emissions for each station category and the activity factors are based on the average data supplied by twelve distribution companies. The annual methane emissions for the distribution segment of the gas industry are around 27 billion standard cubic feet (Bscf), with a 90% confidence interval of ± 85%.

For the transmission segment, the stations include transmission-to-transmission custody transfer points and transmission-to-customer transfer. Emission factors for the transmission segment are derived from the tracer measurement database for

metering/pressure regulating stations and the activity factors are based on survey data from six transmission companies. The annual methane emissions for the transmission segment are 4.5 Bscf, with a 90% confidence interval of ± 835%.

2.0 INTRODUCTION

Methane emissions from metering and pressure regulating (M&R) stations were identified early in the GRI/EPA methane emissions study as potentially significant sources. The primary losses from these stations include fugitive emissions and pneumatic device emissions. Fugitive emissions are leakage from the sealed surfaces of valves, connections, pressure relief valves, and open-ended lines. Some pressure regulating stations use gas-operated pneumatic devices to position the pressure regulators. Depending on the design, these gas-operated pneumatic devices can bleed gas to the atmosphere continuously and/or when the regulator is activated. Other designs bleed the gas downstream into the lower pressure pipeline and, therefore, have no losses associated with the pneumatic devices.

A method was developed to measure methane emissions from an entire facility using a tracer gas approach. The tracer measurement method has been described in a separate report by Aerodyne Research and Washington State University, *Results of Tracer Measurements of Methane Emissions from Natural Gas System Facilities*.[1] The tracer measurement data were used to quantify methane emissions from metering and pressure regulating stations in the distribution and transmission segments of the gas industry. This report describes the results of this analysis. Section 3 describes metering and pressure regulating facilities in gas production, transmission, and distribution. A discussion of the approach used for sampling and data analysis is described in Section 4. A summary of the emission factor and the activity factor is provided in Sections 5 and 6, respectively. Section 7 provides a summary of the total methane emissions results. This report is one of several volumes under the GRI/EPA methane emissions project.

3.0 METERING AND PRESSURE REGULATING FACILITIES

Following is a description of the facilities typical to each segment of the gas industry, as shown in Figure 3-1.

3.1 Production

Metering stations in the production segment of the gas industry are most commonly found at each well site and/or at each central separation facility. These meter runs are typically metering only with no pressure regulation. The purpose of the station varies from direct custody transfer to recording the amount of gas produced by each well for accounting purposes. The emissions from metering stations in the production segment were determined using fugitive emission factors combined with component counts from production site visits. The emissions from production metering stations are included in production well site fugitives and are documented in Volume 8 on equipment leaks.[2]

3.2 Transmission

Meter and pressure regulating stations are used in natural gas transmission to measure flow of gas at a custody transfer point, and/or to reduce and regulate pressure and flow into a downstream pipeline system. Some metering facilities do exist within compressor stations, but these are already accounted for in the compressor station emissions (and are documented in Volume 8 on equipment leaks).[2] In the transmission segment, separate metering/regulating facilities are usually fenced, above-ground facilities that contain valves, piping, and metering runs.

Metering/pressure regulating facilities included within the transmission segment are generally of the following type:

- Delivery to distribution (metering/pressure regulating);

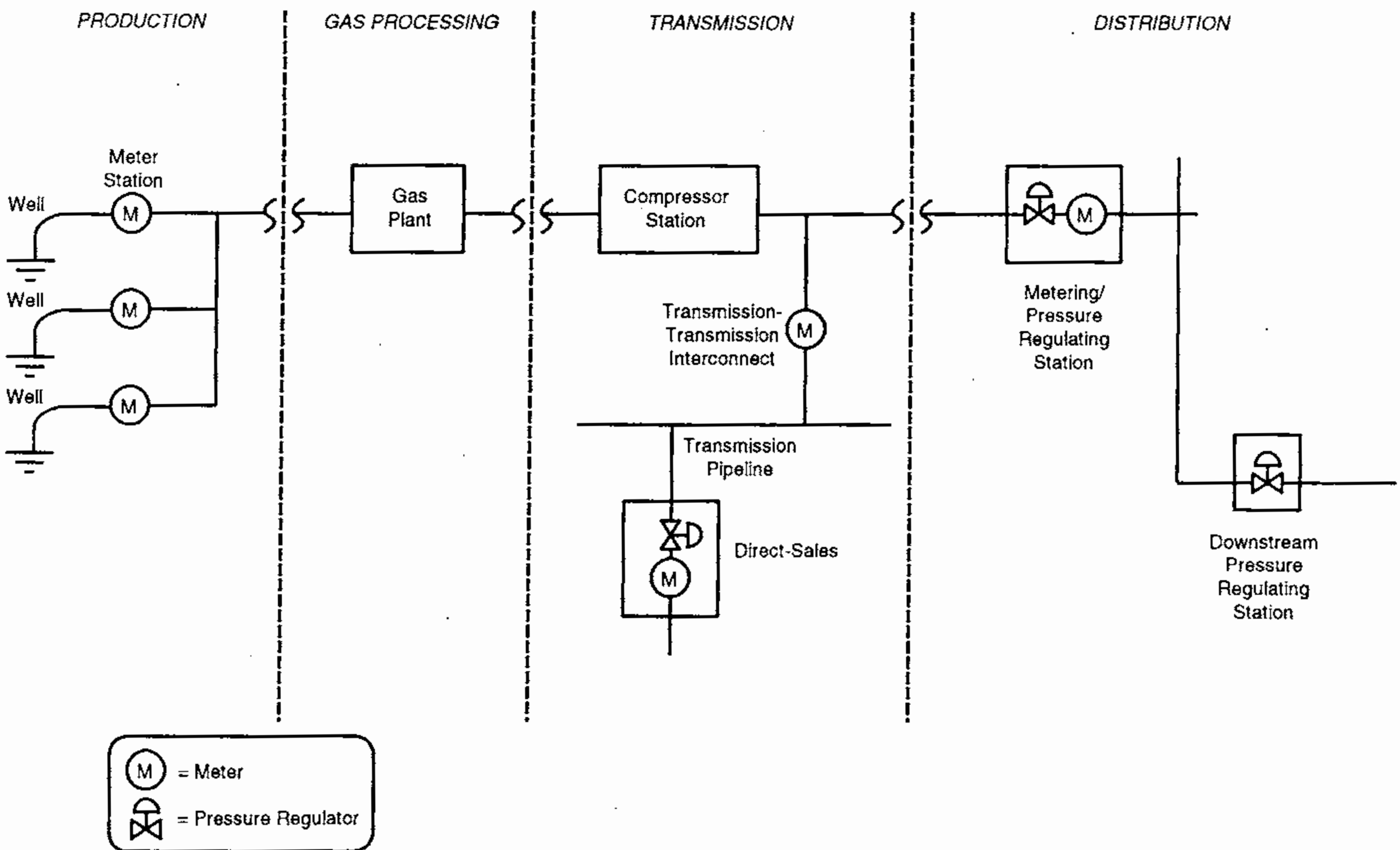

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Figure 3-1. Metering/Pressure Regulating Facilities in the Gas Industry

- Pressure reduction to inter-company transmission lines with low maximum allowable working pressure (MAWP);
- Interconnects/custody transfer (bi-directional) to another transmission company; and
- Direct sales (farm taps, direct industrial sales from transmission lines).

Delivery to distribution has been counted in the distribution segment metering/pressure regulating stations (i.e., city gates). There are some pressure reduction stations within transmission networks that reduce the pressure feeding a line that has a lower MAWP. However, the total count of these stations is negligible, and the transmission companies track them only as part of the total count for delivery to local distribution companies. Therefore, the number is accounted for in the distribution metering/regulating station population.

Most large transmission companies have interconnects with other transmission companies to allow for flexibility of supply. The stations can flow in either direction. The last category (direct sales) is comprised of two types. Of the two types, most industrial direct sales from transmission lines were still owned by LDCs, even if they only owned a few feet of pipeline. There is also a trend to let LDCs handle the farm taps, or to remove them entirely; however, many farm taps are still owned by transmission companies. In the transmission segment, stations include both metering stations and metering/pressure regulating stations.

3.3 Distribution

Distribution stations include both the transmission-to-distribution custody transfer points and the downstream pressure reduction stations. The transmission-to-distribution custody transfer stations are usually referred to as gate stations and include both metering and pressure regulation to reduce the pressure from the transmission line pressures of several hundred pounds per square inch gauge (psig) to the high pressure distribution lines in the local distribution company. In most configurations, the gate station consists of metering runs owned and operated by the transmission company and pressure regulators and sometimes meters, owned and operated by the distribution company. For the purposes of this study, all facilities at a gate station were included as a single source of emissions and classified under the distribution segment of the industry.

Downstream pressure regulating stations reduce the pressure even further as the gas is transported to the customer. Customer meters are not included under this category of leakage because the tracer measurement technique was not used to measure emissions from these meters. [Bagging and screening fugitive measurement methods (EPA Method 21[3]) were used to quantify the losses from customer meters.] The emissions from customer meters in the distribution segment of the gas industry are documented in Volume 8 on equipment leaks.[2]

4.0 APPROACH TO DATA ANALYSIS

Data were collected and measurements were made on 95 metering/pressure regulating stations in the natural gas industry. These data were extrapolated to obtain annual emissions for similar stations throughout the industry. The extrapolation techniques for quantifying nationwide emissions were developed so that the emissions for metering/pressure regulating stations could be quantified with a relatively high level of precision and negligible bias.

The extrapolation approach is a method to scale-up the average emissions from a source, determined by a limited sampling effort, to represent the entire population of similar sources in the gas industry. The extrapolation approach uses the concept of emission and activity factors to quantify emissions based on the limited number of samples. For metering/pressure regulating stations, the emission factor is quantified in terms of emission rate per station and the activity factor is defined as total number of stations. These factors are defined in such a way that their product equals the total emissions from a source. The product of the emission and activity factors equals the annual nationwide emissions from a source in the natural gas industry:

$$EF \times AF = \text{National Emissions} \quad \textbf{(1)}$$

4.1 Sampling Approach

A truly random sampling technique was difficult to implement in the program because little was known about the demographics of metering and pressure regulating stations throughout the industry. Therefore, companies in different geographical areas were selected and contacted to volunteer sites for testing. Initial measurements were made as part of a multi-city study[4] sponsored by GRI and EPA Office of Air and Radiation during the first stage of data collection. These data were analyzed to determine parameters that may influence leakage and could be used to stratify the emissions dataset. By using a stratified approach, the resources required to achieve an acceptable accuracy target could potentially be reduced if the variability within strata is reduced. Furthermore, the resources available could then be concentrated in the categories that contribute the most to the overall uncertainty, thus providing the greatest impact on reducing the uncertainty in the emissions from this category.

Potential parameters were identified that may influence leakage from metering and pressure regulating stations. These parameters included:

- Number of components at a station, including valves, connections, open-ended lines, and pressure relief valves;
- Operating pressure;
- Leak detection and repair practices of the company; and
- Pressure regulator bleed status (bleed to atmosphere or downstream).

Data from companies on component counts at each station in the system were generally not available. Therefore, a surrogate for the component counts at a station was needed. After review of the data, the stations with both metering and pressure regulating equipment were found to have a larger number of components than stations with either metering or pressure regulating equipment alone. Also, in general, there was a correlation between component count and inlet pressure of the station. Stations with higher inlet pressures were generally larger in size with a higher number of components than stations with lower inlet pressures. Therefore, the station type (metering, pressure regulating, or combined metering/pressure regulating) and the inlet pressure of the station were determined to be statistically significant strata for dividing the population of stations, and could be used to replace component counts.

Stations were divided into four inlet pressure ranges, based on typical company design practices. The first category, >300 psig, was selected to include the high pressure transmission-to-distribution custody transfer stations. The remaining three inlet pressure categories, 100-300, 40-100, and <40 psig, are typical of the downstream operating pressure ranges of most distribution systems.

Leak detection and repair practices of the companies were essentially the same for the companies contacted. However, regulating stations located in vaults are screened for leakage on a regular interval to prevent the potential for an explosive gas mixture in the confined space of an underground vault. Regulating stations located above-ground are not subject to rigorous leak detection screening programs as compared to stations in vaults. Therefore, the location of the station in a vault versus above-ground was used as a means to distinguish between differing levels of leak detection and repair practices.

The bleed status of the station was determined to be an important parameter in predicting leakage from metering and pressure regulating stations. However, the bleed status of stations within a company's system was not readily available; therefore, stations were randomly selected to provide a representative sample set and minimize bias. The above-ground stations were randomly chosen and include sites both with and without atmospheric bleed regulators to minimize the potential for bias due to regulator design differences. Because sites were randomly chosen by the host companies for testing, the total sample set should be representative of the average bleed status of stations within the United States.

Furthermore, regulating stations located in vaults did not have regulators that bleed to the atmosphere. Therefore, the data stratification by location (in vaults versus above-ground) accounts to some extent for bleed status.

To minimize bias in the final extrapolation of the data to annual emissions, the parameters that were used to stratify the sample set included:

- Station type (metering; pressure regulating; or combined metering/pressure regulating);

- Inlet pressure range (>300 psig, 100-300 psig, 40-100 psig, and <40 psig); and
- Location (in vaults versus above-ground).

Table 4-1 presents the categories used in the meter and pressure regulating station population stratification.

TABLE 4-1. STRATIFICATION OF POPULATION FOR SAMPLING APPROACH

Station Type	Inlet Pressure, psig	Location (Vault or Aboveground)
M&R	>300	A-G
M&R	100 - 300	A-G
M&R	40 - 100	A-G
M&R	<40	A-G
Regulating	>300	Vault/A-G
Regulating	100 - 300	Vault/A-G
Regulating	40 - 100	Vault/A-G
Regulating	<40	Vault/A-G

A second stage of measurement campaigns was later initiated to collect additional data to improve precision and evaluate the potential for bias in the data. A disproportionate stratified random sampling approach was defined to collect sufficient data to determine the influence of the parameters on leakage. This means that the population of meter/pressure regulating stations was stratified according to the parameters that impact leakage, and samples were randomly chosen within the strata. The number of stations sampled per strata was intentionally not in proportion to the total population distribution. Since the activity factor is stratified into the same categories as the emission factor, a disproportionate number of samples can be collected in any single strata to improve the precision of the estimate.

Additional measurements were made at five distribution companies and three transmission/production companies. The companies contacted to participate in the study were selected from different regions of the country and asked to identify representative sites in each of the categories identified. The host companies randomly selected suitable sites for testing within a given strata. The actual testing of methane emissions using the tracer measurement approach was performed by Aerodyne Research and Washington State University.[1]

4.2 Quality Assurance/Quality Control

The tracer measurement approach was validated in proof of concept tests using a controlled release of methane and tracer gas. The measured average concentrations of methane and tracer compared to the release rates agreed to within 14%. This level of agreement is within the experimental uncertainty associated with the tracer release rate and the measured concentration.

A demonstration test of the tracer approach was conducted at a gas plant, where four individual tests were conducted on two separate days with different wind directions and downwind distances. The experimental results agreed to within 11%.

To help ensure that the tracer measurement data collected as part of the program were representative of the industry, host companies were asked to provide facilities within each of the designated categories, or strata, that they considered representative of their system. To the extent possible, these facilities were randomly selected. Facilities were not eliminated from the potential sample selection process because of either high or low emissions. Each facility identified as a potential test site was visited prior to making measurements to ensure that downwind tracer measurements could be made from a logistical standpoint and to rule out the possibility of other methane interferences in the vicinity.

5.0 EMISSION FACTOR SUMMARY

The emission factors are based on the tracer gas measurements made by Aerodyne Research and Washington State University.[1] The tracer measurement approach can be summarized as follows: a known quantity of tracer gas is released next to a source of methane emissions, and the downwind concentration ratio of methane to tracer gas is measured using real-time instruments and canisters (refer to Figure 5-1). Assuming similar dispersion characteristics, the methane emissions can be determined by the ratio of methane to tracer concentration and the release rate of tracer gas.

Emission factors were derived from the 95 tracer measurements made at a total of 13 different distribution and transmission companies. These data were segregated into categories based on the type of stations in the distribution and transmission segments, as described below.

5.1 Distribution Segment Emission Factor

Table 5-1 presents the number of total measurements made in each of the categories using the tracer measurement approach. (A detailed summary of the individual emissions measurements is presented in the Aerodyne/Washington State University report.)[1] Also shown in Table 5-1 are the average emission factors derived from the data with the standard deviation and 90% confidence limits. As shown, the data were stratified by station type (metering/pressure regulating, regulating, and metering); inlet pressure range (>300, 100-300, 40-100, and <40 psig); and location (vault versus above-ground). Most data were collected in the high pressure categories (>300 psig) for both the metering/pressure regulating station and regulating station categories because these stations had the highest emission factors (180 and 162 scf/station-hr, respectively) and, correspondingly the highest uncertainty.

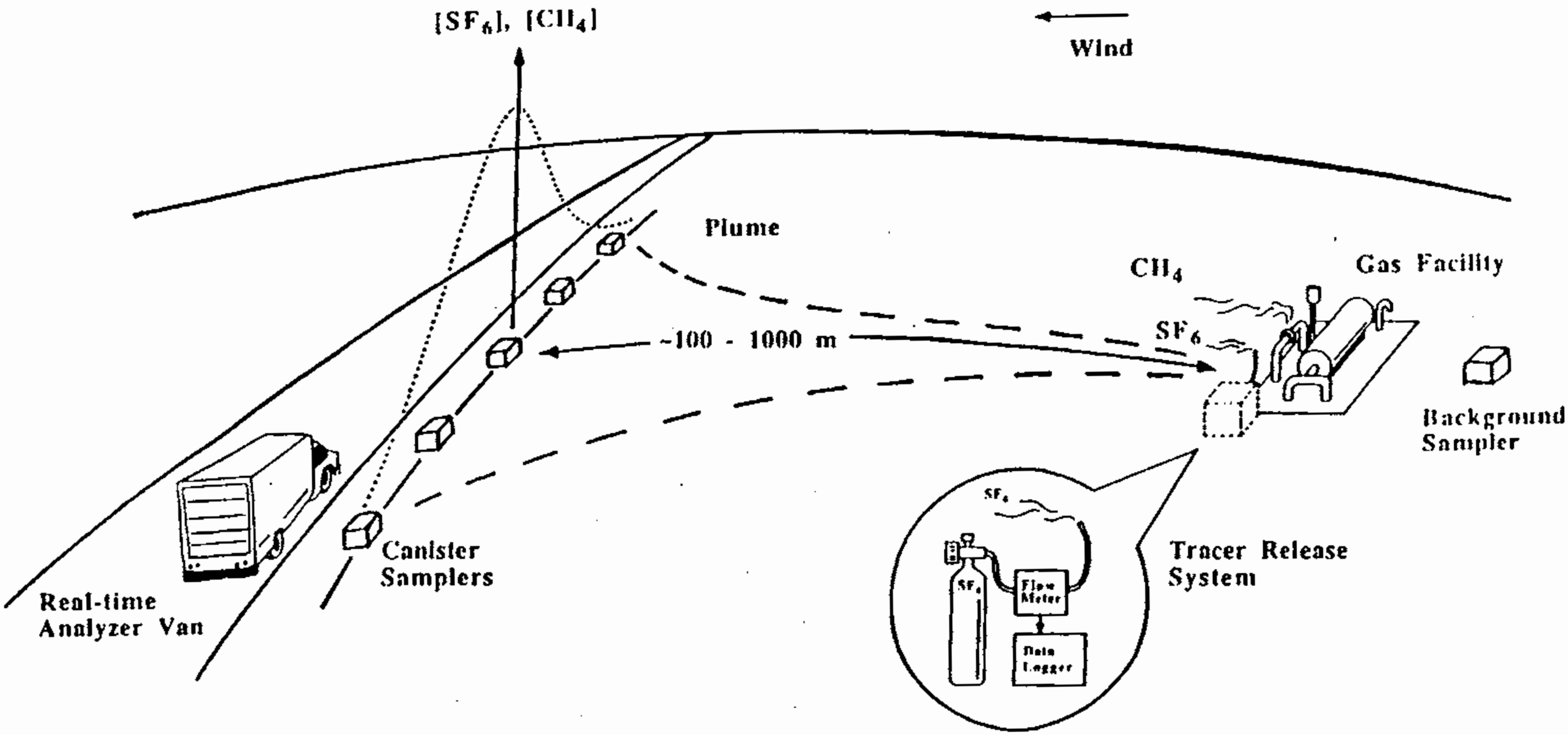

Figure 5-1. Schematic of the Tracer Ratio Emission Measurement Method

TABLE 5-1. EMISSION FACTOR SUMMARY FOR DISTRIBUTION METERING AND PRESSURE REGULATING STATIONS

Station Type	Inlet Pressure (psig)	Location (vault or above-ground)	Number of Samples	Average Emission Factor (scf/sta-hr)	Standard Deviation of Emission Factor (scf/sta-hr)	90% Confidence Interval of Emission Factor[a] (scf/sta-hr)
M&R	>300	A-G	31	179.8	236.1	69.8
M&R	100-300	A-G	6	95.6	130.6	107.4
M&R	<100	A-G	3	4.3	5.8	9.8
Reg.	>300	A-G	13	161.9	188.8	93.3
Reg.	>300	Vault	4	1.3	2.0	2.4
Reg.	100-300	A-G	7	40.5	36.4	26.7
Reg.	100-300	Vault	10	0.2	0.3	0.2
Reg.	40-100	A-G	7	1.0	1.1	0.8
Reg.	40-100	Vault	8	0.1	0.1	0.1
Reg.	<40	Vault	6	0.1	0.2	0.2

[a]90% confidence interval around the mean value (upper bound minus the mean).

As shown in Table 5-1, the emission factor is dependent upon the inlet pressure of the station, with emissions increasing as the inlet pressure increases. For example, metering/pressure regulating stations with an inlet pressure over 300 psig, between 100 and 300 psig, and less than 100 psig have average emission factors of 179.8, 95.6, and 4.3 scf/station-year, respectively. This is likely due to the observation that higher inlet pressure stations have more regulators, in general, or regulators that bleed to the atmosphere at higher rates, as well as a larger number of valves and other components.

As indicated, metering/pressure regulating stations have a higher overall emission rate than above-ground regulating stations in the same inlet pressure category. For example, metering/pressure regulating stations with an inlet pressure range of 100-300 psig have an average emission factor of 95.6 scf/station-hr. In contrast, above-ground regulating stations with an inlet pressure range of 100-300 psig have an average emission factor of 40.4 scf/station-hr. The higher emission rates from metering/pressure regulating stations as compared to regulating stations in the same inlet pressure category is likely due to the higher overall component counts (i.e., connections, valves, pressure relief valves, etc.) for stations with both meters and pressure regulators.

Regulating stations located in vaults have significantly lower emission rates than above-ground regulating stations of the same inlet pressure range. For example, above-ground regulating stations with an inlet pressure >300 psig have an average emission factor of 161.9 scf/station-hr as compared to regulating stations in vaults >300 psig at 1.3 scf/station-hr. The reason that regulating stations in vaults have low emissions is because these facilities do not have atmospheric-bleed regulators for safety reasons. (Atmospheric-bleed regulators located in the confined space of a vault would lead to gas build-up within the vault, leaks are more easily detected, and vaults are screened for leakage on a regular basis.) Some above-ground regulating stations do have regulators that bleed to the atmosphere, resulting in increased emissions from these stations.

Although no data were collected for above-ground regulating stations with an inlet pressure less than 40 psig, the leak rate for this category is expected to be lower than 1.0 scf/station-hr (the emission rate for above-ground regulating stations with an inlet pressure between 40 and 100 psig). Because of the very low emission rate, above-ground regulating stations with an inlet pressure less than 40 psig are not a significant category and the same emission factor for stations in vaults (<40 psig) was used to quantify emissions.

The standard deviation of each stratified emission factor was calculated based on the variability in the emissions test data. The precision of each stratified emission factor represents the 90% confidence interval and is calculated as:

$$P = t \times s \, / \, (n)^{1/2} \tag{2}$$

where:

P = Precision of the estimate at the 90% level of confidence;

t = t-statistic at the 90% level of confidence (function of sample size);

s = Standard deviation of the estimate; and

n = Sample size.

A discussion of this statistical approach is documented in Volume 4 on statistical methodology.[5]

5.2 Transmission Segment Emission Factor

The average emissions for transmission metering/pressure regulating stations were determined by sorting the tracer measurement data based upon the station descriptions. The average design for a transmission metering/pressure regulating station was based upon technical descriptions of station types given by several transmission experts.

Direct-Sales Stations

Transmission farm taps and industrial meters are both direct-connects to high pressure pipelines, and will have 1 or 2 pressure regulators (as opposed to 3 to 22 regulators at city gate stations) in addition to a meter. The pressure regulator is a self-contained device and, therefore, does not have significant pneumatic emissions. Therefore, the tracer measurement dataset was sorted and adjusted for the transmission segment direct-sales stations as follows:

- Includes stations with only one regulator;
- Includes only pressure regulating stations in vaults (which were known to have no-bleed regulators similar to farm taps);
- Does not include regulator only stations in the low pressure range (< 100 psig inlet pressure); and
- Does not include meter only stations.

There were 14 samples in the sorted transmission direct sales (farm taps and industrial meters) dataset, with an average of 31.2 scf/station-day used as the emission factor.

Transmission Company Interconnect Stations

Emissions from transmission company interconnect meter stations were estimated by sorting the tracer dataset for metering/pressure regulating stations with an inlet pressure above 100 psig. A total of 37 samples met this criterion, with an average of 3,984 scf/station-day. Table 5-2 shows the average emission factors and 90% confidence intervals for the two station categories within the transmission segment.

TABLE 5-2. SUMMARY OF TRANSMISSION SEGMENT EMISSION FACTORS

Station Type	Number of Samples Used to Estimate Emission Factor	Average Emission Factor (scf/sta-day)
Transmission-to-Transmission Company Interconnect Points	37	3,984 ± 80%[a]
Farm Taps and Direct Industrial Sales	14	31.2 ± 80%[a]

[a] 90% confidence interval.

6.0 ACTIVITY FACTOR SUMMARY

The activity factor for metering/pressure regulating stations in the distribution and transmission segments of the gas industry were derived based on extrapolation of individual company data to an annual national total. The activity factors represent the total estimated populations of metering/pressure regulating stations, broken down by station category.

6.1 Distribution Segment Activity Factor

For the distribution segment of the industry, the emission factor data were stratified into station type, inlet pressure, and location categories. Therefore, the activity factor was also stratified to quantify emissions from stations in each segment of the gas industry.

For distribution stations, a questionnaire was sent to distribution companies participating in the underground leak measurement program and the companies participating in the metering/regulating station measurement program. A total of twelve companies provided demographic information on the stations in their distribution network. The station counts provided by the companies were disaggregated by station type and inlet pressure range. Table 6-1 shows the demographic information provided by the respective companies.

To extrapolate the individual company data to annual national emissions of the number of stations, a known industry statistic was used. The individual company demographic data were combined with the miles of main and total gas throughput for each company to determine the number of stations in each category on a per mile main and per unit gas throughput basis. A linear regression analysis was performed on the number of stations versus miles of mains and total gas throughput, respectively. It was concluded that the correlation of stations versus miles of main should be used in the extrapolation instead of stations versus throughput, since the correlation to miles of main was stronger.

TABLE 6-1. ACTIVITY DATA PROVIDED BY INDIVIDUAL COMPANIES

Station Type/ Inlet Pressure Range (psig)	Comp. A	Comp. B	Comp. C	Comp. D	Comp. E	Comp. F	Comp. G	Comp. H	Comp. I	Comp. J	Comp. K	Comp. L[a]
M&R Stations												
>300	14	6	18	10	--	25	1	0	--	29	128	15
100-300	8	15	0	0	--	600	0	0	--	286	431	2
40-100	1	2	0	0	--	0	0	0	--	170	252	0
<40	0	0	0	0	--	0	0	0	--	48	97	0
Regulating Stations												
>300	720	0	0	0	0	30	2	1	34	29	87	0
100-300	1,187	0	258	94	25	210	0	0	44	286	835	273
40-100	207	1,257	0	325	44	400	11	8	136	170	2,122	120
<40	12	0	130	28	203	1,000	0	0	53	48	935	0
Miles Main	40,930	3,634	7,594	4,000	3,924	14,900	64	78	4,109	3,396	29,073	1,263

[a] Not considered representative of national average.

The average number of stations per mile in each category was estimated as the average of the values from eleven of the twelve companies supplying data. Based on conversations with one of the companies supplying data, the average number of stations per mile for this company was not considered representative of typical industry practices. Therefore, this company was not included in the overall average, but rather was treated separately. [The mileage of mains from this company was subtracted from the total U.S. mileage (836,760 miles[6]) to calculate the total number of stations excluding this single company; then, the number of stations from this company were added to derive a national total.]

Table 6-2 shows the average number of stations per mile in each of the station type/inlet pressure categories. For the regulating stations in vaults versus above-ground, the percentage breakdown was provided by five companies representing urban, rural, and suburban areas. On average, 37% of the regulating stations with an inlet pressure greater than 300 psig are located in vaults. For regulating stations with an inlet pressure between 40 and 300 psig, it was found that the majority of stations in urban areas were in vaults and in rural areas were above-ground. On average, it was estimated that 31% of the stations are located in vaults with an inlet pressure between 100 and 300 psig. For regulating stations with an inlet pressure between 40 and 100 psig, 47% of the stations are located in vaults. Based on the data collected, 68% of the low pressure (<40 psig inlet pressure) stations are located in vaults.

The standard deviation of each activity factor estimate was calculated based on the variability in the estimated number of stations per mile provided by individual companies. The precision of the activity factor represents the 90% confidence interval.

TABLE 6-2. ACTIVITY FACTOR SUMMARY FOR METERING AND PRESSURE REGULATING STATIONS IN DISTRIBUTION SEGMENT

Station Type	Inlet Pressure (psig)	Location (vault or above-ground)	Stations per Mile	Average Activity Factor (stations)	Standard Deviation of Activity Factor (stations)	90% Confidence Interval of Activity Factor[a] (stations)
M&R	>300	A-G	0.004	3,460	3,965	2,458
M&R	100-300	A-G	0.016	13,335	22,728	14,091
M&R	<100	A-G	0.009	7,127	13,550	8,401
Reg.	>300	A-G	0.005	3,995	4,946	2,702
Reg.	>300	Vault	0.003	2,346	2,905	1,587
Reg.	100-300	A-G	0.015	12,273	13,656	7,461
Reg.	100-300	Vault	0.007	5,514	6,136	3,352
Reg.	40-100	A-G	0.043	36,328	42,785	23,375
Reg.	40-100	Vault	0.039	32,215	37,942	20,729
Reg.	<40	b	0.018	15,377	18,161	9,922

[a] 90% confidence interval around the mean value (upper bound minus the mean).
[b] The above-ground and in-vault categories were combined for the low pressure regulating station category.

6.2 Transmission Segment Activity Factor

The transmission stations include transmission-to-transmission custody transfer, which are typically metering only stations, and transmission-to-customer (not including the local distribution company) transfer or direct sales stations, which include both metering and pressure regulation in most cases. These direct sales stations are comprised mostly of farm taps, which have a single regulator and a meter.

The population of the two categories of transmission metering/pressure regulating stations (direct-sales and interconnect stations) were calculated from survey data provided by the metering departments of three large (over 10,000 miles of pipeline) transmission companies, and from three companies with fewer than 10,000 miles of pipeline.

The overall average number of stations per mile was derived from an average of each company's station count for both transfer stations and direct sales stations, as shown in Table 6-3.

TABLE 6-3. TRANSMISSION METERING/PRESSURE REGULATING STATION ACTIVITY FACTORS

Company	Meter/Pressure Regulating Station Populations			
	Transfer to Another Transmission Company	Direct Sales: Farm Taps	Direct Sales: Direct Industrial Sales	Miles of Pipeline
1	323	23		Confidential
2	5	0		Confidential
3	60	0		Confidential
4	62	48		Confidential
5	40	3,800		Confidential
6	0	10,000		Confidential
Total	490	13,871	658	Total miles in dataset = 55,045 (19% of U.S. total)
Total U.S. Activity Factor Extrapolated by Miles	2,533 ± 776%[a]	71,690 ± 787%[a]	937 ± 100%[a]	284,500

[a] 90% confidence interval.

Only five of the six companies responding to the survey reported having interconnects with other transmission companies. The activity factor was calculated from the total number of interconnects (490) divided by the total miles (55,045) from the company data and extrapolated to annual national emissions using the national pipeline mileage.[7] The activity factor for transmission interconnect stations is 2,533 stations ± 776%.

The number of farm taps reported is highly variable between companies and appears to be regional. Four of the six companies reported farm taps within their system. The activity factor is derived from the overall number of farm taps per total miles from the six companies and extrapolated to annual national emissions using the total transmission pipeline miles in the United States.[7] The activity factor for farm taps is 71,690 ± 787%.

The activity factor for direct industrial sales was developed from data reported to the Federal Energy Regulatory Commission (FERC).[8] FERC reports individual industrial sales greater than 50,000 Mcf, but combines the total gas sales less than 50,000 Mcf. To estimate the number of industrial sales stations less than 50,000 Mcf, the total amount of gas sold was divided by 25,000, which was the assumed rate per meter for meters grouped into the < 50,000 Mcf category. The 90% confidence bound of ± 100% was assigned due to the uncertainty in the data and calculation approach.

7.0 EMISSIONS RESULTS SUMMARY

This section describes the national methane emissions from metering/pressure regulating stations in the distribution and transmission segments. The annual emissions are calculated as a product of the activity factor and emission factor for each category of station.

7.1 Distribution Segment Emissions

The annual methane emissions from metering/pressure regulating stations in the distribution segment was derived by multiplying the emission factor by the activity factor in each category, and summing over all categories. Table 7-1 presents the annual emissions derived from the activity and emission factors. Annual emissions from metering/pressure regulating stations in the distribution segment are around 27 billion standard cubic feet (Bscf).

As shown, the category contributing the most to the overall methane emissions are the high pressure metering/pressure regulating stations with an inlet pressure over 100 psig (5.4 and 11.2 Bscf for >300 psig and 100-300 psig categories, respectively) and the high pressure above-ground regulating stations with an inlet pressure over 100 psig (5.7 and 4.4 for >300 and 100-300 psig categories, respectively). All remaining categories combined contribute less than 1 Bscf. Regulating stations in vaults were nearly insignificant contributors to emissions with combined emissions less than 0.1 Bscf.

TABLE 7-1. EMISSIONS FROM METERING AND PRESSURE REGULATING STATIONS IN DISTRIBUTION SEGMENT

Station Type	Inlet Pressure (psig)	Location (vault or above-ground)	Average Emission Factor (scf/sta-hr)	Average Activity Factor (stations)	Annual Emissions (Bscf)	90% Confidence Interval of Emission Estimate[a] (Bscf)
M&R	>300	A-G	179.8	3,460	5.5	4.7
M&R	100-300	A-G	95.6	13,335	11.2	21.7
M&R	40-100	A-G	4.3	7,127	0.3	1.2
Reg.	>300	A-G	161.9	3,995	5.7	5.5
Reg.	>300	Vault	1.3	2,346	0.03	0.06
Reg.	100-300	A-G	40.5	12,273	4.4	4.3
Reg.	100-300	Vault	0.2	5,514	0.01	0.01
Reg.	40-100	A-G	1.0	36,328	0.3	0.4
Reg.	40-100	Vault	0.1	32,215	0.02	0.02
Reg.	<40	b	0.1	15,377	0.02	0.03
Total				131,970	27.3	23.3

[a]90% confidence interval around the mean value (upper bound minus the mean).
[b]The above-ground and in-vault categories were combined for the low pressure regulating station category.

The precision of the annual emissions is calculated by statistically combining the respective precision estimates of the activity and emission factors in each strata. The equation used to calculate the overall precision of the annual national emissions is:

$$\text{Precision} = [(P_{af}^2 \times EF^2) + (P_{ef}^2 \times AF^2) + (P_{af} \times P_{ef})^2]^{1/2}$$

where:

EF = Emission factor, scf/station-yr;

AF = Activity factor, number of stations;

P_{af} = Precision of the activity factor, expressed as an absolute value (number of stations);

P_{ef} = Precision of the emission factor, expressed as an absolute value (scf/station-yr).

The overall precision of the annual emissions from metering/pressure regulating stations in each category is then calculated as follows:

$$\text{Overall Precision} = (\Sigma\ \text{Precision}_i^2)^{1/2}$$

(The statistical approach is documented in Volume 4.[5])

As shown in Table 7-1, the category contributing the most to the overall uncertainty (i.e., 21.7 Bscf) is metering/pressure regulating stations with an inlet pressure of 100-300 psig. The total precision was calculated as 23.3 Bscf or ± 85%, based on a 90% confidence interval.

7.2 Transmission Segment Emissions

The annual methane emissions from metering/pressure regulating stations in the transmission segment were derived by multiplying the emission factor by the activity factor for direct sales and transmission custody transfer stations. Table 7-2 presents the emissions derived from the activity and emission factors. As shown, the annual emissions are 4.5 Bscf, with custody transfer and direct sales stations contributing 3.7 and 0.8 Bscf, respectively. The precision of the estimate is 37.8 Bscf or ± 835%, which represents the 90% confidence interval around the estimated mean emissions.

TABLE 7-2. EMISSIONS ESTIMATE FROM TRANSMISSION METERING/PRESSURE REGULATING STATIONS

Station Type	Emission Factor (scf/sta-day)	Activity Factor (stations)	Annual Emissions (Bscf)	90% Confidence Interval of Emissions[a] (Bscf)
Transfer Stations	3,984	2,533	3.7	36.9
Direct Sales Stations	31.2	72,315	0.8	8.3
Total		74,848	4.5	37.8

[a] 90% confidence interval around the mean value (upper bound minus the mean).

8.0 REFERENCES

1. Aerodyne Research, Inc., Washington State University, and University of New Hampshire. *Results of Tracer Measurements of Methane Emissions from Natural Gas System Facilities*, prepared for Gas Research Institute, May 1994.

2. Hummel, K.E., L.M. Campbell, and M.R. Harrison. *Methane Emissions from the Natural Gas Industry, Volume 8: Equipment Leaks.* Final Report, GRI-94/0257.25 and EPA-600/R-96-080h. Gas Research Institute and U.S. Environmental Protection Agency, June 1996.

3. *Code of Federal Regulations*, Title 40, Part 60, Appendix A. National Archives and Records Administration, Office of the Federal Register, July 1, 1995.

4. Aerodyne Research, Washington State University, and University of New Hampshire. *Measurement of Methane Emissions from Natural Gas Systems Using Atmospheric Tracer Methods.* GRI-94/0275.43. Gas Research Institute, March 1995.

5. Williamson, H.J., M.B. Hall, and M.R. Harrison. *Methane Emissions from the Natural Gas Industry, Volume 4: Statistical Methodology*, Final Report, GRI-94/0257.21 and EPA-600/R-96-080d. Gas Research Institute and U.S. Environmental Protection Agency, June 1996.

6. U.S. Department of Transportation, Research and Special Programs Administration, 1991.

7. American Gas Association. *Gas Facts*: 1992 Data, Arlington, VA, 1993.

8. Federal Energy Regulatory Commission (FERC) Form No. 2, page 306: Annual Report of Major Natural Gas Companies, 1992 database.

APPENDIX A

Source Sheets

D-1
DISTRIBUTION SEGMENT SOURCE SHEET

SOURCES: Meter/Pressure Regulating Stations
OPERATING MODE: Normal Operations
EMISSION TYPE: Steady, Fugitive
ANNUAL EMISSIONS: 27.3 +/- 23.3 Bscf

BACKGROUND:
Metering/pressure regulating stations are located throughout the distribution network to meter gas where a custody transfer occurs and/or to reduce and regulate the pressure in the downstream main pipeline. Emissions from fugitive losses and normal operations at meter and pressure regulating stations include both continuous and intermittent emissions from equipment components, such as pneumatic devices, valves, flanges, flow meters, and pressure regulators.

EMISSION FACTOR: (scf/station-hour)

The emission factor and standard deviation are given below for facilities located in vaults and above ground for different inlet pressure ranges:

Station Type	Inlet Pressure (psig)	Location in Vault?	Number of Samples	Average Emission Factor (scf/sta.-hr)	Standard Deviation of Emission Factor (scf/sta.-hr)	Precision of Emission Factor (scf/sta.-hr)
M&R	>300	N	31	179.8	236.1	69.8
M&R	100-300	N	6	95.6	130.6	107.4
M&R	<100	N	3	4.3	5.8	9.8
Regulating	>300	N	13	161.9	188.8	93.3
Regulating	>300	Y	4	1.3	2.0	2.4
Regulating	100-300	N	7	40.5	36.4	26.7
Regulating	100-300	Y	10	0.2	0.3	0.2
Regulating	40-100	N	7	1.0	1.1	0.8
Regulating	40-100	Y	8	0.1	0.1	0.1
Regulating	<40	Y	6	0.1	0.2	0.2

The emission factors were derived from data collected using a tracer gas measurement method. Downwind tracer measurements were performed by Aerodyne/Washington State University at 2 West Coast companies, 3 northeastern companies, 4 midwestern towns, and 3 southern plains towns. In total, 95 measurements were performed on metering/regulating stations in distribution and transmission systems.

The test data were analyzed to evaluate the differences in emissions from stations with different configurations (i.e., metering/regulating versus regulating only), inlet pressure ranges, and locations (i.e., in vaults versus above-ground). The test data were disaggregated into four distinct inlet pressure categories (>300 psig, 100-300 psig, 40-100 psig, and <40 psig), two station types (meter/pressure regulating facilities and pressure regulating facilities), and into stations in vaults versus above-ground, resulting in a total of 10 categories. These categories were selected for disaggregation of the data based on knowledge of the gas industry, and were confirmed to be statistically significant based on the data analyses.

ACTIVITY FACTOR: (number of stations)

The mean activity factor and standard deviation for each station type/inlet pressure/location category is given below:

Station Type	Inlet Pressure (psig)	Location in Vault?	Stations per Mile	Average Activity Factor (stations)	Standard Deviation of Activity Factor (stations)	Precision of Activity Factor (stations)
M&R	>300	N	0.004	3,460	3,965	2,458
M&R	100-300	N	0.016	13,335	22,728	14,091
M&R	<100	N	0.009	7,127	13,550	8,401
Regulating	>300	N	0.005	3,995	4,946	2,702
Regulating	>300	Y	0.003	2,346	2,905	1,587
Regulating	100-300	N	0.015	12,273	13;656	7,461
Regulating	100-300	Y	0.007	5,514	6,136	3,352
Regulating	40-100	N	0.043	36,328	42,785	23,375
Regulating	40-100	Y	0.039	32,215	37,942	20,729
Regulating	<40	Y	0.018	15,377	18,161	9,922

The number of stations in each inlet pressure/station type category were provided by twelve distribution companies. The data were extrapolated based on the total mileage of distribution main pipeline in the respective companies. The mean number of stations in each category per mile of main was estimated as the average of the values from eleven of the twelve companies supplying data. Based on conversations with one of the companies supplying data, the average number of stations per mile for the one company were not considered representative of typical industry practices. Therefore, this company was not included in the overall average, but rather was treated separately. The standard deviation represents the variation in the estimated number of stations per mile of main pipeline for each company. The precision represents the 90% confidence interval around the estimated mean activity factor.

The extrapolation from stations per mile to total stations in the U.S. was implemented by multiplying the stations per mile for each category by the total U.S. mileage of main pipeline: 836,760 miles.

Data were collected from five companies representing urban, rural, and suburban areas on the number of regulating stations in vaults versus above-ground in the U.S. On average, 37% of the regulating stations with an inlet pressure greater than 300 psig are located in vaults. For regulating stations with an inlet pressure between 40 and 300 psig, it was found that the majority of stations in urban areas were in vaults and in rural areas were above-ground. On average, it was estimated that 31% of the stations are located in vaults with an inlet pressure between 100 and 300 psig. For regulating stations with an inlet pressure between 40 and 100 psig, 47% of the stations are located in vaults. Based on the data collected, the majority of the low pressure (<40 psig inlet pressure) stations are located in vaults.

ANNUAL EMISSIONS ESTIMATE: (27.3 +/- 23.3 Bscf)

Station Type	Inlet Pressure (psig)	Location in Vault?	Average Activity Factor (stations)	Average Emission Factor (scf/sta.-hr)	Annual Emissions Estimate (Bscf)	90% Confidence Interval of Emissions Estimate (Bscf)
M&R	>300	N	3,460	179.8	5.5	4.7
M&R	100-300	N	13,335	95.6	11.2	21.7
M&R	<100	N	7,127	4.3	0.3	1.2
Regulating	>300	N	3,995	161.9	5.7	5.5
Regulating	>300	Y	2,346	1.3	0.03	0.06
Regulating	100-300	N	12,273	40.5	4.4	4.3
Regulating	100-300	Y	5,514	0.2	0.01	0.01
Regulating	40-100	N	36,328	1.0	0.3	0.4
Regulating	40-100	Y	32,215	0.1	0.02	0.02
Regulating	<40	Y	15,377	0.1	0.02	0.03
Total			131,970		27.3	23.3

The emissions estimate for each category of station was derived by multiplying the respective emission factor (scf/station-hr) by the activity factor (number of stations), and converted to an annualized estimate by assuming continuous fugitive leakage (i.e., 8760 hour per year leakage). The precision represents the 90% confidence interval around the estimated mean emissions for each category.

T-2
TRANSMISSION SOURCE SHEET

SOURCES: Meter and Regulating Stations
OPERATING MODE: Normal Operation
EMISSION TYPE: Steady, Fugitive, and Vented
ANNUAL EMISSIONS: 4.5 Bscf $\pm$ 835%

BACKGROUND:
Metering/pressure regulating (M&PR) stations are located throughout the transmission network to meter gas where a custody transfer occurs. Emissions from M&PR include continuous fugitive losses and also may include intermittent emissions from pneumatic devices such as pressure regulators, if they exist at the station. Fugitive emissions are relatively low-level emissions of process fluid (gas or liquid) from process equipment. Specific source types include various fittings such as valves, flanges, or compressor seals. These components represent mechanical joints, seals, and rotating surfaces, which in time tend to wear and develop leaks.

The transmission segment contains many "metering and regulation stations" (M&R stations) where flow is measured for custody transfer or system control. The table below shows the types of M&R stations that transmission companies count in their system. Most of the meter station types associated with the transmission system have already been counted in other segment calculations (receipt stations in production and delivery stations in distribution).

Only three types remain to be accounted for under the transmission system M&PR stations: 1) farm taps, 2) direct industrial sales from the transmission pipeline, and 3) transmission company-to-transmission company transfer stations.

Transmission Meter and Regulation Station Types

GENERAL STATION SERVICE	SPECIFIC TYPE	STATION TECHNICAL DESCRIPTION	ACCOUNTED FOR IN OTHER SEGMENT SOURCE SHEETS?
RECEIPT TO THE SYSTEM:	1. Gathering meters at production sites	Meter Only	Yes, P-2
INTER-SYSTEM:	2. Meters at compressor stations	Meter Only	Yes, T-1
DELIVERY TO CUSTOMERS:	3. City Gate M&R stations	Meter and Regulation (Pressure regulation)	Yes, D-1
	4. Industrial sales directly off of transmission pipelines	Meter and Regulation (Pressure regulation)	Some in D-1, but those owned by transmission companies in this sheet (T-2)
	5. Farm sales off gathering and transmission pipelines	Meter and Regulation (Pressure regulation)	No, so accounted for in this sheet (T-2)
	6. Sales to Other Transmission Companies (Inter-connects)	Most often Meter only, but can have some flow regulation	No, so accounted for in this sheet (T-2)

Although direct customer connections (sales) on the transmission pipeline are rare, where they exist they are often owned by distribution companies, even if they only own a few feet of line. Many farm taps are still owned by transmission companies, even though there is a trend to let LDCs handle the farm taps or to remove them entirely. Therefore, many direct sales from the transmission pipeline are already accounted for in the distribution M&PR calculations. Only the direct sales from the transmission pipeline that are owned completely by the transmission companies are counted under this source sheet.

Most large transmission companies have interconnects with other transmission companies to allow for flexibility of supply. These shared stations can flow in either direction.

EMISSION FACTOR: (see below)

The average fugitive emission rate for transmission M&R stations was determined by analysis of the GRI tracer measurement tests for gas industry M&R stations. Transmission farm taps and industrial meters are both direct-connects to high pressure pipelines, and will have one pressure regulator (and not 3 to 22 regulators, as some city gates had) in addition to a meter. The pressure regulator is a self contained device, and so does not have significant pneumatic emissions. Therefore the tracer data set was sorted and adjusted as follows:

1) include only stations with one regulator,
2) include only stations in vaults (which were known to have no-bleed regulators similar to farm taps),
3) delete regulator only stations in the low pressure range (0 to 100 psig inlet pressure), and
4) delete meter only stations.

The average of the 14 samples in the new transmission direct sales (farm tap & industrial meters) data set is used for the emission factor.

The transmission company inter-connect meter stations were taken by sorting the tracer data set for M&R stations with inlet pressures above 100 psig. Thirty-seven samples met this criterion.

Summary of Component Counts and Overall Emission Factors (scf/day)

METER STATION TYPE	SAMPLES (Number of Tracer Measurements Fitting this Type)	EMISSION FACTOR (Methane SCFD)
Trans-Trans Co. Interconnect points	37	3984 ± 80%
Farm Taps and direct industrial sales	14	31.2 ± 80%

EF DATA SOURCES:

1. Tracers result based on downwind tracer measurements performed by Aerodyne/WSU[1] at over 100 gas industry meter/regulation stations.
2. Analysis of tracer results was based upon technical descriptions of meter station types given by several transmission company measurement experts.
3. Definition of transmission segment boundaries and other measurement programs shows that several meter types have already been accounted for. See sheet D-1 for sales to distribution M&R stations, see sheet T-1 and S-1 for compressor station meter fugitive emissions and see

sheet P-2 for production receipt meters which have already been accounted for at gas production sites.

EF PRECISION:

Basis:

The transmission meter/pressure regulation station (M&PR) upper bounds are based upon rigorous propagation of error from the standard deviation of the multiple tracer measurements.

ACTIVITY FACTOR:

Trans-to-trans company interconnects	**2533 ± 776%**
Farm taps and Direct Industrial Sales	**72630 ± 780%**

As discussed above, types 1, 2, and 3 of transmission M&R stations are actually already accounted for in other activity factors. In the production segment meter runs were counted in the well site data. Delivery to distribution has been counted in the distribution segment M&R stations (i.e. city gates). There is also a trend to let LDCs handle the farm taps, or to remove them entirely; however, many farm taps are still owned by transmission companies.

Transfers to other transmission companies and farm taps were calculated from survey data provided by the metering departments of three large (over 10,000 miles of pipeline) transmission companies, and from three companies with fewer than 10,000 miles of pipeline, as shown in the following table.

Transmission M&R Station Populations

Company	Transfer to another Transmission Co.	Farm Taps	Direct Industrial Sales	Miles of Pipeline
1	323	23		Confidential
2	5	0		Confidential
3	60	0		Confidential
4	62	48		Confidential
5	40	3,800		Confidential
6	0	10,000		Confidential
Total	490	13,871	658	55,045 (19.3% of U.S. total)
Total U.S. Activity Factor Extrapolated by Miles	2,533 ± 776%	71,690 ± 787%	937 ± 100%	284,500

Only five of the six companies that responded to the survey reported having interconnects with other transmission companies. The activity factor was extrapolated based on pipeline miles and was calculated to be 2533 interconnects (transfers). The 90% confidence bound was determined to be ± 776%.

The count of farm taps appears to be extremely regional. Based on interviews, it seems that most companies have no farm taps, while others have thousands. The activity factor for farm taps was calculated to be 71,690 ± 787%.

The calculated activity factor is believed to be conservatively high, since only a small percentage of all transmission companies have these M&R stations, yet two of the six companies in our data set reported a large number of farm taps.

The activity factor for direct industrial sales was developed from FERC Form No. 2, page 306.[2] Industrial sales greater than 50,000 Mcf are listed individually, while sales less than 25,000 Mcf are combined into a single item. In the latter case, the total amount of gas sold was divided by 50,000 to provide an estimate of the number of sales. Due to the uncertainty that this approach introduced to the activity factor and to the complexity of retrieving data from FERC, a confidence bound of ± 100% was assigned based on engineering judgement.

The activity factor for the direct industrial sales was combined with that for farm taps based upon similar construction of the two station types.

AF DATA SOURCES:

1. For interconnects and farm taps, six transmission companies responded to the GRI/EPA survey to determine average ratios of meter types per mile of transmission line. Averages from the survey were extrapolated to national interconnect M&R number by multiplying the ratio by the known miles of U.S. transmission line.
2. Miles of transmission line were from *Gas Facts*.[3]
3. Direct industrial sales were determined from gas sales reported to FERC.[2]

AF PRECISION:

Basis:

1. For interconnects and farm taps, rigorous propagation of error based upon the standard deviation of the ratio data from individual transmission companies.
2. For direct industrial sales: An engineering estimate based upon interview data.

ANNUAL EMISSIONS: **(4.5 Bscf ± 835%)**

The annual emissions were determined by multiplying an emission factor for an each equipment type by the population of equipment in the segment.

REFERENCES

1. Aerodyne Research, Inc., Washington State University, and University of New Hampshire. *Results of Tracer Measurements of Methane Emissions from Natural Gas System Facilities*, Final Report, GRI-94/0257.43, Gas Research Institute, May 1994.

2. Federal Energy Regulatory Commission (FERC) Form No. 2, page 306: Annual Report of Major Natural Gas Companies, 1992 database.

3. American Gas Association. *Gas Facts: 1992 Data*, Arlington, VA, 1993.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/R-96-080j	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Methane Emissions from the Natural Gas Industry, Volumes 1-15 (Volume 10: Metering and Pressure Regulating Stations in Natural Gas Transmission and Distribution)		5. REPORT DATE June 1996
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) L. Campbell, M. Campbell, M. Cowgill, D. Epperson, M. Hall, M. Harrison, K. Hummel, D. Myers, T. Shires, B. Stapper, C. Stapper, J. Wessels, and *		8. PERFORMING ORGANIZATION REPORT NO. DCN 96-263-081-17
9. PERFORMING ORGANIZATION NAME AND ADDRESS Radian International LLC P.O. Box 201088 Austin, Texas 78720-1088		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 5091-251-2171 (GRI) 68-D1-0031 (EPA)
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air Pollution Prevention and Control Division Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 3/91-4/96
		14. SPONSORING AGENCY CODE EPA/600/13

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16. ABSTRACT The 15-volume report summarizes the results of a comprehensive program to quantify methane (CH4) emissions from the U.S. natural gas industry for the base year. The objective was to determine CH4 emissions from the wellhead and ending downstream at the customer's meter. The accuracy goal was to determine these emissions within +/-0.5% of natural gas production for a 90% confidence interval. For the 1992 base year, total CH4 emissions for the U.S. natural gas industry was 314 +/- 105 Bscf (6.04 +/- 2.01 Tg). This is equivalent to 1.4 +/- 0.5% of gross natural gas production, and reflects neither emissions reductions (per the voluntary American Gas Association/EPA Star Program) nor incremental increases (due to increased gas usage) since 1992. Results from this program were used to compare greenhouse gas emissions from the fuel cycle for natural gas, oil, and coal using the global warming potentials (GWPs) recently published by the Intergovernmental Panel on Climate Change (IPCC). The analysis showed that natural gas contributes less to potential global warming than coal or oil, which supports the fuel switching strategy suggested by the IPCC and others. In addition, study results are being used by the natural gas industry to reduce operating costs while reducing emissions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Prevention	13B
Emission	Stationary Sources	14G
Greenhouse Effect	Global Warming	04A
Natural Gas		21D
Gas Pipelines		15E
Methane		07C

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 44
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

U.S. ENVIRONMENTAL PROTECTION AGENCY
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