EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 1.4 NATURAL GAS COMBUSTION

Prepared for:

Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC

Prepared by:

Eastern Research Group
1600 Perimeter Park
Morrisville, NC 27560

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Emission Factor Documentation for AP-42 Section 1.4
Natural Gas Combustion

1.0 Introduction

The revised AP-42 section described in this report replaces the section published in September 1996 as Supplement B to the Fifth Edition. This background report replaces the Emission Factor (EMF) Documentation for AP-42 Section 1.4, Natural Gas Combustion, issued April 1993. The purpose of this background report is to provide technical documentation supporting the Supplement D revisions to AP-42 Section 1.4.

The EPA publishes emission factors in its Compilation of Air Pollutant Emission Factors, EPA Publication No. AP-42 (AP-42). The document has been published since 1972 as the primary compilation of EPA's emission factor information. Federal, State and local agencies, consultants, and industry use the document to identify major contributors of atmospheric pollutants, develop emission control strategies, determine applicability of permitting programs, and compile emission inventories for ambient air impact analyses and State Implementation Plans (SIPs). Volume 1, Stationary Sources is published by Emission Factor Inventory Group (EFIG) in EPA's Office of Air Quality Planning and Standards (OAQPS).

1.1 Reasons For Updating

The Clean Air Act Amendments of 1990 added greatly to the number of air pollution sources for which emission factor development was required, and also called for the improvement of existing factors. There are several reasons for updating or revising AP-42 sections and emission factors.

- New Standard. After the proposal of a standard, the EPA reviews the available material to determine if sufficient information has been gathered to support the development of emission factors for the industry or process being studied. Oftentimes, the proposal or development of a new standard for a source or source category will trigger a re-evaluation of emission factors for a particular source. In the proposal of a standard, the proposal team gathers tremendous amounts of data to support the standard, much more data than is typically gathered for AP-42. The proposal team may compare their new data with existing information used to develop AP-42 emission factors. If, in the comparison, the team discovers a deficiency in the existing information, they may turn their data over to EFIG, who in turn may use the information to improve emission factors.

- Outside Requests. The EPA receives requests for better source and emission factor information. Requests may come from other Office of Air Quality Planning and Standards (OAQPS) branches, EPA laboratories and regional offices, State agencies, trade associations, special interest groups, or private individuals. The requests may take the form of directives, letters, oral inquiries, or comments on published emission factors.

- Improvement of the National Inventory. The EPA may determine that a particular source category is a significant contributor to the National Inventory and that EPA should develop or improve emission factors.

- New Information. New information will be useful that may have been developed initially for Emission Standards Division (ESD) background documents involving new source performance standards (NSPS), national emission standards for hazardous air pollutants (NESHAP), and Control Techniques Guidelines (CTG), and reports by various EPA laboratories.

- Contractor Expertise. A contractor or consultant may have gained expertise on a source category during previous work, either for EPA or for other clients, and may warrant considering a relatively low-expense update and expansion of available information.

Section 1.4 has been updated to incorporate new available data on this source category. New information has been used to better characterize this source category, develop improved volatile organic compound (VOC) and particulate matter (PM) emission factors, and update criteria pollutant emission factors. In response to the upcoming NESHAP for this source category, an expanded hazardous air pollutant (HAP) emission factor list has also been provided.

This background report consists of four sections. This introduction provides background information on AP-42 and documents such as this one that are issued to update sections of AP-42. Section 2 presents the data search and screening steps, discusses the references used to revise AP-42 Section 1.4, and defines the emissions data quality rating system. Section 3 discusses overall revisions to AP-42 Section 1.4, provides details about the database built for storing the available data, presents the calculations used to calculate emission factors, and defines the emission factor quality rating system. Section 4 presents the proposed revision of the existing AP-42 section as it would appear in Supplement D.

1.2 References For Section 1

1. Procedures For Preparing Emission Factor Documents, Third Revised Draft Version, Office Of Air Quality Planning And Standards, U.S. EPA, Research Triangle Park, NC 27711, November 1996.

2.0 Literature Search and Screening

Data used in this section were obtained from a number of sources within OAQPS and from outside organizations. The AP-42 background files were reviewed for information on these sources, demonstrated pollution control technologies, and emissions data. The Factor Information Retrieval System (FIRE) was searched for emission data on natural gas-fired combustion sources. The Source Test Information Retrieval System (STIRS) data set, compiled by EFIG, was reviewed and provided emissions data from several sources. The STIRS data set is a collection of emission test reports that have been scanned and stored on CD-ROM.

In the review of available references, emissions data were accepted if:

- sufficient information about the combustion source and any pollution control devices was given.
- the test report identified if the emissions tests were conducted before or after a pollution control device.
- emission levels were measured by currently accepted test methods.
- emission test results were reported in units which could be converted into the reporting units selected for this AP-42 section.
- sufficient data existed to characterize operating conditions.

2.1 Emission Data Quality Rating System[1]

After reviewing the test reports, it should be possible to assign a data quality rating to each pollutant emission rate for each test series. The individual data quality ratings are not to be confused with the overall emission factor ratings. The data quality ratings are an appraisal of the reliability of the basic emission data that will be used to later develop the factor.

Test data quality is rated A through D, based on the following criteria:

A - Tests are performed by a sound methodology and are reported in enough detail for adequate validation.

B - Tests are performed by a generally sound methodology, but lacking enough detail for adequate validation.

C - Tests are based on an unproven or new methodology, or are lacking a significant amount of background information.

D - Tests are based on a generally unacceptable method, but the method may provide an order-of-magnitude value for the source.

The quality rating of test data helps identify good data, even when it is not possible to extract a factor representative of a typical source in the category from those data. For example, the data from a given test may be good enough for a data quality rating of “A,” but the test may be for a unique feed material, or the production specifications may be either more or less stringent than at the typical facility.

In following the general guidelines discussed above, four specific criteria can be considered to evaluate the emission data to ensure that the data are based on a sound methodology, and documentation provides adequate detail. A test series is initially rated “A through D” in each of the following four areas.

- Source operation. If the manner in which the source was operated is well documented in the report, and the source was operating within typical parameters during the test, an A rating should be assigned. If the report stated parameters were typical, but lacked detailed information, a B rating is assigned. If there is reason to believe operation was not typical, a C or D rating is assigned.

- Test method and sampling procedures. In developing ratings, the accuracy of the test method as well as the adequacy of the documentation are considered. In general, if a current EPA reference test method appropriate for the source was followed, the rating should be higher (A or B). If other methods are used, an assessment is made of their validity. If it is judged that the method was likely to be inaccurate or biased, a lower rating (C or D) is given. A complete report should indicate whether any procedures deviated from standard methods and explain any deviations. If deviations were reported, an evaluation is made of whether these were likely to influence the test results.

- Sampling and process data. During testing, many variations can occur without warning and sometimes without being noticed. Such variations can induce wide deviations in sampling results. If a large spread between test run results cannot be explained by information contained in the site test report or from test reports of other sources, the data are suspect and are given a lower rating. However, it should be recognized that a process may have highly variable emissions and a lower rating may not be appropriate solely on the basis of wide deviations in sampling results.

- Analysis and calculations. Ideally, test reports should contain original raw data sheets and other QA documentation. If there are data sheets, the nomenclature and equations used are compared with those specified by EPA to establish equivalency. The depth of review of the calculations is dictated by the reviewers’ confidence in the ability and conscientiousness of the tester, based on such factors as consistency of results and completeness of other areas of the test report. Reports may indicate that raw data sheets were available but were not included. If the test report is of high quality based on the other criteria, the quality rating should not be lowered due to a lack of data sheets.

An overall emission data quality rating is developed considering the scores on the four criteria. There is no precise equation for the relative weighting of the factors, because each report presents different issues, and the rating system needs to provide flexibility to consider the strengths and weaknesses of each test series and reach a judgment on the overall rating. However, the two criteria concerning (1) the test method and sampling procedures and (2) the sampling and process data should be weighted most heavily.

If either of these two criteria are assigned a low rating, this low rating should be assigned as the overall data quality rating, no matter how complete the documentation is.

2.2 Review of Data Sets

A total of 42 documents were reviewed in the process of developing emission factors for this revision to AP-42 Section 1.4, Natural Gas Combustion. A summary review of the references used to develop emission factors and their associated database identification numbers is presented in Table 2-1, following this section. The majority of the references which were used to revise the emission factors for natural gas combustion sources were either compliance test reports or summaries of compliance test results. Seven of the references used in the development of this data were the results of research or specific information gathering efforts. Furthermore, NO_x emission factors for several natural gas combustion sources were developed from an electronic database received from the Acid Rain Division (ARD) of EPA. The data received from the ARD, and the corresponding emission factor averages, are presented in Appendix A.

<u>References 2 Through 6, 8, and 41</u>

References 2 through 6, reference 8, and reference 41 are the results of several research or specific information gathering efforts on natural gas-fired boilers. The data extracted from these reports make up the vast majority of all the HAP information contained in the revision of AP-42 Section 1.4. Pollutants tested in references 2, 3, and 41 also included speciated polycyclic aromatic hydrocarbons (PAH) and speciated metals. The test results reported in these references were all from emission measurements conducted on tangential- and wall-fired utility boilers. Most of the sources detailed in these references were uncontrolled, however, some incorporated flue gas recirculation (FGR) for NO_x control. All of the emission test data contained in these references were assigned a rating of A due to the detailed information provided.

<u>References 7, 9 Through 40, and 43 Through 44</u>

These references were all compliance test results from both utility and industrial boilers firing natural gas. The majority of these compliance tests focused on NO_x and CO emissions, however, several tests included results of total hydrocarbon (THC), non-methane hydrocarbon (NMHC), methane, and particulate matter (PM) measurements. Some of the boilers reported in these references were operated with low-NO_x burners, FGR, or selective non-catalytic reduction (SNCR) for NO_x control. All of the emission test data contained in these references were assigned a rating of A due to the detailed information provided.

<u>Reference 42</u>

Reference 42 is a NO_x emission summary for all national gas-fired utility boilers required to submit CEM data to the ARD as required by Title IV of the Clear Air Act Amendments. These data represent average NO_x emissions from these boilers for the 3rd quarter of 1996. This data set included NO_x emissions from 121 wall-fired boilers, 62 tangential-fired boilers, and five wall-fired boilers with low-NO_x burners. The data received from ARD, and the corresponding emission factor averages, are presented in Appendix A.

Table 2.2-1. SUMMARY OF REFERENCES USED IN THE REVISION OF SECTION 1.4

Reference Number[a]	General Information Concerning Document	Pollutants Tested	Data Quality	Database I.D.
2	Source Test on a Tangential-Fired Utility Boiler	NO_x, CO, speciated HAP's, metals	A	1
3	Source Test on a Wall-Fired Utility Boiler	NO_x, CO, speciated HAP's, metals	A	2
4	Source Test on a Wall-Fired Utility Boiler	Benzene, Formaldehyde	A	3
5	Source Test on a Wall-Fired Utility Boiler	Benzene, Formaldehyde	A	4
6	Source Test on a Package Boiler	NO_x, CO, Methane, Ethane, PM	A	6
7	Compliance Test on a Package Boiler	NO_x, CO	A	7
8	Source Tests on Seven Wall-Fired Utility Boilers	Benzene, Formaldehyde	A	8, 9, 10, 11, 12, 13, 14
9	Source Test on a Wall-Fired Utility Boiler With SNCR Control	NO_x, CO, Hydrocarbons, PM	A	15
10	Compliance Test on a Wall-Fired Utility Boiler With SNCR Control	NO_x, CO, Hydrocarbons, PM	A	23
11	Compliance Test on Two Tangential-Fired Utility Boilers With SNCR Control	NO_x, CO, Hydrocarbons, PM	A	17
12	Compliance Test on Two Wall-Fired Utility Boilers With SNCR Control	NO_x, CO, Hydrocarbons	A	18
13	Compliance Test on a Tangential-Fired Utility Boiler With SNCR Control	NO_x, CO, Hydrocarbons, PM	A	19
14	Compliance Test on a Tangential-Fired Utility Boiler With SNCR Control	NO_x, CO, Hydrocarbons	A	20
15	Compliance Test on a Tangential-Fired Utility Boiler With SNCR Control	NO_x, CO, Hydrocarbons	A	22
16	Compliance Test on a Wall-Fired Utility Boiler	NO_x, CO, Hydrocarbons	A	16
17	Compliance Test on a Tangential-Fired Utility Boiler With SNCR	NO_x, CO, Hydrocarbons	A	21

Table 2.2-1. SUMMARY OF REFERENCES USED IN THE REVISION OF SECTION 1.4
(Continued)

Reference Number[a]	General Information Concerning Document	Pollutants Tested	Data Quality	Database I.D.
18	Compliance Test on a Boiler	NO_x, CO	A	106
19	Compliance Test on a Boiler	NO_x, CO	A	107
20	Compliance Test on a Boiler	NO_x, CO	A	108
21	Compliance Test on Two Boilers	NO_x, CO	A	109
22	Compliance Test on a Boiler	NO_x, CO, Hydrocarbons	A	110
23	Compliance Test on Two Boilers	NO_x	A	111
24	Compliance Test on a Boiler	NO_x, CO, Hydrocarbons	A	112
25	Compliance Test on Two Boilers	NO_x	A	113
26	Compliance Test on a Boiler	NO_x, CO, PM	A	114
27	Compliance Test on a Boiler	NO_x, CO, Hydrocarbons	A	115
28	Compliance Test on a Boiler	NO_x, CO	A	116
29	Compliance Test on a Boiler	NO_x, CO, Hydrocarbons	A	117
30	Compliance Test on a Boiler	NO_x	A	119
31	Source Test on a Boiler	NO_x, CO	A	120
32	Source Test on a Boiler	NO_x, CO, Hydrocarbons, PM	A	121
33	Compliance Test on a Boiler	NO_x	A	122
34	Compliance Test on a Boiler	NO_x	A	123
35	Compliance Test on a Boiler	NO_x, CO	A	125
36	Compliance Test on Two Boilers	NO_x, CO	A	126
37	Compliance Test on a Boiler	PM	A	131
38	Compliance Test on a Boiler	NO_x, PM	A	132

Table 2.2-1. SUMMARY OF REFERENCES USED IN THE REVISION OF SECTION 1.4
(Continued)

Reference Number[a]	General Information Concerning Document	Pollutants Tested	Data Quality	Database I.D.
39	Compliance Test on a Boiler	NO_x, CO, Hydrocarbons	A	133
40	Compliance Test on Four Boilers	NO_x, CO, Hydrocarbons	A	134
41	Source Tests on Two Wall-Fired and Two Tangential-Fired Boilers	NO_x, CO, speciated HAP’s, metals	A	200
42	CEM Data Submitted to ARD	NO_x,	A	Not in Database
43	Compliance Test on One Boiler	PM	A	201
44	Compliance Test on One Boiler	PM	A	202

[a]Reference number corresponds to the reference listing at the end of this section.

2.3 References For Section 2

1. Procedures for Preparing Emission Factor Documents, Third Revised Draft Version, Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, NC 27711, November 1996.

2. *PICES Field Chemical Emissions Monitoring Project Site 120 Emissions Report*. Carnot, Tustin, CA, December 1995.

3. *PICES Field Chemical Emissions Monitoring Project Site 121 Emissions Report.* Carnot, Tustin, CA, December 1995.

4. *Emission Inventory Testing at El Segundo Generating Station No. 1 for Southern California Edison Company*, Carnot, April 1990.

5. *Air Toxics Emissions Inventory Testing at Alamitos Unit 5*, Carnot, May 1990.

6. *Gas Research Institute/WP Natural Gas @ Boise Cascade Timber and Wood Products Division #2 Package Boiler*, Amtest Air Quality, Inc., May 1995.

7. *Source Test For Measurement Of Nitrogen Oxides And Carbon Monoxide Emissions From Boiler Exhaust At GAF Building Materials*, Pacific Environmental Services, Inc., Baldwin Park, CA, May 1991.

8. *Field Chemical Emissions Monitoring Project: Emissions Report For Sites 103 - 109. Preliminary Draft Report*. Radian Corporation, Austin, TX, March 1993. (EPRI Report)

9. *Urea Permit Compliance Testing at Alamitos Generation Station Unit 2*, Carnot, November 1992.

10. *Emissions Source Test Report For Urea Injection Compliance Testing Huntington Beach Unit 1 Permit Application No. R-249463*, Geraghty & Miller, March 1994.

11. *SCE Etiwanda Units 1 and 2 Urea Compliance Source Test Report, Final Report, Volume 1 of II,* Radian Corporation, March 1994.

12. *Source Test Report For Urea Permit Compliance Testing Redondo Beach Generating Station Units 5 and 6*, Sierra Environmental Engineering, Inc., October 1992.

13. *Urea Permit Compliance Testing at Alamitos Generation Station Unit 4,* Carnot, April 1993.

14. *Urea Permit Compliance Testing at El Segundo Generating Station Unit 3,* Carnot, September 1993.

15. *Emissions Source Test Report For Recirculation Gas By-Pass and Urea Compliance Testing Etiwanda Unit 3 Permit Application No. 261513,* Acurex Environmental, March 1994.

16. *Emissions Source test Report: Permit Application No. R-249462, Huntington Beach Generating Station,* Acurex Environmental, March 1996.

17. *Urea Permit Compliance Testing at El Segundo Generating Station Unit 4,* Carnot, September 1993.

18. *California Fruit Produce, Fresno, Ca. Boiler Emissions Test 12-4-92.* Best Environmental, Inc., San Leandro, CA, December 17, 1992.

19. *California Fruit Produce, Madera, Ca. Boiler Emissions Test 12-2-92.* Best Environmental Inc., San Leandro, CA, December 17, 1992.

20. *Emission Testing at Zacky Farms Kewanee Boiler, Dinuba, California.* Steiner Environmental, Inc., Bakersfield, CA, July 1993.

21. *Compliance Test Report Determination of* NO_x *emission rates From Boilers 3, 4, and 5. Harrison Radiator, Dayton, Ohio.* Hayden Environmental Group, Inc., Miamisburg, OH, March 20, 1990.

22. *R. F. MacDonald Source Emissions Testing at Tomatek, Inc.* Ecoserve Environmental Services, Inc. Pittsburg, CA, October 1989.

23. *Nitrogen Oxide Emission Tests Boilers Number 4 and 5. Whiteman Air Force Base.* Shell Engineering and Associates, Inc., August 20 and 21, 1990.

24. *Source Emissions Survey of Firestone Synthetic Rubber & Latex company Boiler EB-114 Exhaust Stack, Orange, Texas.* METCO Environmental, Addison, TX, November 1990.

25. *A Compliance Emission Test Report Determination of Nitrogen Oxides. Dual-Fuel Generating Units Nos. 1 and 2.* Greiner, Incorporated, Grand Rapids, MI, September 2, 1993.

26. *Texaco Refining & Marketing, Inc. P. O. Box 1476, Bakersfield, California. Boilers A and B. Annual Compliance Test.* Steiner Environmental, Inc., Bakersfield, CA, June 19, 1992.

27. *Source Emission Test for* NO_x*, CO, and ROC From Conventional Steam Boiler at Thomas Plant, Building 373, Naval Construction Battalion Center, Port Hueneme, California.* Naval Energy and Environmental Support Activity, October 1990.

28. *Chevron U.S.A., Inc. Section 26C Steam Plant Steam Generator # 50-6 and 50-7. Initial Compliance Test.* Genesis Environmental Services Company, Bakersfield, CA, June 11, 1991.

29. *Source Test for Measurement of Oxides of Nitrogen, Carbon Monoxide and VOC from Boiler Exhaust at Candlewick Yarns, Lemoore, California.* Pacific Environmental Services, Inc., Baldwin Park, CA, April 21, 1993.

30. *Compliance Test for* $NO_{x.}$ *Siemens Energy and Automation Natural Gas Fired Boiler #2.* K&B Design, Inc., August 26, 1994.

31. *Source Test Report Gibson 7028-01, Gibson Oil and Refining Company, Bakersfield, California.* Brown and Caldwell, Pleasant Hill, CA, September 11, 1992.

32. *Source Test Report Gibson Oil and Refining Company, Inc.* Bakersfield, California. Brown and Caldwell, Emeryville, CA, May 14-17, 1990.

33. *Compliance Test Report: Determination of Nitrogen Oxide Emissions, Annapolis Hospital Westland Center Boilers #1, 2, and 3, Oakwood Hospital, Westland Michigan*. WW Engineering & Science, Grand Rapids, MI, November 1993.

34. *Report on Compliance Testing for General Motors Corporation, Fort Wayne Assembly Plant, Roanoke, Indiana,* Clean Air Engineering,

35. *Stella Cheese. P. O. Box 1379, Tulare, California. Superior Mohawk Boiler. Initial Compliance Test.* Steiner Environmental, Inc., Bakersfield, CA, July 30, 1993.

36. *Crystal Geyser Water Company. 1233 East California Avenue. Bakersfield, California. Boiler #1 & 2, Initial Compliance Test.* Steiner Environmental, Inc., Bakersfield, CA, February 26, 1993.

37. *Results of the Emissions Testing Services at Minnesota Corn Processors. Marshall Minnesota. December 20-21, 1994.* Nova Environmental Services, Inc., Chaska, MN, January 31, 1995.

38. *Results of the July 27, 1994 Air Emission Compliance Testing of the No. 10 Boiler at the Virginia Public Utilities Plant in Virginia, Minnesota.* Interpoll Laboratories, Inc., Circle Pines, MN, August 17, 1994.

39. *Los Gatos Tomato Products Compliance Emissions Testing*. Best Environmental, Inc., Hayward, CA, April 1991.

40. *Gallo Winery Fresno Plant Boilers # 1, 2, 3, & 4 Emissions Compliance Testing*. Best Environmental, Inc., San Leandro, CA, May 1992.

41. *Gas-Fired Boiler and Turbine Air Toxics Summary Report*. Prepared by Carnot Technical Services, Tustin, CA, For the Gas Research Institute and The Electric Power Research Institute, August 1996.

42. NO_x Emission Reporting for Utility Boilers for 3rd Quarter 1996. Acid Rain Division, U.S. EPA.

43. *Compliance Particulate Matter Source Emissions Measurement Program: Nebraska Package Boiler, Kimberly-Clark Corporation, Neenah, WI*. Geraghty & Miller, Inc., July 1994.

44. *Results of the September 14 and 15, 1994 Air Emission Compliance Tests on the No. 11 Boiler at the Appleton Paper Plant in Combined Locks, WI*. Interpoll Laboratories Inc., October 1994.

3.0 AP-42 Section Development

3.1 Revisions to Section Narrative

The technical discussion in AP-42 Section 1.4 did not need major revisions because no significant technological changes in this source category were identified since the last publication. Some of the discussion on NO_x and PM formation was revised to better describe emissions from this source category.

3.2 Pollutant Emission Factor Development

3.2.1 Database Design

The emission data assembled for the development of natural gas combustion emission factors were stored in a database except for the data received from ARD. A database approach was chosen to easily access and manipulate the large amount of data collected for this section and to facilitate data transfer within other concurrent projects at EPA. The design of this database was accomplished in conjunction with the Industrial Combustion Coordinated Rulemaking (ICCR) effort ongoing within the Emission Standards Division (ESD). Data entered under either of these projects were easily transferred between databases. Furthermore, the common design of the database will allow for future additions to the database and simple recalculation of emission factors.

Within the database, data were stored in two tables to reduce repetitive entry of data. These tables, and the data fields associated with each table are as follows:

Facilities Table

- Facility name
- Location
- Testing Company
- Date of Test
- Boiler Manufacturer
- Boiler Type (wall-fired, tangential-fired, etc.)
- Air Supply (forced draft, induced draft, balanced draft etc.)
- Capacity (MW)
- Load (percent of capacity)
- Fuel Type
- Fuel Higher Heating Value
- Heat Input (MMBtu/hr)
- Post-combustion Emission Controls
- Application (electrical generation, process steam, etc.)

Test Data Table

- Pollutant
- Test Method
- Pollutant Concentration (as reported)
- Detection Limit

- Exhaust Oxygen Percentage
- Data Rating
- Fuel Exhaust Factor (F-Factor)
- Exhaust Flow Rate
- Fuel Flow Rate
- Exhaust Moisture Fraction
- Molecular Weight of Pollutant

The database was programmed to merge the data in the two tables and calculate emission factors for the available pollutants in units of pounds of pollutant per million standard cubic feet of fuel burned. To ensure consistent calculation of emission factors, the database was programmed to use the emission concentration data and process data taken during the testing period to calculate the emission factors. Emission factors provided in test reports were not used. The EPA concluded that this method of calculation would provide the highest quality emission factors. This method of calculating emission factors was chosen because different methods of calculation emission factors were used in some of the references and in some cases, the method of calculating emission factors was not given. Equations used to calculate emission factors for this section were dependent on the pollutant concentration units.

The following equations were used to convert concentration data to the selected emission factors used in this section.

For concentration in parts per million by volume - dry (ppmvd), the following equation was used:

$$EF_{scf} = \frac{(C_{ppmvd} * F * 1{,}020 * MW)}{(10^6 * 385.5)} * \text{temperature correction} * \text{oxygen correction}$$

For concentration in parts per million by volume - wet (ppmvw), the following equation was used:

$$EF_{scf} = \frac{(C_{ppmvw} * F * 1{,}020 * MW)}{(10^6 * 385.5) * (1 - W_c)} * \text{temperature correction} * \text{oxygen correction}$$

For concentration in micrograms per dry standard cubic feet, the following equation was used:

$$EF_{scf} = \frac{(C_{\mu gf} * F * 1{,}020)}{(10^6 * 453.6)} * \text{oxygen correction}$$

For concentration in parts per billion by volume - dry, the following equation was used:

$$EF_{scf} = \frac{(C_{ppbvd} * F * 1{,}020 * MW)}{(10^9 * 385.5)} * \text{temperature correction} * \text{oxygen correction}$$

For concentration in volume percent, the following equation was used:

$$EF_{scf} = \frac{(C_{\%} * F * 1{,}020 * MW)}{(100 * 385.5)} * \text{temperature correction} * \text{oxygen correction}$$

For concentration in nanograms per dry standard cubic feet, the following equation was used:

$$EF_{scf} = \frac{(C_{ngf} * F * 1{,}020)}{(10^9 * 453.6)} * \text{oxygen correction}$$

For concentration in grains/dscf, the following equation was used:

$$EF_{scf} = (C_{grf} * F * 1{,}020 * 1.43 * 10^{-4}) * \text{oxygen correction}$$

For concentration in micrograms per dry standard cubic meter, the following equation was used:

$$EF_{scf} = \frac{(C_{\mu gm} * F * 1{,}020)}{(10^6 * 453.6 * 35.31)} * \text{oxygen correction}$$

Where:

Ef_{scf}	=	Emission factor (pounds per million standard cubic feet of fuel input)
C_{ppmvd}	=	Concentration (parts per million by volume, dry)
C_{ppmvw}	=	Concentration (parts per million by volume, wet)
$C_{\mu gf}$	=	Concentration (micrograms per dry standard cubic foot)
C_{ppbvd}	=	Concentration (parts per billion by volume, dry)
$C_{\%}$	=	Concentration (percent by volume)
C_{ngf}	=	Concentration (nanograms per dry standard cubic foot)
C_{grf}	=	Concentration (grains per dry standard cubic foot)
$C_{\mu gm}$	=	Concentration (micrograms per dry standard cubic meter)
F	=	F-Factor (dry standard cubic feet per million Btu)
MW	=	Molecular weight (pounds per pound-mole)
T_{std}	=	Reference temperature of F-Factor

$\%O_2$	=	Percent of oxygen in exhaust, by volume
1,020	=	Natural gas heating value (MMBtu per 10^6 scf)
385.5	=	Volume occupied by 1 lb-mole of gas at $68^{O}F$ (standard cubic feet per lb-mole)
60	=	Conversion factor (minutes per hour)
W_c	=	Water volume fraction in exhaust
453.6	=	Conversion factor (grams per pound)
$1.43*10^{-4}$	=	Conversion factor (pounds per grain)
35.31	=	Conversion factor (dry standard cubic feet per dry standard cubic meter)

$$\begin{matrix}\text{Temperature correction}\\ \text{for F-Factor}\\ \text{(to }68^{\circ}\text{F)}\end{matrix} = \left(\frac{528^{\circ}R}{460^{\circ}R_t + T_{std}\ ^{\circ}F}\right)$$

$$\begin{matrix}\text{Oxygen correction}\\ \text{(to 0\% }O_2\text{)}\end{matrix} = \left(\frac{20.9}{20.9 - \%O_2}\right)$$

Detection Limits

Test results from several tests of trace organic and metallic compounds reported concentrations below the method detection limits. If a detection limit was provided in the test report, EPA used that information in the development of AP-42 emission factors. To effectively use this data, two methods were employed. For cases where a portion of the test data for a specific pollutant were below the method detection limit but other test data report detection of that compound, then one-half of the detection limit was averaged with the detected concentrations to calculate of the emission factor for that pollutant. In cases where all of the test data for a specific pollutant reported concentrations below the method detection limit, the lowest detection limit was reported for the emission factor for that pollutant, and that factor noted as a detection limit. If an emission factor for an individual boiler was developed from a detection limit and the resulting emission factor was higher than the emission factors generated from detected concentrations, the emission factor based on a detection limit was removed from the average. The goal of this decision was to prevent an unusually high detection limit from artificially increasing an average emission factor. These methods for addressing detection level issues were provided in the Procedures For Preparing Emission Factor Documents.[1]

Calculation of Average Emission Factors

To provide average emission factors for these sources, the arithmatic average of the emission factors from all tests on a specific source type was calculated in the database. For tests that consisted of multiple runs, the arithmetic average of the runs was used to develop the emission factor of that test. Individual tests were given equal weight in the calculation of average emission factors for each boiler group. In the case of NO_x data received from ARD, the quarterly average from each boiler was treated like an individual test.

Presentation of Data

Due to the size of the database, a printout of all the test data used to generate the boiler emission factors in Section 1.4 is not presented. The NO_x data provided by the Acid Rain Division is provided in Appendix A. For the remaining data that was stored in the database, EPA is providing an electronic copy of the database on the Technology Transfer Network (TTN). This decision has resulted in a substantial decrease in paper needed for this background information document and will provide users with a more detailed background data set for this section. Providing the database to the public will allow anyone to use or augment the database for their individual needs, providing a substantial building block for anyone interested in compiling an extensive database on natural gas-fired combustion sources. An electronic copy of the database in Microsoft Access® format, can be downloaded from the TTN at http://www.epa.gov/oar/oaqps/efig/. In this website, go to AP-42 and follow the main menu options to locate and download the database file.

3.2.2 Results of Data Analysis

3.2.2.1 Source Category Selection and Data Review

An important step in emission factor development is to determine which emission sources are similar enough to be grouped together and represented by a single emission factor. This is accomplished by investigating what parameters influence emissions and should be used to establish distinct groups within the natural gas combustion category. The emission factors for each test contained in the database were analyzed to determine appropriate groupings.

NO_x Emission Factors

Based on the analysis of available NO_x data, this category was separated into four general groups: large wall-fired boilers with a heat input greater than 100 MMBtu/hr, small boilers with a heat input less than 100 MMBtu/hr, tangential-fired boilers, and residential furnaces. These groups were further separated into the following subcategories:

- Large Wall-Fired Boilers (>100 MMBtu/hr)
  - Uncontrolled (pre-NSPS)
  - Uncontrolled (post-NSPS)
  - Controlled-Low-NO_x burner
  - Controlled-Flue Gas Recirculation (FGR)
- Small Boilers (<100 MMBtu/hr)
  - Uncontrolled
  - Controlled-Low-NO_x burner
  - Controlled-Low-NO_x burner/FGR
- Tangential-Fired Boilers
  - Uncontrolled

- Controlled-FGR

- Residential Furnaces

The designation of pre- and post-NSPS refers to boilers that are subject to 40 CFR 60 Subparts D and Db. Post-NSPS units are boilers with greater than 250 MMBtu/hr of heat input that commenced construction, modification, or reconstruction after August 17, 1971, and units with heat input capacities between 100 and 250 MMBtu/hr that commenced construction, modification, or reconstruction after June 19, 1984. Analysis of the NO_x data showed that uncontrolled wall-fired boilers subject to the NSPS have considerably lower NO_x emissions that those not subject to the NSPS. Such a distinction was not seen in the data for the tangential boilers and therefore they were not further subcategorized.

The NO_x emission factors for the following categories were developed from data received from ARD: large wall-fired uncontrolled, large wall-fired controlled-low NO_x burners, and tangential-fired uncontrolled. The ARD data were determined to be more representative of these categories than NO_x data taken from compliance and source tests. The ARD data were from all operating utility boilers in the U.S. and averaged continuously over a three-month period. Since most of the data stored in the database were from short-term compliance and source tests, and from a much smaller population of boilers, the ARD data were used for categories where they were available. The NO_x emission factors for the remaining categories, where ARD data were unavailable, were developed from data stored in the database.

The NO_x emission factor for residential furnaces is based on test data from 41 sources.[2-3] Since no new data for NO_x from residential furnaces were obtained during this revision, this factor remains unchanged from the previous version of Section 1.4.

<u>N_2O Emission Factors</u>

The emission factors for N_2O from large wall-fired boilers is based on test data from five source tests conducted at three separate locations.[4-5] The N_2O factor for the large wall-fired boilers with low-NO_x burners is based on two source tests.[4-5] Since no new data for N_2O were obtained during this revision, these factors remain unchanged from the previous version of Section 1.4.

<u>CO Emission Factors</u>

Emission factors for CO were not grouped as extensively as the NO_x emission factors. For the wall-fired boiler groups, no clear correlation was observed between boiler type or size and CO emission levels. CO emission factors for the wall-fired boilers showed wide scatter and average emission factors developed for the distinct grouping were not consistent with expected values. The EPA believes that boiler operation plays a more critical role in determining CO emissions than the boiler type. Therefore, all CO data for wall-fired boilers were averaged to provide a single CO emission factor. For the tangential-fired boilers, CO emission factors showed less scatter and were strongly dependent on boiler type. Therefore, CO emission factors for tangential-fired boilers were grouped under the uncontrolled and controlled-flue gas recirculation categories.

The CO emission factor from residential furnaces is based on test data from 41 sources.[2-3] Since no new data for CO from residential furnaces were obtained during this revision, this factor remains unchanged from the previous version of Section 1.4.

Organic Compound Emission Factors

Similar to CO emission factors from wall-fired boilers, organic compound emission factors (TOC, VOC, methane, formaldehyde, etc.) showed wide scatter and no correlation was observed with boiler type or size. The EPA believes that the randomness of the organic compound emission factors from natural gas combustion sources is driven more by individual source operation than source type. Therefore, the organic compound emission factors for natural gas combustion sources were averaged across the entire source category to provide single factors for all sources covered by AP-42 Section 1.4.

3.2.2.2 Data Not Included in the Database

Several of the emission factors presented in AP-42 Section 1.4 are not calculated via a simple averaging procedure in the database. These emission factors include TOC, VOC, PM, CO_2, SO_2, and controlled emission factors. The next several sections will discuss the development of these emission factors.

VOC and TOC Emission Factors

The VOC emission factor for this source category was calculated to correspond with EPA's definition that VOC comprises total organic compounds excluding methane, ethane, and several chlorinated and fluorinated compounds.[1] Since VOCs cannot be measured directly, VOC emission factors must be calculated from other organic measurements. Data on hydrocarbon emissions collected for the revision of AP-42 Section 1.4 included as total hydrocarbons (THC) and non-methane hydrocarbons (NMHC). Based on an evaluation of the quality and quantity of data available on hydrocarbons, EPA determined that the NMHC data was the most representative for this source category. Given the NMHC as the basis for calculating the VOC emission factor, the ethane emission factor was subtracted and the formaldehyde emission factor added to the NMHC emission factor to provide an estimate of the VOC emission factor. This calculation is shown below. The TOC emission factor was estimated by adding the methane and formaldehyde emission factors to the NMHC emission factor. This calculation is shown below. The data used in these calculations can be found in Table 3.4-1.

$$
\begin{aligned}
VOC &= NMHC + Formaldehyde - Ethane \\
&= 8.5 + 0.07 - 3.1 \\
&= 5.5 \ (lb/10^6 \ scf)
\end{aligned}
$$

$$
\begin{aligned}
TOC &= NMHC + Formaldehyde + Methane \\
&= 8.5 + 0.07 + 2.3 \\
&= 10.9 \ (lb/10^6 \ scf)
\end{aligned}
$$

PM Emission Factors

For a limited number of tests, PM measurements were conducted. These PM measurements included both condensable and filterable PM. As with the organic compounds emitted from natural gas combustion sources, no correlation between combustion source type and PM emission levels could be established. Therefore, the PM emission factors presented in AP-42 Section 1.4 are intended to represent all natural gas combustion sources. To provide a total PM emission factor, the average condensible and filterable PM fractions were added together. This calculation is shown below. The EPA has assumed that all condensable and filterable PM resulting from natural gas combustion is less that 1 micrometer (μm) in diameter. Therefore, the total PM emission factor also provided an estimate of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ emissions from natural gas combustion sources. The EPA believes that these assumptions for PM size are valid since natural gas does not contain ash and the nucleation of PM from combustion products ill not yield particles larger than 1 μm.

$$\text{PM (Total)} = \text{PM (Condensable)} + \text{PM (Filterable)} = PM_{10} = PM_{2.5} = PM_{1.0}$$

$$= 5.7 + 1.9$$

$$= 7.6 \ (\text{lb}/10^6 \ \text{scf})$$

CO_2 and SO_2

As outlined in the Procedures for Preparing Emission Factor Documents,[1] emission factors for CO_2 were calculated by mass balance. This approach was also taken for calculating SO_2. Since the carbon and sulfur content in pipeline-quality natural gas is fairly consistent, EPA believes that this is the best method for calculating CO_2 and SO_2 emission factors. For CO_2, it was assumed that approximately 100 percent of the fuel carbon was converted to CO_2. For SO_2, a 100 percent conversion of fuel sulfur was assumed. The CO_2 emission factor was based on a carbon weight percent in natural gas of 76 percent and the SO_2 emission factor was based on a sulfur content in natural gas of 2,000 grains per million standard cubic feet.

Selective Non-catalytic Reduction (SNCR) Controlled Emission Factors

Several of the data sources provided emissions data for sources operating with SNCR control. To evaluate SNCR control efficiency, only tests where NO_x measurements were taken upstream and downstream of the ammonia or urea injection area were considered. This method was chosen to evaluate SNCR performance while avoiding the effects of boiler performance, with respect to NO_x emissions. To estimate SNCR performance, NO_x control efficiency was based on tests conducted upstream and downstream of the control device. Thirty-three sets of upstream and downstream tests on SNCR performance were evaluated. The SNCR performance data for wall-fired boilers are presented in Table 3.2-1 and SNCR performance data for tangential-fired boilers are presented in Table 3.2-2. The average NO_x reduction efficiency achieved by SNCR control on wall-fired and tangential-fired units was 24 percent and 13 percent, respectively. These reduction efficiencies were also put in the footnotes to the tables presented in Section 1.4 so these reduction efficiencies could be applied to the NO_x emission factor if necessary.

3.3 Emission Factor Quality Rating System

The quality of the emission factors developed from analysis of the test data was rated using the following general criteria:

A--Excellent: Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough that variability within the source category population may be minimized.

B--Above average: Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough that variability within the source category population may be minimized.

C--Average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. The source category is specific enough that variability within the source category population may be minimized.

D--Below average: The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are always noted in the emission factor table.

Table 3.2-1. SNCR TEST RESULTS FOR WALL-FIRED BOILERS (NO_x)

Database I.D.	Uncontrolled Emission Factor (1b/10^6 scf)	Controlled Emission Factor (1b/10^6 scf)	Percent Reduction (%)
16.1/16.2	1.32E+02	1.17E+02	11
16.3/16.4	8.14E+01	6.31E+01	23
16.5/16.6	5.57E+01	4.53E+01	19
23.1/23.2	1.12E+02	9.64E+01	14
23.3/23.4	8.20E+01	5.96E+01	27
23.5/23.6	5.24E+01	4.10E+01	22
15.1/15.2	1.78E+02	1.29E+02	27
15.3/15.6	1.08E+02	9.25E+01	14
15.8/15.7	1.79E+02	1.51E+02	16
18.2/18.1	1.97E+02	1.30E+02	34
18.4/18.3	1.03E+02	7.76E+01	25
18.6/18.5	5.29E+01	3.08E+01	42
18.7/18.8	1.76E+02	1.25E+02	29
18.9/18.10	1.01E+02	7.79E+01	23
18.12/18.11	7.91E+01	4.81E+01	39
		Average =	24

Table 3.2-2. SNCR TEST RESULTS FOR TANGENTIAL-FIRED BOILERS (NO_x)

Database I.D.	Uncontrolled Emission Factor (1b/10^6 scf)	Controlled Emission Factor (1b/10^6 scf)	Percent Reduction (%)
20.2/20.1	5.45E+01	4.70E+01	14
20.4/20.3	8.21E+01	6.87E+01	16
20.6/20.5	9.08E+01	8.12E+01	11
21.1/21.2	6.63E+01	5.93E+01	10
21.4/21.3	9.36E+01	7.77E+01	17
21.6/21.5	1.05E+02	9.42E+01	10
22.2/22.3	6.83E+01	5.82E+01	15
22.5/22.6	4.08E+01	3.53E+01	13
17.1/17.2	6.70E+01	6.47E+01	3
17.10/17.9	7.39E+01	5.97E+01	19
17.12/17.11	8.70E+01	7.34E+01	16
17.4/17.3	5.42E+01	4.79E+01	12
17.6/17.5	7.16E+01	4.43E+01	38
17.8/17.7	8.36E+01	7.64E+01	9
19.2/19.3	8.38E+01	7.40E+01	12
19.6/19.8	4.35E+01	4.10E+01	6
19.7/19.8	4.35E+01	4.10E+01	6
19.10/19.9	4.79E+01	4.38E+01	9
		Average =	13

E--Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always noted, in the emission factor table.

The above criteria for emission factor ratings are defined in and OAQPS document which provided guidance for preparing emission factor documents. The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer. As these criteria were applied to the emission factors, the term “number of facilities” was interpreted to mean “number of different boilers”. This criteria prevented emission factors generated from multiple tests on a single boiler from receiving higher emission factor ratings.

Emission factors for this section were rated in the following manner:

A-Rated — Emission factor average based on results of A-rated data from 20 or more different boilers, or from approved mass balance calculations.

B-Rated — Emission factor average based on results of A-rated data from 10 to 19 different boilers.

C-Rated Emission factor average based on results of A-rated data from five to nine different boilers.

D-Rated Emission factor average based on results of A-rated data from three to four different boilers.

E-Rated Emission factor based on less than three A- or B-rated source tests.

In several cases for the revision of AP-42 Section 1.4, the data did not show a strong enough correlation to boiler type, boiler size, or combustion control to justify the grouping of data by these parameters. Where data were averaged across these parameters, the resulting emission factors were rated by the above criteria but subsequently lowered one rating. The decision was made to lower the emission factor rating in these cases to reflect the lack of certainty in the resulting emission factor.

3.4 Emission Factors

The emission factors for the sources covered in Section 1.4 of the AP-42 document are presented in Table 3.4-1. This table provides the number of source tests used in calculating the various emission factors as well as the relative standard deviation associated with each emission factor. This additional information is intended to provide greater insight to the reader about the background of each emission factor. For further detail on each emission factor, the database used to generate most of these factors (except for NO_x emission factors generated from ARD data) is provided on the TTN (See Section 3.2.1 of this document for more details on the database). For NO_x emission factors generated from data provided by the Acid Rain Division, the supporting data is provided in Appendix A.

3.5 Peer Review Process

Part of the development processes of an AP-42 section includes review by a peer group. This group include individuals from EPA, industry, and environmental organizations. In the peer review process, EPA gains an extra level of confidence in the final version of a section. Comments received on the draft version of a section are reviewed to determine if they warrant any changes to the draft version of the section before it becomes final. Appendix B presents the substantial comments received on the draft AP-42 Section 1.4 and EPA's responses to those comments.

3.6 References for Section 3

1. Procedures for Preparing Emission Factor Documents, EPA-454/R-95-015, Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, North Carolina 27711, September 1997.

2. Muhlbaier, J.L. "Particulate and Gaseous Emissions from Natural Gas Furnaces and Water Heaters," Journal of the Air Pollution Control Association, December 1981.

3. Evaluation of the Pollutant Emissions from Gas-Fired Forced Air Furnaces: Research Report No. 1503, American Gas Association Laboratories, Cleveland, OH. May 1975.

4. Nelson, L.P., L.M. Russell, J. J. Watson. "Global Combustion Sources of Nitrous Oxide Emissions," Research Project 2333-4 Interim Report. Radian Corporation, Sacramento, California. 1991.

5. Peer, R.L., E.P. Epner, R.S. Billings. "Characterization of Nitrous Oxide Emission Sources," Prepared for U.S. EPA Contract 68-D1-0031. Radian Corporation, Research Triangle Park, North Carolina. 1995.

Table 3.4-1. SUMMARY OF EMISSION FACTORS FOR AP-42 SECTION 1.4

Pollutant	Number of Tests	Emission Factor ($lb/10^6$ scf)	Relative Standard Deviation (%)
2-Methylnaphthalene	4	2.4E-5	72.77%
3-Methylchloranthrene	1	<1.8E-6	
7,12-Dimethylbenz(a)anthracene	1	<1.6E-5	
Acenaphthene	1	<1.8E-6	
Acenaphthylene	1	<1.8E-6	
Anthracene	1	<2.4E-6	
Arsenic	2	2.0E-4	22.36%
Barium	3	4.4E-3	38.85%
Benz(a)anthracene	1	<1.8E-6	
Benzene	17	2.1E-3	172.00%
Benzo(a)pyrene	1	<1.2E-6	
Benzo(b)fluoranthene	1	<1.8E-6	
Benzo(g,h,i)perylene	1	<1.2E-6	
Benzo(k)fluoranthene	1	<1.8E-6	
Beryllium	1	<1.2E-5	
Butane	1	2.1	
Cadmium	3	1.1E-3	166.72%
Chromium	5	1.4E-3	55.69%
Chrysene	1	<1.8E-6	
CO (Wall-Fired)	49	84	124.00%
CO (Tangential-Uncontrolled)	17	24	179.00%
CO (Tangential-FGR)	7	98	57.00%
Cobalt	2	8.4E-5	63.59%
Copper	4	8.5E-4	49.36%
Dibenzo(a,h)anthracene	1	<1.2E-6	
Dichlorobenzene	1	1.2E-3	
Ethane	4	3.1	43.77%
Fluoranthene	1	3.0E-6	
Fluorene	2	2.8E-6	14.02%
Formaldehyde	22	8.1E-2	194.00%
Hexane	2	1.8	95.61%
Indeno(1,2,3-cd)pyrene	1	<1.8E-6	
Lead	4	4.6E-4	77.61%
Manganese	2	3.8E-4	2.53%
Mercury	2	2.6E-4	43.50%
Methane	42	2.3	118.83%
Molybdenum	2	1.1E-3	64.41%
Naphthalene	2	6.1E-4	85.19%

Table 3.4-1. SUMMARY OF EMISSION FACTORS FOR AP-42 SECTION 1.4 (Continued)

Pollutant	Number of Tests	Emission Factor ($lb/10^6$ scf)	Relative Standard Deviation (%)
Nickel	5	2.1E-3	72.26%
NMHC	48	8.5	150.26%
NOx (Small-Unc.)	18	104	51.00%
NOx (Small-Low NOx)	5	50	54.00%
NOx (Small-Low NOx/FGR)	15	32	18%
NOx (Large Wall-Fired-Low NOx)	5	136	37.00%
NOx (Large Wall-Fired-FGR)	4	101	25.00%
NOx (Large Wall-Fired Unc. Pre-NSPS)	108	275	93.00%
NOx (Large Wall-Fired Unc. Post-NSPS)	13	192	36.00%
NOx (Tangential-Unc.)	62	167	37.00%
NOx (Tangential-FGR)	8	76	64.00%
Pentane	1	2.6	
Phenanthrene	4	1.7E-5	63.82%
PM, Condensible	4	5.7	69.79%
PM, Filterable	21	1.9	111.47%
Propane	1	1.6	
Pyrene	1	5.0E-6	
Selenium	1	<2.4E-5	
Toluene	11	3.4E-3	93.00%
Vanadium	3	2.3E-3	71.77%
Zinc	1	2.9E-2	

4.0 AP-42 Section 1.4

APPENDIX A

Acid Rain Division Data

UNCONTROLLED NOx EMISSION DATA FOR LARGE PRE-NSPS WALL-FIRED BOILERS

util code	utility	plant	state	Average heat input (MMBtu/hr)	nox rate-3Q (lb/MMBtu)	nox rate-3Q (lb/MMscf)
3892	City of Coffeyville Mun. Lght & Pow	Coffeyville	KS	283	0.155	158
814	ENTERGY	Harvey Couch	AR	129	0.282	288
44372	TU Electric	Handley	TX	518	0.403	411
19804	City of Vero Beach	Vero Beach Municipal	FL	337	0.124	126
1167	Baltimore Gas and Electric Company	Riverside	MD	308	0.338	345
22500	Western Resources, Inc.	Murray Gill	KS	251	0.211	215
15474	Central and South West Services	Southwestern	OK	149	0.278	284
14354	Illinois Power	Gadsby	UT	438	0.104	106
814	ENTERGY	Lake Catherine	AR	506	0.24	245
44372	TU Electric	Parkdale	TX	509	0.339	346
44372	TU Electric	Lake Creek	TX	519	0.282	288
17718	Southwestern Public Service Co.	Plant X	TX	348	0.347	354
814	ENTERGY	Harvey Couch	AR	502	0.1	102
16572	Salt River Project Ag. Imp. & Power	Kyrene	AZ	391	0.28	286
14534	City of Pasadena, Water & Power Dep	Broadway	CA	145	0.097	99
22500	Western Resources, Inc.	Murray Gill	KS	381	0.165	168
15474	Central and South West Services	Southwestern	OK	149	0.257	262
44372	TU Electric	Eagle Mountain	TX	736	0.509	519
3278	Central and South West Services	Lon C Hill	TX	447	0.254	259
44372	TU Electric	Morgan Creek	TX	449	0.412	420
14063	Oklahoma Gas & Electric Co.	Mustang	OK	726	0.302	308
44372	TU Electric	Parkdale	TX	620	0.41	418
22500	Western Resources, Inc.	Murray Gill	KS	428	0.224	228
14063	Oklahoma Gas & Electric Co.	Muskogee	OK	826	0.303	309
3278	Central and South West Services	Lon C Hill	TX	433	0.222	226
17698	Central and South West Services	Knox Lee	TX	436	0.324	330
44372	TU Electric	Mountain Creek	TX	704	0.237	242
44372	TU Electric	Eagle Mountain	TX	1051	0.29	296

UNCONTROLLED NOx EMISSION DATA FOR LARGE PRE-NSPS WALL-FIRED BOILERS (CONTINUED)

util code	utility	plant	state	Average heat input (MMBtu/hr)	nox rate-3Q (lb/MMBtu)	nox rate-3Q (lb/MMscf)
16572	Salt River Project Ag. Imp. & Power	Agua Fria	AZ	742	0.25	255
16572	Salt River Project Ag. Imp. & Power	Agua Fria	AZ	752	0.25	255
44372	TU Electric	Parkdale	TX	648	0.369	376
6958	City of Garland	Ray Olinger	TX	630	0.187	191
14063	Oklahoma Gas & Electric Co.	Horseshoe Lake	OK	842	0.189	193
44372	TU Electric	Stryker Creek	TX	1050	0.36	367
44372	TU Electric	Mountain Creek	TX	779	0.5	510
44372	TU Electric	Permian Basin	TX	185	0.26	265
22500	Western Resources, Inc.	Murray Gill	KS	315	0.263	268
14063	Oklahoma Gas & Electric Co.	Mustang	OK	396	0.546	557
44372	TU Electric	Lake Creek	TX	1280	0.28	286
44372	TU Electric	Morgan Creek	TX	1233	0.29	296
44372	TU Electric	North Lake	TX	770	0.173	176
20404	Central and South West Services	Paint Creek	TX	169	0.137	140
44372	TU Electric	Graham	TX	1579	0.29	296
17609	Southern California Edison Co.	Cool Water	CA	534	0.098	100
22500	Western Resources, Inc.	Gordon Evans	KS	546	0.225	230
3265	Central Louisiana Electric Co., Inc	Coughlin	LA	488	0.321	327
13407	Nevada Power Company	Clark	NV	361	0.262	267
44372	TU Electric	North Lake	TX	1051	0.24	245
44372	TU Electric	Valley	TX	1114	0.24	245
20404	Central and South West Services	Oak Creek	TX	548	0.209	213
6616	Fort Pierce Utilities Auth	Henry D King	FL	189	0.198	202
20391	WestPlains Energy	Arthur Mullergren	KS	378	0.12	122
20391	WestPlains Energy	Cimarron River	KS	394	0.219	223
14063	Oklahoma Gas & Electric Co.	Horseshoe Lake	OK	1275	0.137	140
16604	City Public Service	W B Tuttle	TX	851	0.131	134
6958	City of Garland	C E Newman	TX	86	0.434	443
2172	Brazos Electric Power Cooperative,	North Texas	TX	245	0.299	305
44372	TU Electric	Handley	TX	2383	0.281	287

UNCONTROLLED NOx EMISSION DATA FOR LARGE PRE-NSPS WALL-FIRED BOILERS (CONTINUED)

util code	utility	plant	state	Average heat input (MMBtu/hr)	nox rate-3Q (lb/MMBtu)	nox rate-3Q (lb/MMscf)
7294	City of Glendale, Public Service De	Grayson	CA	161	0.06	61
17609	Southern California Edison Co.	Cool Water	CA	709	0.106	108
13407	Nevada Power Company	Sunrise	NV	379	0.354	361
20447	Western Farmers Electric	Mooreland	OK	252	0.323	329
44372	TU Electric	North Lake	TX	2025	0.28	286
8901	Houston Lighting & Power Company	Webster	TX	1823	0.237	242
11269	Lower Colorado River Authority	Sim Gideon	TX	664	0.202	206
18445	Electric Operations	S O Purdom	FL	272	0.202	206
3265	Central Louisiana Electric Co., Inc	Coughlin	LA	797	0.301	307
1015	City of Austin Electric Utility Dpt	Holly Street	TX	810	0.157	160
5063	City of Denton	Spencer	TX	354	0.334	341
44372	TU Electric	Morgan Creek	TX	3671	0.591	603
10620	City of Lake Worth	Tom G Smith	FL	158	0.234	239
22500	Western Resources, Inc.	Gordon Evans	KS	1514	0.409	417
15474	Central and South West Services	Southwestern	OK	576	0.372	379
44372	TU Electric	Valley	TX	3312	0.25	255
16463	Ruston Utilities System	Ruston	LA	42	0.182	186
20447	Western Farmers Electric	Mooreland	OK	648	0.213	217
2172	Brazos Electric Power Cooperative,	R W Miller	TX	499	0.175	179
11269	Lower Colorado River Authority	Sim Gideon	TX	659	0.189	193
20391	WestPlains Energy	Judson Large	KS	600	0.159	162
7634	City of Greenville	Powerlane Plant	TX	31	0.136	139
44372	TU Electric	Tradinghouse	TX	3111	0.335	342
44372	TU Electric	Graham	TX	2161	0.42	428
2442	Bryan Utilities	Bryan	TX	139	0.211	215
20404	Central and South West Services	Rio Pecos	TX	912	0.384	392
814	ENTERGY	Lake Catherine	AR	2469	0.22	224
20813	City of Winfield	East 12Th St	KS	194	0.261	266
17568	South Missisippi Elec. Power Assoc.	Moselle	MS	454	0.323	329
17568	South Missisippi Elec. Power Assoc.	Moselle	MS	486	0.303	309

UNCONTROLLED NOx EMISSION DATA FOR LARGE PRE-NSPS WALL-FIRED BOILERS (CONTINUED)

util code	utility	plant	state	Average heat input (MMBtu/hr)	nox rate-3Q (lb/MMBtu)	nox rate-3Q (lb/MMscf)
17568	South Missisippi Elec. Power Assoc.	Moselle	MS	434	0.28	286
14063	Oklahoma Gas & Electric Co.	Seminole	OK	1806	0.167	170
44372	TU Electric	Lake Hubbard	TX	2198	0.17	173
17698	Central and South West Services	Wilkes	TX	1759	0.299	305
18445	Electric Operations	Arvah B Hopkins	FL	433	0.239	244
2777	Cajun Electric Power Cooperative	Big Cajun 1	LA	925	0.437	446
3265	Central Louisiana Electric Co., Inc	Teche	LA	1758	0.22	224
44372	TU Electric	Eagle Mountain	TX	2021	0.17	173
44372	TU Electric	Valley	TX	2276	0.161	164
17698	Central and South West Services	Wilkes	TX	1653	0.263	268
20404	Central and South West Services	Paint Creek	TX	521	0.309	315
6909	Gainesville Regional Utilities	Deerhaven	FL	638	0.151	154
2777	Cajun Electric Power Cooperative	Big Cajun 1	LA	657	0.347	354
14063	Oklahoma Gas & Electric Co.	Seminole	OK	1870	0.188	192
44372	TU Electric	Tradinghouse	TX	4972	0.441	450
2172	Brazos Electric Power Cooperative,	R W Miller	TX	993	0.36	367
5063	City of Denton	Spencer	TX	418	0.294	300
44372	TU Electric	Permian Basin	TX	3929	0.873	890
44372	TU Electric	Lake Hubbard	TX	2844	0.214	218
20404	Central and South West Services	Fort Phantom	TX	966	0.331	338

Pre-NSPS Average Nox (lb/MMscf) = 275
(lb/MMBtu) = 0.27

UNCONTROLLED NOX EMISSION DATA FOR LARGE POST-NSPS WALL-FIRED BOILERS (CONTINUED)

util code	utility	plant	state	Average heat input (MMBtu/hr)	nox rate-3Q (lb/MMBtu)	nox rate-3Q (lb/MMscf)
20447	Western Farmers Electric	Mooreland	OK	721	0.224	228
14063	Oklahoma Gas & Electric Co.	Seminole	OK	1773	0.205	209
3278	Central and South West Services	La Palma	TX	1005	0.272	277
44372	TU Electric	Decordova	TX	5148	0.324	330
6616	Fort Pierce Utilities Auth	Henry D King	FL	291	0.121	123
9096	Lafayette Utilities System	Doc Bonin	LA	822	0.252	257
44372	TU Electric	Handley	TX	2629	0.15	153
6958	City of Garland	Ray Olinger	TX	1009	0.177	181
18445	Electric Operations	Arvah B Hopkins	FL	1510	0.187	191
7634	City of Greenville	Powerlane Plant	TX	162	0.097	99
44372	TU Electric	Handley	TX	2577	0.12	122
20404	Central and South West Services	Fort Phantom	TX	1189	0.122	124
5109	Detroit Edison Company	Greenwood	MI	2483	0.19	194

Post-NSPS Average NOx (lb/MMscf) =192
(lb/MMBtu) = 0.19

NOx EMISSION DATA FOR WALL-FIRED BOILERS WITH LOW NOx BURNERS

util code	utility	plant	state	Average heat input (MMBtu/hr)	NOx rate-3Q (lb/MMBtu)	NOx rate-3Q (lb/MMscf)
2507	City of Burbank - Public Service De	Magnolia	CA	105	0.108	110
14534	City of Pasadena, Water & Power Dep	Broadway	CA	145	0.107	109
2507	City of Burbank - Public Service De	Olive	CA	147	0.082	84
3265	Central Louisiana Electric Co., Inc	Rodemacher	LA	1737	0.203	207
13998	Ohio Edison Company	Edgewater	OH	380	0.167	170

Average NOx (lb/MMscf) = 136
(lb/MMBtu) = 0.13

UNCONTROLLED NOx EMISSION DATA FOR TANGENTIAL FIRED BOILERS

util code	utility	plant	state	Average heat input (MMBtu/hr)	nox rate-3Q (lb/MMBtu)	nox rate-3Q (lb/MMscf)
9726	GPU Generation Corporation	Gilbert	NJ	505	0.238	243
195	Alabama Power Company	Chickasaw	AL	256	0.168	171
12686	Mississippi Power Company	Sweatt	MS	344	0.335	342
3249	Central Hudson Gas & Electric Corp.	Danskammer	NY	205	0.08	82
14354	Illinois Power	Gadsby	UT	392	0.093	95
12686	Mississippi Power Company	Sweatt	MS	346	0.325	332
17718	Southwestern Public Service Co.	Plant X	TX	605	0.125	128
803	Arizona Public Service Company	Saguaro	AZ	720	0.335	342
6452	Florida Power & Light Company	Cutler	FL	518	0.083	85
3249	Central Hudson Gas & Electric Corp.	Danskammer	NY	381	0.102	104
803	Arizona Public Service Company	Saguaro	AZ	622	0.219	223
6452	Florida Power & Light Company	Cutler	FL	919	0.079	81
44372	TU Electric	Collin	TX	753	0.139	142
17718	Southwestern Public Service Co.	Plant X	TX	529	0.158	161
14354	Illinois Power	Gadsby	UT	624	0.08	82
17609	Southern California Edison Co.	San Bernardino	CA	395	0.1	102
17698	Central and South West Services	Lieberman	LA	471	0.15	153
12686	Mississippi Power Company	Jack Watson	MS	309	0.197	201
17718	Southwestern Public Service Co.	Cunningham	NM	502	0.225	230
24211	Tucson Electric Power Company	Irvington	AZ	363	0.147	150
17609	Southern California Edison Co.	San Bernardino	CA	393	0.103	105
803	Arizona Public Service Company	Yuma Axis	AZ	343	0.071	72
17698	Central and South West Services	Lieberman	LA	424	0.14	143
803	Arizona Public Service Company	Ocotillo	AZ	598	0.147	150
803	Arizona Public Service Company	Ocotillo	AZ	561	0.138	141
24211	Tucson Electric Power Company	Irvington	AZ	367	0.185	189
7806	Entergy Corporation	R S Nelson	LA	810	0.161	164
17698	Central and South West Services	Arsenal Hill	LA	505	0.134	137

UNCONTROLLED NOx EMISSION DATA FOR TANGENTIAL FIRED BOILERS (CONTINUED)

util code	utility	plant	state	Average heat input (MMBtu/hr)	nox rate-3Q (lb/MMBtu)	nox rate-3Q (lb/MMscf)
12686	Mississippi Power Company	Jack Watson	MS	307	0.149	152
1015	City of Austin Electric Utility Dpt	Holly Street	TX	512	0.102	104
8901	Houston Lighting & Power Company	T H Wharton	TX	954	0.157	160
24211	Tucson Electric Power Company	Irvington	AZ	443	0.202	206
12686	Mississippi Power Company	Jack Watson	MS	490	0.194	198
17718	Southwestern Public Service Co.	Nichols Station	TX	652	0.15	153
17698	Central and South West Services	Wilkes	TX	841	0.151	154
17718	Southwestern Public Service Co.	Plant X	TX	859	0.181	185
22500	Western Resources, Inc.	Hutchinson	KS	579	0.272	277
17718	Southwestern Public Service Co.	Cunningham	NM	1200	0.208	212
44372	TU Electric	Stryker Creek	TX	3615	0.16	163
16604	City Public Service	V H Braunig	TX	1216	0.162	165
17718	Southwestern Public Service Co.	Maddox	NM	883	0.154	157
6958	City of Garland	Ray Olinger	TX	332	0.12	122
44372	TU Electric	Mountain Creek	TX	3481	0.162	165
16604	City Public Service	V H Braunig	TX	1069	0.179	183
17718	Southwestern Public Service Co.	Nichols Station	TX	945	0.218	222
9096	Lafayette Utilities System	Doc Bonin	LA	427	0.141	144
14063	Oklahoma Gas & Electric Co.	Horseshoe Lake	OK	590	0.081	83
1015	City of Austin Electric Utility Dpt	Decker Creek	TX	1574	0.155	158
16604	City Public Service	V H Braunig	TX	1945	0.218	222
17718	Southwestern Public Service Co.	Jones Station	TX	1422	0.249	254
16604	City Public Service	O W Sommers	TX	2138	0.205	209
11269	Lower Colorado River Authority	Sim Gideon	TX	1603	0.174	177
8901	Houston Lighting & Power Company	Greens Bayou	TX	2094	0.113	115
16604	City Public Service	O W Sommers	TX	2525	0.153	156
16463	Ruston Utilities System	Ruston	LA	17	0.14	143
1015	City of Austin Electric Utility Dpt	Holly Street	TX	1151	0.178	182
17718	Southwestern Public Service Co.	Jones Station	TX	1368	0.245	250
11269	Lower Colorado River Authority	T C Ferguson	TX	2120	0.175	179

UNCONTROLLED NOx EMISSION DATA FOR TANGENTIAL FIRED BOILERS (CONTINUED)

util code	utility	plant	state	Average heat input (MMBtu/hr)	nox rate-3Q (lb/MMBtu)	nox rate-3Q (lb/MMscf)
1015	City of Austin Electric Utility Dpt	Decker Creek	TX	2504	0.113	115
16687	Savannah Electric and Power Co.	Riverside	GA	175	0.114	116
17718	Southwestern Public Service Co.	Moore County Station	TX	345	0.138	141
44372	TU Electric	Trinidad	TX	1550	0.204	208

Average (lb/MMscf) = 167
(lb/MMBtu) = 0.16

APPENDIX B

Reviewer Comments and EPA Responses

List of Addresseses for Draft Section 1.4

Mr. Lawrence C. Bradbury, P.E., J.D.
(provided comments)
Director, Environment & Safety
Atlanta Gas Light Company
P.O. Box 4569
Atlanta, GA 30302-4569

Mr. Ray A. Bradford **(provided comments)**
Manager Safety
Environmental & Regulatory Compliance
Phillips Petroleum Company
P.O. Box 1967
Houston, TX 77251-1967

Mr. Nicholas J. Bush
Natural Gas Supply Association
1129 20th Street N.W.
Suite 300
Washington, D.C. 20036

Mr. R.E. Cannon
Gas Processors Association
6526 E. 60th Street
Tulsa, OK 74145

Mr. Paul Chu **(provided comments)**
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Dr. A. Kent Evans
Sr. Environmental Planner
Consumers Energy
1945 West Parnall Road
Jackson, WI 49201-8642

Mr. Jeff Glenn
Texas Natural Resource Conservation Commission
P.O. Box 13087
MC 164
Austin, TX 78711-3087

Mr. Robert Hall
Air Pollution Prevention and Control Division (MD-65)
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Mr. Craig S. Harrison
Hunton & Williams
2000 Pennsylvania Avenue, N.W.
Washington, D.C. 20036

Mr. Roy Huntley **(provided comments)**
U.S. Environmental Protection Agency
Emission Factor and Inventory Group (MD-14)
Research Triangle Park, N.C. 27711

Mr. David G. Lachapelle **(provided comments)**
U.S. Environmental Protection Agency
Air Pollution Prevention and Control Division (MD-04)
Research Triangle Park, N.C. 27711

Mr. Bill Maxwell **(provided comments)**
Office of Air Quality Planning and Standards (MD-13)
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Mr. Jim McCarthy
Gas Research Institute
8600 W. Bryn Mawr Avenue
Chicago, IL 60631

Mr. Russ Mosher **(provided comments)**
American Boiler Manufacturers Association
950 N. Glebe Road
Suite 160
Arlington, VA 22203

Mr. Peter Mussio
Supervisor, Environmental Engineering
Union Gas Limited/Centra Gas Ontario, Inc.
50 Keil Drive North
Chatham, Ontario N7M 5M1

Natural Resources Defense Council
40 West 20th Street

New York, NY 10011

Mr. Ted M. Polychronis
Senior Air Quality Engineer
South Coast
Air Quality Management District
Planning & Technology Advancement
21865 Copley Drive
Diamond Bar, CA 91765

Mr. John Pratapas
Gas Research Institute
8600 W. Bryn Mawr Avenue
Chicago, IL 60631

Mr. Ralph Roberson
5400 Glenwood Ave.
Suite G-11
Raleigh, NC 27612

Ms. Marise Lada Textor
Unit Manager, Water & Ecology
Chevron Research & Technology Company
P.O. Box 1627
Richmond, CA 94802-1627

Ms. Glenda Smith
American Petroleum Institute
1220 L Street, N.W.
Washington, DC 20005

R.E. Sommerlad **(provided comments)**
Gas Research Institute (GRI)
8600 West Bryn Mawr Avenue
Chicago, IL 60631-3562

Mr. John Stower **(provided comments)**
Staff Environmental Analysis
Burns and McDonald Engineering
9400 Ward Parkway
Kansas City, MO 64114

Ms. Lori Traweek
American Gas Association
1515 Wilson Blvd.
Arlington, VA 22209

Summary of Comments

Section 1.4 - Natural Gas Combustion

Emission Factors

GRI: In Table 1.4-1, small wall-fired and residential furnaces (<100 MMBtu/hr) are grouped in one category. Previous versions had size ranges at <0.3, 0.3 to <10, 10 to <100, and >100 MMBtu/hr. With the present single grouping of <100 MMBtu/hr, the implication is that NO_x, CO, and N_2O emissions are independent of size. Is there data to support this grouping under one size range?

Response: Based on the available data, EPA determined that boiler size had no clear effect on NO_x and CO emissions for boilers less than 100 MMBtu/hr of heat input. The majority of boilers that are smaller than 100 MMBtu/hr are package units and emissions appear to be more dependent on individual boiler operation than boiler size.

Atlanta Gas: The EPA should consider adding a third category to Table 1.4-1 to address either “other” boilers by heat input or address the “ring retention” type boilers. Atlanta Gas has only ring retention type, fire tube, water/glycol boilers. In order for Atlanta Gas to use emission factors versus stack testing on boilers, it would need the previously published emission factors that used heat input or a new category for ring retention.

Response: The EPA changed the small boiler category to include “other” boiler types. In addition, a footnote to Table 1.4-1 provides a conversion factor for heat input: to convert from lb/10^6 scf to lb/MMBtu, divide by 1,020.

GRI: In Table 1.4-1, the value of 84 lb/10^6 scf for CO converts to about 115 ppm, which seems high. In addition, this value implies there is no variation as a function of size. Previous versions had additional size categories. Is there a reason for the change?

Response: The data supports a CO emission factor for wall-fired boilers that is not dependent on size. There were 49 tests conducted on 23 boilers, with an average emission factor of 84.15 and a relative standard deviation of 124 percent. The EPA analyzed CO emissions versus boiler size and determined that there is no clear relation between size and CO emissions. It is true that if CO emissions were averaged across the previous size ranges, the various boiler size categories would have slightly different CO emission factors, but the overall data set showed no clear relation to size. Therefore, CO emission factors were not categorized by size for the wall-fired and small boiler categories. During the next revision of this section, if additional CO emission data indicates a stronger correlation between size and CO emission levels, then CO emission factors would be distinguished by size.

Burns & McDonnell: Footnote “d” is not properly referenced in Table 1.4-2. It should appear with SO_2 in the pollutant column. Also, EPA should stress that since the emission factors are based on a natural gas heat content of 1,020 Btu/scf, users may need to adjust the emission factors. If the heat content of their natural gas differs from the 1,020 Btu value, users should adjust the emission factor by a ratio of the heat rates (actual Btu heat content /1,020 Btu value). In addition, this same approach applies to the assumed 2,000 grains of sulfur/MMscf for the SO_2 emission rates within the Table 1.4-2.

Response: Footnote “d” has been corrected to properly reference the SO_2 emission factor. Footnote “d” of Table 1.4-2 was also amended to provide guidance on adjusting emission factors for sources firing natural gas with Btu ratings different from 1,020 Btu/scf. A similar approach was taken with the SO_2 emission factor; in this case, EPA provided guidance to adjust the SO_2 emission factor at sources where the sulfur content of the natural gas was different from 2,000 grains/MMscf.

U.S. EPA, EFIG: The CO_2 emission factor in Table 1.4-2 should be 120,000, not 12,000. Also, correct footnote “b” calculation.

Response: The emission factor has been corrected to 120,000 lb/MMscf. The EPA also corrected an error in footnote “b” regarding the calculation of the CO_2 emission factor.

GRI: Table 1.4-2 indicates a conversion of fuel carbon to CO_2 of 99.5%. This converts to about 5,000 ppm of CO and other hydrocarbons. This seems high for commercial boilers. Typical values of CO are less than 50 ppm and other hydrocarbons are typically below 100 ppm. These would result in a conversion efficiency of 99.995% rounded down to 99.9%. Is this value correct?

Response: The assumed fuel carbon conversion as been changed to 99.9%. This adjustment will not change the CO_2 emission factor since it was rounded to two significant figures.

Unidentified commenter via U.S. EPA, EFIG: Put Chemical Abstract Services (CAS) numbers with the Hazardous Air Pollutant (HAP) in the tables. The HAP list in the section is confusing because many of those compounds listed are not listed in section 112(b) of the 1990 Amendments to the Clean Air Act, and they only qualify as HAPs because they are Polycylic Organic Matter (POMs). It would be more clear to label which compounds are HAPs and which are HAPs because they are POMs.

Response: CAS numbers were assigned to all pollutants for easy identification. The EPA also distinguished between HAPs and compounds that are classified as HAPs because they are POMs.

GRI: GRI suggests adding a footnote to the tables to explain to the casual reader the meaning of "emission factor rating."

Response: Rather than footnote each table with an explanation of emission factor ratings, the ratings are discussed at the end of the section. In addition, the EPA fully discusses emission factor ratings in the introduction to AP-42 and in the Emission Factor Documentation for Section 1.4 (background report).

Phillips: The emissions data suggest that grouping the toxics data into specific categories of heaters/boilers could provide more accurate emission factors for air toxics. In the database enclosed with the report, arithmetic averages are used to calculate the criteria pollutant and toxics emission factors. By using arithmetic averages, the assumption is made that the distribution is normal. However, Phillips' review of the normality and probability of the toxics data shows non-random behavior (non-normal distribution). The commenter suggests that, if it has not already been considered, the toxics data may be grouped by heater/boiler heat input to increase the accuracy of the resulting emission factors. (The commenter recognizes that small sample sizes reduce the effectiveness of normality tests.) If this suggested grouping has already been considered and would not work, EPA should discuss this in the background report. Otherwise, EPA should consider a new grouping.

Response: The toxic data were analyzed for these source categories to determine if grouping these data by source type would provide more accurate emission factors. Based on this analysis and given the limited data available, no clear relation is apparent between these source categories and toxic emission levels. Therefore, EPA maintains that the current grouping is the most appropriate. The background report provides a discussion of this decision.

Phillips: The emission factors for natural gas-fired heaters should be delayed pending the results of the GRI/API/Radian study of engine emissions. A program for characterizing and quantifying emissions from reciprocating engines used in oil and gas production is underway and the data will be available in October 1997. The program will also investigate the emissions from a 62.5 MMBtu/hr boiler and a heater treater which is representative of small heaters used in the oil and gas production industry. The list of analytes chosen for this effort includes those reported in Tables 1.4-2 and 1.4-4. The resulting data meet EPA's criteria for an emission factor rating of "A." The value of the data justifies a short delay in publishing the revised emission factors.

Response: The EPA is aware of the data that will be available in the GRI/API/Radian study but that the final report will not be ready for distribution until early 1998. Given the time frame of the publication of this report, EPA does not want to delay the revision of Section 1.4 of AP-42 to include this data. The EPA understands that the report has data from 1 boiler and that the inclusion of 1 extra boiler in the database should have little effect on the emission factors in this revision. However, the emission test data from the boilers tested in the GRI study will be incorporated in the next revision to Section 1.4.

Phillips: Only emission factors with an emission factor rating of A, B, or C should be published in the public domain. The use of emission factors based on poor quality data may have far-reaching, undesirable consequences.

Response: The primary purpose of AP-42 is to provide emission factors for emission inventories. The EPA provides emission factors for as many sources and as many pollutants as available resources allow. The factors are rated "A" through "E" to provide the user with an indication of how good an emission factor is, with an "A" being excellent and "E" being poor. The criteria that are used to determine a rating for a factor can be found in the document entitled "Procedures for Preparing Emission Factor Documents, EPA-454/R-95-0150." While the EPA shares your concern about poor quality emission factors for various reasons, the factor rating is used to judge whether the factor is appropriate.

Controls

GRI: Section 1.4 states that low-NO_x burners and flue gas recirculation (FGR) are the most prevalent combustion NO_x control techniques being applied to natural gas-fired boilers. GRI agrees that low-NO_x burners are prevalent in all classes and size ranges of boilers. However, GRI does not agree that FGR is prevalent for boilers with capacities less than 100 MMBtu/hr. Also, one NO_x control system not mentioned is gas reburning. Gas reburning is an attractive technical and economic alternative to SNCR or SCR. The commenter cited demonstrations of gas reburn on a tangentially-fired utility boiler, a front-wall boiler, and an opposed-wall boiler. The tangentially-fired boiler achieved a 55-65% reduction of NO_x and the opposed-wall and front-wall burners achieved 80% and 73% reductions, respectively.

Response: The EPA is aware that FGR technology is most prevalent in boilers with heat inputs greater than 100 MMBtu/hr, however, EPA has data from boilers with heat inputs less than 100 MMBtu/hr that employ FGR and low-NO_x burners for NO_x control. The EPA has received tests from several boilers with heat inputs less than 100 MMBtu/hr that have FGR and low-NO_x burners. Furthermore, there is a separate category for the boilers for NO_x emission factors. With respect to gas reburning, EPA does not have any data to evaluate the performance of gas reburning. In the final version of this revision to Section 1.4, gas reburning will be mentioned as a NO_x control technology. However, NO_x reduction efficiencies will not be presented in this revision to Section 1.4 due to the lack of supporting data.

GRI: Section 1.4 states that the addition of low-NO_x burners and FGR may reduce combustion efficiency. This implies that low-NO_x burners and FGR are the direct cause of reduced combustion efficiency. This is not necessarily correct. Incomplete combustion can be unburned fuel, unburned carbon, and newly formed solid, liquid, or gaseous hydrocarbons. One of the later species could be CO. GRI suggests the following revision to the paragraph: "Improperly tuned boilers and boilers operating at off-design levels can result in increased partially oxidized combustibles (e.g., CO) and thus, decreased combustion efficiency. The addition of NO_x control systems such as low-NO_x burners and FGR may also result in increased CO or other partially oxidized combustibles, and likewise, decreased combustion efficiency."

Response: The effects of improperly tuned boilers on CO and hydrocarbon emissions were addressed in the discussions on CO and hydrocarbon emissions. Therefore, GRI's suggestion will not be added.

GRI: It is also worth mentioning that current NO_x control systems can lower NO_x emissions without increases in other emissions such as CO, VOCs, and PM. An example of this is shown in Section 2, Reference 6.

Response: The EPA will add this to its discussion of NO_x control technologies.

GRI: There has been significant testing of minor products of combustion and also significant development of low-NO_x burners and NO_x control technology in recent years. If it is not within EPA's current resources to obtain later information, it would be well to indicate the data in the tables are from sources with publication dates ranging from 1990-1996.

Response: The background report provides a list of all the references used in this revision including testing dates. If users wish to evaluate the age of the data, they can download this document from the TTN.

Emission Data

ABMA and EPRI both provided emission data for natural gas fired boilers. The data provided by ABMA was used for comparative purposes and was not included for emission factor development because it did not contain complete testing information. The data provided by EPRI did contain complete testing information and was used in the development of emission factors.