INDUSTRY-SPECIFIC EMISSION FACTORS FOR THE ASPHALT ROOFING MANUFACTURING INDUSTRY

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1. INTRODUCTION

According to the Asphalt Roofing Manufacturers Association (ARMA)'s website, asphalt has proved the most popular roofing material in North America.[1] ARMA's quarterly report for the fourth quarter of 2018 states that over 143 million squares of asphalt shingles were shipped during the year.[2] This paper summarizes the development of industry-specific emissions factors for the asphalt roofing manufacturing industry.

The federal Clean Air Act requires industrial facilities, including those in the asphalt roofing manufacturing industry, to quantify emissions to the ambient atmosphere for permitting and compliance purposes. The U.S. Environmental Protection Agency (EPA)'s primary source of standard emission factors to be used to quantify emissions from stationary sources is *Volume I, Stationary Point and Area Sources*, or the *Compilation of Air Pollutant Emission Factors*, known as AP-42. Section 11.2 of AP-42 provides emission factors and emission calculation methodologies for asphalt roofing, but was last updated in January 1995. The factors provided in this AP-42 section were based on limited data from a few sources for a limited number of pollutants. These factors are now over 20 years old, were based on data from the 1970s, and include test results from sources operating with control technologies that are now obsolete.[3]

Recognizing that the AP-42 factors published by the EPA in 1995 were not representative of the emissions test data available at the time, ARMA produced an internal report in 2003 (ARMA 2003) that evaluated the stack test data from over twenty facilities around the country (2003 emissions database) that included emission factors for certain criteria air pollutants, criteria pollutant precursors, and hazardous air pollutants (HAPs) emitted by asphalt blowing stills, oxidized asphalt tanks, and coaters.[4] In 2005, the emissions factors from the internal ARMA 2003 report were published in a peer reviewed paper (the Trumbore 2005 paper).[5] Since that time, the Trumbore 2005 paper has been widely used as the basis for permitting asphalt roofing manufacturing processes by the industry and accepted by EPA and state regulatory agencies in lieu of AP-42 emission factors. ARMA 2003 and Trumbore 2005 include the same set of emission factors based on the 2003 emissions database. For the remainder of this report, these factors will be referred to as the Trumbore 2005 emission factors since that publication is publicly available and was peer-reviewed.

In 2015, Trinity Consultants (Trinity) was contracted by ARMA to develop a database of stack testing data as a first step in developing emissions factors using more recent stack testing data and the methodologies published in the Trumbore 2005 paper. In 2019, Trinity collected and compiled emissions test data for testing conducted

[1] https://asphaltroofing.org/about-arma/about-us/
[2] https://asphaltroofing.org/wp-content/uploads/2019/01/ARMA-q4-upload-doc.pdf
[3] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278. DOI: 10.1002/ep.10071
[4] EME Solutions, Inc., "Proposed Emission Factors For Criteria Pollutants and Hazardous Air Pollutants from Asphalt Roofing Manufacturing," May 2003.
[5] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278. DOI: 10.1002/ep.10071

after 2003 in order to ensure no overlap with the 2003 emissions database (the 2019 emissions database). The 2019 emissions database includes stack testing data from 43 plants belonging to nine different asphalt roofing manufacturing companies and developed emission factors for the industry based on this database. This report details the emission factors and calculation methodologies. Please note that the emissions factors presented in this report are based on the best available data as provided to Trinity during the data gathering effort and are not intended to supersede or replace the emissions factors published in the Trumbore 2005 paper. The emission factor development methodology used in this report is consistent with the methodology used in the Trumbore 2005 paper.

Differences between the emissions factors recommended in this report and those in the Trumbore 2005 paper should be resolved on a case-by-case basis by evaluating all relevant factors, including changes in process since the 2003 emissions database was compiled, the underlying stack testing data, and the requirements of the permitting or other settings in which these emissions factors are being used. Companies should use their discretion in determining whether and when the use of the emission factors presented here is appropriate.

This report is organized as follows:

- Section 2 provides an overview of the asphalt roofing manufacturing process including a description of emission sources;
- Section 3 provides a description of methodologies used to develop the 2019 emission factors including: data used to develop factors, emission factor ratings, test methods, and emission factor calculation methodology;
- Section 4 provides a summary of the emission factors;
- Appendix A provides tables documenting emission factor development;
- Appendix B provides Q-Q plots for non-normally or non-log-normally distributed data sets; and
- Appendix C provides information on datasets that only include one data point.

2. ASPHALT ROOFING MANUFACTURING PROCESS AND EMISSION SOURCES

The asphalt roofing industry manufactures various asphalt products used mainly in roof construction, including asphalt-saturated felt rolls, fiberglass shingles, organic shingles, mineral-surfaced rolled roofing, and smooth-surfaced rolled roofing.[6] Asphalt roofing manufacturing begins with processing of asphalt flux in the "blowing" process which may be done onsite or pre-blown asphalt can be purchased. Asphalt roofing product manufacturing process consists of six major operations: (1) saturation (for products that contain organic mat only), (2) coating, (3) mineral surfacing (top and bottom), (4) cooling and drying, (5) finishing, and (6) packaging.[7] The emissions factors for these sources of air emissions were calculated and are presented in this report. They are discussed in the following sections.

2.1. EMISSION SOURCE TYPES

2.1.1. Blow stills

Blow stills are process vessels in which asphalt flux is oxidized by bubbling air through the heated asphalt, to raise the softening point, and to reduce penetration of the oxidized asphalt. According to the 2005 Trumbore paper, airflow typically ranges from 15 to 50 cubic feet per minute (cfm) per ton of asphalt throughput at

[6] AP-42, Section 11.2.1.
[7] AP-42, Section 11.2.2.

asphalt temperatures ranging from 400 to 540 degrees Fahrenheit (°F).[8] Blow stills may operate with or without a metal chloride catalyst such as ferric chloride or ferrous chloride and amendments including polyphosphoric acid, and Recycled Engine Oil Bottoms.

The oxidation reactions which occur, generally yield compounds of higher apparent molecular weight through increased polarity and dehydrogenation.[9] Emissions generated during the oxidation process include particulate matter (PM), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxide (NO_X), and organic compound emissions. The 2019 emissions database includes emissions from blow stills controlled with direct fired thermal oxidizers (DFTOs) and regenerative thermal oxidizers (RTOs). Emission factors are based on available data for blow stills operating with and without catalyst.

2.1.2. Applicators

Various applicator processes are used in asphalt roofing manufacturing including coaters, laminate applicators, sealant applicators, and saturators. Coaters apply oxidized asphalt with various mineral fillers to shingles and other roofing products. Laminators apply a mixture of asphalt flux, mineral fillers and polymers to shingles to form layered shingle products.[10] Sealant applicators apply a mixture of asphalt flux and polymers to the shingle. Saturators are used to impregnate organic felt with asphalt to make underlayment and rolled roofing products. Emissions from applicators can include PM, SO_2, CO, and organic compounds. Emissions data for the 2019 emissions database were provided for applicators controlled with RTOs, DFTOs, and fume filters, alone or in combination with RTOs, cartridge filters, or high efficiency air filters (HEAF). The 2019 emissions factors include factors for representative applicator types controlled with and without add-on controls. Emission factors for applicators are provided by process type, including coaters, saturators, and other saturators/coaters[11]. One source test result was provided for laminators. Due to lack of sufficient data, no factors are calculated for laminators.

2.1.3. Wet Loopers

Wet loopers allow the roofing product to continuously move while asphalt has time to penetrate onto the felt.[12] The 2019 emissions database includes wet loopers controlled with fume filters. Emissions from wet loopers can include PM. AP-42 emission factors for saturators include emissions from wet loopers. Since test results for wet loopers are provided, emission factors for this emission source alone are included. Wet loopers are not addressed in the Trumbore 2005 paper.

2.1.4. Tanks

Asphalt flux and finished coating are typically stored in fixed roof tanks operating at temperatures ranging from 250 to 475°F.[13] Emissions from tanks may be controlled by a variety of methods, including RTO, thermal

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[8] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278.
[9] Ibid.
[10] AP-42, Section 11.2.2.

[11] Other saturators/coaters include those units identified as "Organic Saturator/Coater," "Other Saturator/Coater," or "Organic Saturator/mat coater" in data provided by industry. Since no further defining characters were provided, these units were grouped together in this other saturators/coaters category.
[12] AP-42, Section 11.2.2.
[13] Ibid.

oxidation and filters, or may be uncontrolled. This report presents organic compound factors for coating and flux tanks.

2.1.5. Mixers

Mixers are used to combine asphalt, polymers, and mineral stabilizers. Emissions from mixers may be controlled with fume or cartridge filters or scrubbers.[14] Emissions from mixers can include PM, SO_2, and organic compounds.

2.1.6. Cooling Sections

After coating and application of mineral surfacing, the hot shingles are cooled using water-cooled rolls and/or water sprays.[15] The cooling process has the potential to generate PM emissions and, based on available industry test data, organic compound emissions. The cooling sections included in the 2019 emissions database are not controlled. Emission factors for cooling sections are not presented in AP-42 or in the Trumbore 2005 paper.

2.1.7. Loading Racks

Loading racks are used to load asphalt onto trucks and/or railcars for delivery. Emissions from loading racks include PM, SO_2, CO, NO_X, and organic compounds. Based on available industry test data, emissions from loading racks are typically controlled with RTOs combined with a fume filter. Emission factors for loading racks are not presented in AP-42 or in the Trumbore 2005 paper. Factors are provided for the first time in this paper for this emission source type because sufficient test data are available.

2.1.8. Limestone Crushers

One source test result for filterable particulate were provided for limestone crushers controlled by dust collectors. Due to lack of sufficient data a factor is not calculated for limestone crushers. Emission factors for limestone crushers are not presented in AP-42 or in the Trumbore 2005 paper.

2.1.9. Other Potential Sources

There are other potential sources of emissions at asphalt roofing manufacturing facilities including, but not limited to, granule storage silos, mineral storage silos, mineral run tanks, and granule run tanks. No emissions test data were available for these sources and as such, no emission factors are presented.

3. EMISSION FACTOR DEVELOPMENT METHODOLOGIES

Emission factors were developed for criteria pollutants PM, SO_2, CO, NO_X, and organic compounds for the following emission source categories:

- Blow still operating with catalyst
- Blow still operating without catalyst
- Applicators (without RTO or DFTO): Coaters
- Applicators (with RTO or DFTO): Coaters

[14] Ibid.
[15] Ibid.

- Applicators (without RTO or DFTO): Saturators
- Applicators (with RTO or DFTO): Saturators
- Applicators (without RTO or DFTO): Other coaters/saturators
- Applicators (with RTO or DFTO): Other coaters/saturators
- Wet Looper
- Coating Tanks
- Flux Tank
- Mixers
- Cooling sections
- Loading Racks (with RTO or DFTO)

Emission factors were developed for HAPs including hydrogen sulfide (H_2S), hydrochloric acid (HCl), and benzene where sufficient data were available. Test data was not provided for other HAPs and as such, no emission factors are presented.

3.1. TREATMENT OF PARTICULATE EMISSIONS

This paper provides emissions factors for filterable particulate matter (PM-filt), condensable particulate matter (PM-cond), particulate matter less than 10 microns in diameter (PM_{10}), and particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) where test results are available.[16] The regulated particulate pollutants under air quality regulations are PM_{10} and $PM_{2.5}$, including both filterable and condensable PM. However, where PM_{10} and $PM_{2.5}$ factors are not available, total PM can be used as a conservative estimate of PM_{10} and $PM_{2.5}$. Similarly, in cases where PM_{10} emissions factors are presented and no $PM_{2.5}$ emission factor is available, use of the PM_{10} factor as $PM_{2.5}$ is suggested as a conservative estimate.

Test methods 5A and 5 provide a measure of the total filterable PM, while test method 202 provides a measure of total condensable PM. Test method 201A provides a measure of filterable-only PM_{10} and $PM_{2.5}$ emissions. Test method 201A combined with 202 can be used to determine combined, filterable and condensable, PM_{10} and $PM_{2.5}$ emissions. Test results for PM_{10} or $PM_{2.5}$ which were based on method 201A (filterable) only were excluded from the emission factor determination.[17]

3.2. TREATMENT OF ORGANIC COMPOUND EMISSIONS

This paper provides factors for total organic compounds (TOC) and total non-methane organic compounds (TNMOC), where test results are available. The regulated pollutant under air quality regulations is often volatile organic compounds (VOC). By definition, VOC excludes methane (which is included in TOC) and ethane (which is included in both TOC and TNMOC). However, where VOC factors are not available, TNMOC or TOC can be used as a conservative estimate of VOC. Test method 25A provides a measure of TOC while a combination of test methods 25A and 18 can provide a measure of TNMOC. To ensure consistency and accurate emission factors,

[16] A small number of test results are reported as total PM (PM-tot), which would include all filterable and condensable PM. However, the tests which provide PM-tot also provide results for PM-filt and PM-cond. Therefore, emission factors for PM-tot are not presented but can be derived from the proposed PM-filt and PM-cond factors.

[17] Filterable only PM_{10} and $PM_{2.5}$ results were excluded since more test data was available for combined filterable and condensable particulate. In addition, developing emission factors for filterable and another set of factors for total (filterable + condensable) would not be appropriate since they would be based on different data sets and could provide conflicting emission factors.

test results based on method 25A are assumed to represent TOC and results based on methods 25A and 18 are assumed to represent TNMOC, regardless of the pollutant name under which the result was reported.[18]

3.3. DATA USED TO DEVELOP EMISSIONS FACTORS

Emission test data from 43 plants belonging to nine (9) different companies in the asphalt roofing manufacturing industry were used to develop emission factors. Test data provided were gathered from stack testing conducted between 1986 and 2018, and only data generated after 2003 were used in the emission factor development.[19] Emission test data were provided as mass-based emission rates, in pounds of emissions per ton of shingles produced (lb/ton shingles) and pounds of emissions per ton asphalt throughput (lb/ton asphalt). It is important to use lb/ton of shingles or lb/ton of asphalt since these emission factors are based on output or input, respectively, and therefore can be used for equipment of varying capacities and operating speeds. Simple pound per hour (lb/hr) emission factors cannot be accurately applied from one piece of equipment since they cannot similarly be scaled for equipment size.

All data provided are post-control technology, when applicable. As such, all developed emission factors are post-control technology when a control technology is utilized.

[18] Some test results were originally reported as VOC in the available test data. These results are used to calculate TOC factors if determined with method 25A or TNMOC if determined with method 25A and 18.

[19] Data generated in 2003 or earlier were excluded to avoid overlapping of data between the previously developed emission factors and this report.

3.3.1. Test Methods

Table 3-1 provides a summary of the test methods used to develop the emissions factors.

Table 3-1 Stack Testing Methods

Pollutant	Test Methods Used
PM-filt	5A (majority), 5
PM-cond	202
PM_{10}	201A+202
$PM_{2.5}$	201A+202
SO_2	6C (majority), 6, 15/16
CO	10
NO_X	7E
TOC	25A
TNMOC	25A+18
H_2S	15
HCl	26, 320
Benzene	0030

3.3.2. Control Technologies

Table 3-2 below provides a summary of the control technologies included in the test results used to develop the emissions factors for each emission source type. In most cases, the emission factor developed was based on results from representative units with various control types. Applicators are the one exception. Separate emission factors were developed for applicators with and without RTOs or DFTOs, as use of an RTO or DFTO is expected to have a significant impact on emissions and sufficient data were available to support two sets of factors.

Note control technologies shown in Table 3-2 only represent those indicated in data submissions for the 2019 emissions database and may not be inclusive of all control technologies used by industry. For example, the data for tanks in the 2019 emission database was from a single participating company with tanks with uncontrolled emissions. Industry practice demonstrates that tank emissions may be controlled by a variety of methods, including RTO, thermal oxidation and filters, or may be uncontrolled.

Table 3-2 Control Technologies in the 2019 Emissions Database by Source Type

Emission Source Type [A]	Control Technologies
Blow still operating with metal chloride catalyst	DFTO, DFTO/knockout tank
Blow still operating without metal chloride catalyst	DFTO, DFTO/knockout tank, RTO/fume filter, other
Applicators (asphalt-based factors, without RTO or DFTO): Coaters	Fume filter/cartridge filter, fume filter
Applicators (shingles-based factors, without RTO or DFTO): Coaters	Fume filter
Applicators (shingles-based factors, with RTO or DFTO): Coaters	RTO, RTO/fume filter
Applicators (shingles-based factors, without RTO or DFTO): Saturators	Fume filter
Applicators (shingles-based factors, with RTO or DFTO): Saturators	DFTO
Applicators (shingles-based factors, without RTO or DFTO): Other saturators/coaters	Fume filter
Applicators (shingles-based factors, with RTO or DFTO): Other saturators/coaters	RTO
Wet Looper	Fume filter
Coating Tank (asphalt-based factors)	None for data included in this study
Flux Tank (asphalt-based factors)	None for data included in this study
Mixers (shingles-based factors)	Fume filter
Mixers (asphalt-based factors)	Scrubber, fume filter/cartridge filter, fume filter
Cooling sections (shingles-based factors)	None for data included in this study
Loading Racks (asphalt-based factors)	RTO/fume filter

[A] Refer to Section 3.3 for discussion of asphalt-based and shingle-based factors.

3.3.3. Test Result Units

Test data were provided in units of lb/ton asphalt and lb/ton shingles depending on whether the test information allowed conversion from one unit to the other. Therefore, where both units were provided, separate factors were developed for each. Test results provided in other units (e.g., mg/dscfm) could not be

used in development of emission factors, because sufficient data was not available to convert these tests to lb/ton asphalt or lb/ton shingles.

3.4. EMISSION FACTOR CALCULATION METHODOLOGY

Emission factors were calculated based on available data for each pollutant, unit of measure, and emission source type combination. In cases where multiple test results are available from a plant for a given pollutant, an emission factor for the plant is first determined by averaging test data provided from the plant. Then, the 2019 emission factor is calculated as the average of the available plant emission factors in the 2019 emissions database. This methodology is consistent with the Trumbore 2005 paper, which generated average emission factors for each plant and then calculated emission factors based on the average of the plant factors.

3.4.1. Non-Detects

The Trumbore 2005 paper handles non-detect emission results in accordance with recommendations in EPA's procedures for preparing emission factor documents, from AP-42. Due to the nature of the test results provided (in lb/ton asphalt or shingles) for the 2019 emissions database, Trinity was unable to determine whether any results were non-detect. Mass-based emission rates provided are used in the development of factors unless otherwise noted in this section.

3.4.2. Data Assumptions Used

For particulate emissions and organic compounds, where the test method was not consistent with the form of the pollutant listed, Trinity assumed that the test method was correct and updated the pollutant accordingly. Test results based on method 25A are assumed to represent TOC and results based on methods 25A and 18 are assumed to represent TNMOC, regardless of the pollutant name under which the result was reported. Test results based on methods 5A and 5 are assumed to represent total filterable PM, test method 202 is assumed to represent total condensable PM, and test method 201A is assumed to represent filterable-only PM_{10} and $PM_{2.5}$ emissions.

3.4.3. Data Excluded from Emission Factor Development

The following methods were used to exclude data from the development of emission factors:

- ***Outliers.*** Outliers are determined in accordance with Appendix C of the EPA's Draft Final Recommended Procedures for Development of Emission Factors and Use of the WebFIRE Database20 using ProUCL, an EPA-developed statistical package. The outlier test is applied to log-transformed data sets in an iterative process until outliers identified with a 95% confidence level have been removed.[21] The Rosner outlier test is used for data sets containing twenty five (25) or more values, and the Dixon outlier test is used for data sets containing less than 25 values and more than two (2) values. A total of eighteen (18) outliers were identified in this study.

- ***Test results listed as zero or results with no pollutant or method specified.*** Test results listed as zero (0) were excluded. Sufficient information was not available to determine whether zero entries were below the

[20] U.S. EPA Office of Air Quality Planning and Standards, Sectors Policies & Programs Division, Measurement Policy Group, Draft Final *Recommended Procedures for Development of Emission Factors and Use of the WebFIRE Database*, EPA-453/D-13-001 (August 2013).
[21] Ibid.

detection limit, an omission in data entry, or no test result was obtained for some reason. Additionally, where a pollutant or test method is not specified, test results are not used, as sufficient information was not available to assign a pollutant.

- ***PM_{10} and $PM_{2.5}$ calculated using Method 201A only.*** As previously discussed, the PM_{10} and $PM_{2.5}$ emission factors developed and presented in this report include both filterable and condensable PM. Therefore, test results based on Method 201A (filterable only) were excluded from factor development.

- ***Data sets containing only one (1) test result.*** Emission factors were determined only for those data sets for which at least two (2) valid test results are available. The table in Appendix C contains a list of emission source type and pollutant combinations that were excluded for this reason.

- ***Test results generated in or before 2003.*** Test results generated in or before the year 2003 were excluded from the emission factor calculation.

3.4.4. Normality Test

Each set of test results with at least three data points was reviewed for normality using the Anderson Darling test, similar to the normality test conducted in the Trumbore 2005 paper.[22] A data set which has probability values (p values) less than the significance level of 0.05 is assumed to be normally distributed. Additionally, each set of test results was also log-transformed and then again tested for normality. A log-transformed data set which has p values less than 0.05 is assumed to be log-normally distributed. In most cases, the test data was at least log-normally distributed. EPA supports the acceptance of log-normally distributed data for environmental data in its Data Quality Assessment Guidance, noting that "the lognormal is an important probability distribution when analyzing environmental data where normality cannot be assumed."[23] P values for each data set are provided in the tables in Appendix A.

Table 3-3 provides a summary of the results of the Anderson-Darling tests for the emission test data sets.

[22] Normality test conducted using excel formulas from www.spcforexcel.com.
[23] U.S. EPA Office of Environmental Information. "Guidance document, Data Quality Assessment: Statistical Methods for Practitioners EPA QA/G-9S," EPA/240/B-06/003, February 2006, page 27.

Table 3-3 Results of Anderson-Darling Normality Tests

Emission Source Type [c]	Normally or log-normally distributed data sets	Data sets not normally or log-normally distributed
Blow still operating with metal chloride catalyst	PM-filt, PM-cond, SO_2, CO, NO_X, TOC, TNMOC, HCl	H_2S
Blow still operating without metal chloride catalyst	PM-cond, PM_{10}, $PM_{2.5}$, SO_2, NO_X, TOC, HCl, Benzene	PM-filt, CO, TNMOC
Applicators (asphalt-based factors, without RTO or DFTO): Coaters	PM-filt	None
Applicators (shingles-based factors, without RTO or DFTO): Coaters	PM-cond, $PM_{2.5}$[a], CO, TOC, Benzene[a]	PM-filt, SO_2, TNMOC, H_2S
Applicators (shingles-based factors, with RTO or DFTO): Coaters	$PM_{2.5}$, TOC[a], H_2S[b], SO_2[a], TNMOC	PM-filt, PM-cond, CO
Applicators (shingles-based factors, without RTO or DFTO): Saturators	PM-filt	none
Applicators (shingles-based factors, with RTO or DFTO): Saturators	PM-filt	none
Applicators (shingles-based factors, without RTO or DFTO): Other saturators/coaters	PM-filt	none
Applicators (shingles-based factors, with RTO or DFTO): Other saturators/coaters	PM-filt[a]	none
Wet Loopers	PM-filt	none
Coating Tank (asphalt-based factors)	TNMOC	none
Flux Tank (asphalt-based factors)	TNMOC	none
Mixers (shingles-based factors)	PM-filt[b]	none
Mixers (asphalt-based factors)	PM-filt[a], TOC, SO_2	none
Cooling sections (shingles-based factors)	PM-filt, PM-cond, $PM_{2.5}$	TOC
Loading Racks (asphalt-based factors)	PM_{10}, SO_2, CO, NO_x[a], TOC, TNMOC	none

[a] Distribution of data set could not be determined using the Anderson-Darling test because the data set contained only two values.
[b] Distribution of data set could not be determined using the Anderson-Darling test because values in the data set were the same.
[c] Refer to Section 3.3 for discussion of asphalt-based and shingle-based factors.

Appendix B provides Q-Q plots for the log-transformed data sets which were determined to not be normally or log-normally distributed using the Anderson Darling test. A Q-Q plot provides a visual method to assess log-normality. A linear pattern displayed by the majority of the data suggests approximate log-normality and a

correlation coefficient of 0.95 or greater suggests log-normality.[24] Of the twelve (12) data sets which were not normally or log-normally distributed under Anderson Darling, four (4) have a correlation coefficient greater than 0.95. Twelve data sets visually appear to have a generally linear pattern. As such, no data is excluded on the basis of distribution, and emission factors were developed for all data sets for which at least two valid data points are available.

3.5. EMISSION FACTOR RATINGS

Ratings are assigned to each emission factor. To maintain consistency with previously developed factors, EPA's rating system, which is also used in the Trumbore 2005 paper is used in this analysis. EPA's rating descriptions for AP-42 factors are provided in Table 3-4 below. The table also provides a translation of how the ratings were quantitatively assigned to the emission factors.

[24] U.S. EPA ORD Site Characterization and Monitoring Technical Support Center "ProUCL Version 5.1.002 Technical Guide; Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations ." EPA/600/R-07/041, October 2015, page 48.

Table 3-4 Emission Factor Ratings

Rating	EPA Description[25, 26]	Application of Rating
A	Excellent. Emission factor is developed primarily from A and B rated source test data taken from many randomly chosen facilities in the industry population. The source category population is sufficiently specific to minimize variability.	> 10 plant sampled and > 20 data points
B	Above average. Emission factor is developed primarily from A or B rated test data from a moderate number of facilities. Although no specific bias is evident, is not clear if the facilities tested represent a random sample of the industry. As with the A rating, the source category population is sufficiently specific to minimize variability.	> 5 plant sampled and > 10 data points
C	Average. Emission factor is developed primarily from A, B, and C 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. As with the A rating, the source category population is sufficiently specific to minimize variability.	> 1 plant sampled and > 5 data points
D	Below average. Emission factor is developed primarily from A, B and C rated test data from a small number of facilities, and there may be 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 population.	> 1 plant sampled or > 5 data points
E	Poor. Factor is developed from C and D rated test data from a very few number of facilities, and there may be 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.	1 plant and ≤ 5 data points
U	Unrated (Only used in the L&E documents). Emission factor is developed from source tests which have not been thoroughly evaluated, research papers, modeling data, or other sources that may lack supporting documentation. The data are not necessarily "poor," but there is not enough information to rate the factors according to the rating protocol. "U" ratings are commonly found in L&E documents and FIRE rather than in AP 42.	N/A

4. EMISSION FACTORS

Tables 4-1 through 4-4 provide summaries of the developed criteria pollutant emission factors developed for each emission source type in the asphalt roofing manufacturing industry. Table 4-5 provides a summary of developed HAP emission factors.

[25] From AP-42 FAQS (https://www3.epa.gov/ttnchie1/faq/ap42faq.html#ratings).
[26] Trinity assumed that emissions test data provided was of high-quality and would be considered either A or B rated source test data under the EPA rating methodology.

Table 4-1 Criteria Pollutant Emission Factors – Blow Stills

Source Type	Units	PM-filt	PM-cond	PM_{10}	$PM_{2.5}$	SO_2	CO	NO_X	TOC	TNMOC
Blow still operating with metal chloride catalyst	lb/ton asphalt	0.025	0.038	No Data	No Data	0.587	0.255	0.074	0.004	0.035
	Standard Deviation	0.02	0.03			0.09	0.20	0.01	0.003	0.03
	Rating	B	C			C	C	C	C	D
Blow still operating without metal chloride catalyst	lb/ton asphalt	0.068	0.028	0.090	0.072	1.074	0.315	0.079	0.025	0.009
	Standard Deviation	0.09	0.03	0.03	0.03	0.37	0.63	0.05	0.033	0.008
	Rating	A	B	E	E	C	B	C	C	C

Table 4-2 Criteria Pollutant Emission Factors – Applicators and Wet Loopers

Source Type	Units	PM-filt	PM-cond	$PM_{2.5}$	SO_2	CO	TOC	TNMOC
Applicators (asphalt-based factors, without RTO or DFTO): Coaters	lb/ton asphalt Standard Deviation Rating	0.011 0.004 D	No Data	No Data	No Data	No Data	No Data	No Data
Applicators (shingles-based factors, without RTO or DFTO): Coaters	lb/ton shingle Standard Deviation Rating	0.005 0.01 A	0.002 0.001 B	0.001 0.0001 E	0.002 0.004 C	0.005 0.003 C	0.024 0.005 D	0.052 0.02 C
Applicators (shingles-based factors, with RTO or DFTO): Coaters	lb/ton shingle Standard Deviation Rating	0.004 0.004 C	0.001 3E-4 C	0.001 2E-4 D	0.005 6E-5 E	0.010 0.007 C	0.014 N/A E	0.003 0.004 D
Applicators (shingles-based factors, without RTO or DFTO): Saturators	lb/ton shingle Standard Deviation Rating	0.036 0.04 C	No Data	No Data	No Data	No Data	No Data	No Data
Applicators (shingles-based factors, with RTO or DFTO): Saturators	lb/ton shingle Standard Deviation Rating	0.004 0.002 E	No Data	No Data	No Data	No Data	No Data	No Data
Applicators (shingles-based factors, without RTO or DFTO): Other saturators/coaters	lb/ton shingle Standard Deviation Rating	0.005 0.003 D	No Data	No Data	No Data	No Data	No Data	No Data
Applicators (shingles-based factors, with RTO or DFTO): Other saturators/coaters	lb/ton shingle Standard Deviation Rating	0.054 0.03 E	No Data	No Data	No Data	No Data	No Data	No Data
Wet Loopers	lb/ton shingle Standard Deviation Rating	0.004 0.004 D	No Data	No Data	No Data	No Data	No Data	No Data

Table 4-3 Criteria Pollutant Emission Factors –Tanks and Mixers

Source Type	Units	PM-filt	SO_2	TOC	TNMOC
Coating Tank (asphalt-based factors)[27]	lb/ton asphalt Standard Deviation Rating	No Data	No Data	No Data	0.069 0.05 E
Flux Tank (asphalt-based factors)[28]	lb/ton asphalt Standard Deviation Rating	No Data	No Data	No Data	0.022 0.02 E
Mixers (shingles-based factors)	lb/ton shingle Standard Deviation Rating	0.001 2E-19 C	No Data	No Data	No Data
Mixers (asphalt-based factors)	lb/ton asphalt Standard Deviation Rating	0.135 0.19 D	0.027 0.02 D	0.049 0.04 E	No Data

Table 4-4 Criteria Pollutant Emission Factors – Cooling Sections and Loading Racks

Source Type	Units	PM-filt	PM-cond	PM_{10}	$PM_{2.5}$	SO_2	CO	NO_X	TOC	TNMOC
Cooling sections (shingles-based factors)	lb/ton shingle Standard Deviation Rating	0.024 0.02 C	0.006 0.01 D	No Data	0.010 N/A E	No Data	No Data	No Data	0.004 0.004 C	No Data
Loading Racks (asphalt-based factors)	lb/ton asphalt Standard Deviation Rating	No Data	No Data	0.002 0.0005 E	No Data	0.005 0.003 D	0.0005 0.001 E	0.0003 2E-5 E	0.021 0.02 D	0.0014 0.0002 E

Table 4-5 HAP Emission Factor Summary

Source Type	Units	H_2S	HCl	Benzene
Blow still operating with metal chloride catalyst	lb/ton asphalt Standard Deviation Rating	0.0006 0.0003 C	0.429 0.44 C	No Data
Blow still operating without metal chloride catalyst	lb/ton asphalt Standard Deviation Rating	No Data	0.014 0.01 C	0.001 0.0003 E
Applicators (shingles-based factors, without RTO or DFTO): Coaters	lb/ton shingle Standard Deviation Rating	0.0001 4E-5 D	No Data	0.0004 N/A E
Applicators (shingles-based factors, with RTO or DFTO): Coaters	lb/ton shingle Standard Deviation Rating	0.008 N/A E	No Data	No Data

Tables showing the development of each factor, including number of data points, normality test results, etc., are provided in Appendix A. Additionally, Appendix B provides Q-Q plots for the log-transformed data sets which were determined to not be normally or log-normally distributed using the Anderson Darling test.

[27] The emission factor for coating tanks was based on stack testing for tank liquid temperatures ranging from approximately 360 °F to 490 °F.

[28] The emission factor for flux tanks was based on stack testing for tank liquid temperatures ranging from approximately 355 °F to 495 °F.

APPENDIX A: DETAILED FACTOR DEVELOPMENT TABLES

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-1.1: Blow still operating with catalyst - comparison

Source	Units	PM-filt	PM-cond	SO_2	CO	NO_X	TOC	TNMOC	H2S	HCl
Proposed	Proposed EF (lb/ton asphalt)	0.025	0.038	0.59	0.26	0.07	0.004	0.03	0.0006	0.429
	# data points	22	10	11	12	8	8	4	9	7
	# plants sampled	9	3	2	2	2	2	2	2	2
	std deviation	0.02	0.03	0.09	0.20	0.01	0.003	0.03	0.0003	0.44
	Proposed EF rating	B	C	C	C	C	C	D	C	C
Change in Factors	Change from 1995 to 2005	--	--	--	--	--	--	--	--	--
	Change from 2005 to 2019	-65%	--	31%	--	--	--	--	--	87%
	Change from 1995 to 2019	--	--	--	--	--	--	--	--	--
Trumbore - 2005	Proposed EF (lb/ton asphalt) [2]	0.072	--	0.45	--	--	--	--	--	0.230
	# data points	3	--	2	--	--	--	--	--	4
	# plants sampled	--	--	--	--	--	--	--	--	--
	std deviation	0.045	--	0.11	--	--	--	--	--	0.035
	Proposed EF rating	C	--	D	--	--	--	--	--	B
AP-42 - 1995	EF (lb/ton asphalt) [3]	--	--	--	--	--	--	--	--	--
	# plants sampled	--	--	--	--	--	--	--	--	--
	EF rating	--	--	--	--	--	--	--	--	--

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.

[2] Emission factors for blow still operating with catalyst from Tables 4 and 5 of Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278. The Trumbore paper does not clarify whether the PM emission factor is PM-filterable or PM-total (filterable + condensable). Test methods used to develop the factor are not provided. Since the PM factor is compared to the AP-42 factor, which includes filterable only, it is assumed that the PM factor in the Trumbore paper is PM-filterable. The Trumbore paper provides an emission factor for naphthalene which is not considered in this analysis because naphthalene test results were not available.

[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type. AP-42 Tables 11.2-2 and 11.2-4 provide PM and TOC factors for asphalt blowing with an afterburner. These factors are provided in the "Blow still operating without catalyst" table.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-1.2: Blow still operating with catalyst - factor development

Plant	PM-filt	PM-cond	SO_2	CO	NO_X	TOC	TNMOC	H2S	HCl
5	0.006	no data	no data	no data	no data	no data	no data	no data	no data
6	0.027	no data	no data	no data	no data	no data	no data	no data	0.120
8	0.023	no data	no data	no data	no data	no data	no data	no data	no data
11	0.030	no data	no data	no data	no data	no data	no data	no data	no data
21	0.024	no data	no data	no data	no data	no data	0.060	no data	no data
26	0.010	0.010	no data	no data	no data	no data	no data	no data	no data
28	0.050	no data	no data	no data	no data	no data	no data	no data	no data
29	0.023	0.064	0.633	0.298	0.069	0.003	0.009	0.000	0.739
40	0.032	0.040	0.542	0.213	0.078	0.005	no data	0.001	no data
Calculated Emission Factor [1]	0.025	0.038	0.587	0.255	0.074	0.004	0.035	0.001	0.429
Propose Factor? [2]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# data points available	22	10	13	12	8	9	4	9	8
# data points used	22	10	11	12	8	8	4	9	7
# data points excluded [3]	0	0	2	0	0	1	0	0	1
# plants sampled based on data used	9	3	2	2	2	2	2	2	2
Test Method(s) Used	5, 5A	202	6C	10	7E	25A	25A+18	15	26, 320
Control Device(s)	DFTO, Knockout Tank	DFTO	DFTO	DFTO	DFTO	DFTO	DFTO	DFTO	DFTO
Standard Deviation	0.021	0.028	0.094	0.203	0.008	0.003	0.026	0.0003	0.438
Anderson-Darling Normality Test p-Value - Test Results [4]	0.06	0.83	0.35	0.16	0.96	0.16	0.07	0.04	0.29
Is Data Normally Distributed? [5]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.50	0.54	0.38	0.22	0.98	0.40	0.54	0.11	0.46
Is Data Log-Normally Distributed? [5]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Minimum	0.002	0.010	0.461	0.039	0.061	0.001	0.005	0.000	0.120
Maximum	0.078	0.096	0.781	0.663	0.086	0.008	0.060	0.001	1.270
Average	0.028	0.044	0.583	0.255	0.072	0.004	0.022	0.001	0.650

[1] Units for all emission factors are lb/ton asphalt.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-2.1: Blow still operating without catalyst - comparison

Source	Units	PM-filt	PM-cond	PM10 [1]	PM2.5 [1]	SO_2	CO	NO_X	TOC	TNMOC	HCl	Benzene
Proposed	Proposed EF (lb/ton asphalt)	0.068	0.028	0.090	0.072	1.074	0.315	0.079	0.025	0.009	0.014	0.001
	# data points	95	39	3	3	23	47	21	15	24	6	3
	# plants sampled	18	8	1	1	5	8	4	4	4	2	1
	std deviation	0.09	0.03	0.03	0.03	0.37	0.63	0.05	0.033	0.008	0.01	0.0003
	Proposed EF rating	A	B	E	E	C	B	C	C	C	C	E
Change in Factors	Change from 1995 to 2005	-90%	--	--	--	--	--	--	-76%	--	--	--
	Change from 2005 to 2019	-15%	--	--	--	19%	-55%	32%	-38%	--	142%	-84%
	Change from 1995 to 2019	-92%	--	--	--	--	--	--	-85%	--	--	--
Trumbore - 2005	Proposed EF (lb/ton asphalt) [2]	0.08	--	--	--	0.9	0.7	0.06	0.04	--	0.0056	0.0033
	# data points	112	--	--	--	14	22	13	17	--	--	
	# plants sampled	17	--	--	--	11	14	10	13	--	3	5
	std deviation	0.05	--	--	--	0.29	0.58	0.03	0.04	--	0.0043	0.0054
	Proposed EF rating	A	--	--	--	A	B	A	A	--	B	B
AP-42 - 1995	EF (lb/ton asphalt) [3]	0.81	--	--	--	--	No Data	--	0.17	--	--	--
	# plants sampled	1	--	--	--	--	--	--	1	--	--	--
	EF rating	D	--	--	--	--	--	--	D	--	--	--

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.
[2] Emission factors for blow still operating without catalyst from Tables 2 and 3 of Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278. The Trumbore paper does not clarify whether the PM emission factor is PM-filterable or PM-total (filterable + condensable). Test methods used to measure the PM results and used to calculate the PM emission factor are not provided. Since the PM factor is compared to the AP-42 factor, which includes filterable only, it is assumed that the PM factor in the Trumbore paper is PM-filterable. The Trumbore paper provides emission factors for other hazardous air pollutants (HAP) which are not considered in this analysis because test results were not available.
[3] AP-42 factors from AP-42 Table 11.2-2 and 11.2-4 (1/95) for asphalt blowing, coating asphalt with afterburner. There is a conversion error in the TOC values for Controlled Blow Stills in AP-42, Process SCC 3-05-001-02 for Asphalt Blowing of Coating Asphalt. In Table 11.2-3, the metric emission factor is 0.085 kg/Mg. The English factor is given as 0.017 lb/ton. We have assumed the metric number is correct and in that case, this should be 0.17 lb/ton because of the following analysis: 0.085 kg/Mg x (2,000 lbs/ton)/(1,000 kg/Mg) = 0.17 lb/ton.

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2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-2.2: Blow still operating without catalyst - factor development

Plant	PM-filt	PM-cond	PM10	PM2.5	SO_2	CO	NO_X	TOC	TNMOC	HCl	Benzene
1	0.066	0.014	no data	no data	no data	0.001	no data	no data	no data	no data	no data
9	no data	no data	no data	no data	no data	no data	no data	0.025	no data	no data	no data
10	0.021	0.023	no data	no data	no data	no data	no data	no data	no data	no data	no data
13	0.032	0.006	no data	no data	no data	no data	no data	no data	no data	no data	no data
14	0.030	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
16	0.046	0.056	no data	no data	no data	no data	no data	no data	no data	no data	no data
17	0.026	0.018	no data	no data	0.708	0.580	no data	no data	0.012	no data	no data
19	0.150	no data	no data	no data	no data	no data	no data	no data	0.010	no data	no data
22	0.029	0.074	no data	0.072	0.909	0.001	0.068	0.033	no data	no data	no data
23	0.300	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
24	no data	no data	no data	no data	no data	0.026	0.111	no data	0.003	no data	no data
25	0.020	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
27	0.068	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
28	0.038	no data	no data	no data	no data	0.710	no data	no data	no data	no data	no data
29	0.036	0.014	no data	no data	1.383	0.330	no data	0.038	no data	0.017	no data
30	0.092	no data	no data	no data	1.490	0.732	0.091	0.003	no data	no data	no data
33	0.030	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
38	0.040	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
41	0.071	0.023	0.090	no data	0.880	0.140	0.047	no data	0.010	0.010	0.001
42	0.127	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
Calculated Emission Factor [1]	0.068	0.028	0.090	0.072	1.074	0.315	0.079	0.025	0.009	0.014	0.001
Propose Factor? [2]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# data points available	103	41	3	3	24	47	21	16	24	6	3
# data points used	95	39	3	3	23	47	21	15	24	6	3
# data points excluded [3]	8	2	0	0	1	0	0	1	0	0	0
# plants sampled based on data used	18	8	1	1	5	8	4	4	4	2	1
Test Method(s) Used	5A	202	201A+202	201A+202	6, 6C	10	7E	25A	25A+18	26	Not Provided
Control Device(s)	DFTO, Knockout Tank RTO/Fume filter	DFTO, RTO/Fume filter	DFTO	DFTO	DFTO	DFTO	DFTO	DFTO	DFTO	DFTO	DFTO
Standard Deviation	0.091	0.030	0.029	0.026	0.373	0.625	0.052	0.033	0.008	0.005	0.0003
Anderson-Darling Normality Test p-Value - Test	7.40E-31	1.50E-10	0.215	0.565	0.047	6.35E-14	0.038	1.20E-05	6.67E-04	0.643	0.148
Is Data Normally Distributed? [5]	No	No	Yes	Yes	No	No	No	No	No	Yes	Yes
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.00094	0.142	0.160	0.448	0.061	0.0003	0.492	0.063	0.002	0.491	0.264
Is Data Log-Normally Distributed? [5]	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Minimum	0.000	0.005	0.057	0.044	0.530	0.000	0.024	0.000	0.000	0.007	0.000
Maximum	0.670	0.151	0.112	0.096	1.727	2.800	0.208	0.091	0.029	0.021	0.001
Average	0.062	0.027	0.090	0.072	1.151	0.384	0.090	0.023	0.008	0.014	0.001

[1] Units for all emission factors are lb/ton asphalt.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- PM-Tot. PM-Tot is provided only for Stills – No Cat. In all cases when a PM-Tot value is provided, PM-filt and PM-cond is also provided. However, PM-filt + PM-cond is < PM-Tot in all cases. PM-filt + PM-cond should = PM-tot, since the test methods provided for PM-tot are the same test methods used for PM-filt and PM-cond. As such, separate factors for PM-filt and PM-cond are provided.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.
- PM2.5 test results for which Method 201A only is listed. Method 201A provides filterable PM emissions only. PM2.5 and PM10 factors calculated and proposed are filterable + condensable, so only results based on 201A (filterable) and 202 (condensable) are used.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

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Table A-3.1: Applicators (asphalt-based factors): Coaters - comparison

Source	Units	PM-filt
Proposed	Proposed EF (lb/ton asphalt) # data points # plants sampled std deviation Proposed EF rating	0.011 5 4 0.004 D
Change in Factors	Change from 1995 to 2005 Change from 2005 to 2019 Change from 1995 to 2019	-- -- --
Trumbore - 2005	Proposed EF (lb/ton asphalt) [2] # data points # plants sampled std deviation Proposed EF rating	-- -- -- -- --
AP-42 - 1995	EF (lb/ton asphalt) [3] # plants sampled EF rating	-- -- --

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.
[2] Fiberglass coater emission factors in lb/ton asphalt are provided in Tables 10 and 11 of Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278. However, the paper notes that the factors are for coaters with no post-control. All applicators for which test data was provided for this analysis have post control. Therefore, the Trumbore factors are not comparable and are not included in the table.
[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

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2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-3.2: Applicators (asphalt-based factors): Coaters - factor development

Plant	PM-filt
3	0.015
18	0.005
34	0.014
37	0.010
Calculated Emission Factor [1]	0.011
Propose Factor? [2]	Yes
# data points available	6
# data points used	5
# data points excluded [3]	1
# plants sampled based on data used	4
Test Method(s) Used	5A
Control Device(s)	Fume Filter, Cartridge Filter
Standard Deviation	0.004
Anderson-Darling Normality Test p-Value - Test Results [4]	0.580
Is Data Normally Distributed? [5]	Yes
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.227
Is Data Log-Normally Distributed? [5]	Yes
Minimum	0.005
Maximum	0.016
Average	0.012

[1] Units for all emission factors are lb/ton asphalt.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

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2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-4.1: Applicators (shingles-based factors, without RTO or DFTO): Coaters - comparison

Source	Units	PM-filt	PM-cond	PM2.5 [1]	SO_2	CO	TOC	TNMOC	H2S	Benzene
Proposed	Proposed EF (lb/ton shingles)	0.005	0.002	0.001	0.002	0.005	0.024	0.052	0.0001	0.0004
	# data points	199	32	2	12	15	6	9	6	2
	# plants sampled	18	8	1	3	3	1	2	1	1
	std deviation	0.01	0.001	0.0001	0.004	0.003	0.005	0.02	4E-05	0.00
	Proposed EF rating	A	B	E	C	C	D	C	D	E
Change in Factors	Change from 1995 to 2005	--	--	--	--	--	--	--	--	--
	Change from 2005 to 2019	--	--	--	--	--	--	--	--	--
	Change from 1995 to 2019	--	--	--	--	--	--	--	--	--
Trumbore - 2005	Proposed EF (lb/ton shingles) [2]	--	--	--	--	--	--	--	--	--
	# data points	--	--	--	--	--	--	--	--	--
	# plants sampled	--	--	--	--	--	--	--	--	--
	std deviation	--	--	--	--	--	--	--	--	--
	Proposed EF rating	--	--	--	--	--	--	--	--	--
AP-42 - 1995	EF (lb/ton shingles) [3]	--	--	--	--	--	--	--	--	--
	# plants sampled	--	--	--	--	--	--	--	--	--
	EF rating	--	--	--	--	--	--	--	--	--

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.

[2] Fiberglass coater emission factors in lb/ton asphalt are provided in Tables 10 and 11 of Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278. However, the paper notes that the factors are for coaters with no post-control. All applicators for which test data was provided for this analysis have post control. Therefore, the Trumbore factors are not comparable and are not included in the table.

[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-4.2: Applicators (shingles-based factors, without RTO or DFTO): Coaters - factor development

Plant	PM-filt	PM-cond	PM2.5	SO_2	CO	TOC	TNMOC	H2S	Benzene
1	0.006	no data	no data	no data	no data	no data	no data	no data	no data
2	0.002	0.001	no data	no data	no data	no data	no data	no data	no data
4	0.002	no data	no data	no data	no data	no data	no data	no data	no data
10	0.002	0.001	no data	no data	no data	no data	no data	no data	no data
13	0.009	no data	no data	0.004	0.006	no data	0.039	0.000	no data
16	0.003	0.003	no data	no data	0.004	no data	0.065	no data	0.000
17	0.001	0.001	no data	0.001	no data	no data	no data	no data	no data
20	0.003	0.001	0.001	no data	no data	no data	no data	no data	no data
28	0.002	no data	no data	no data	no data	no data	no data	no data	no data
29	0.018	0.002	no data	0.000	0.005	0.024	no data	no data	no data
30	0.003	no data	no data	no data	no data	no data	no data	no data	no data
31	0.010	no data	no data	no data	no data	no data	no data	no data	no data
32	0.004	no data	no data	no data	no data	no data	no data	no data	no data
33	0.001	no data	no data	no data	no data	no data	no data	no data	no data
35	0.002	0.003	no data	no data	no data	no data	no data	no data	no data
36	0.000	no data	no data	no data	no data	no data	no data	no data	no data
41	0.020	0.003	no data	no data	no data	no data	no data	no data	no data
43	0.003	no data	no data	no data	no data	no data	no data	no data	no data
Calculated Emission Factor [1]	0.005	0.002	0.001	0.002	0.005	0.024	0.052	0.0001	0.00042
Propose Factor? [2]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# data points available	200	33	2	12	15	6	9	6	3
# data points used	199	32	2	12	15	6	9	6	2
# data points excluded [3]	1	1	0	0	0	0	0	0	1
# plants sampled based on data used	18	8	1	3	3	1	2	1	1
Test Method(s) Used	5A	202	201A+202	6, 6C	10	25A	25A+18	15	Not Provided
Control Device(s)	Fume Filter	Fume Filter	Fume Filter	Fume Filter	Fume Filter	Fume Filter	Fume Filter	Fume Filter	Fume Filter
Standard Deviation	0.012	0.001	0.000	0.004	0.003	0.005	0.021	0.00004	0.000
Anderson-Darling Normality Test p-Value - Test Results [4]	0.00E+00	0.001	N/A - two data points	1.44E-06	0.238	0.485	0.014	0.007	N/A - two data points
Is Data Normally Distributed? [5]	No	No	N/A	No	Yes	Yes	No	No	N/A
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	3.50E-09	0.061	N/A - two data points	0.014	0.793	0.611	0.005	0.007	N/A - two data points
Is Data Log-Normally Distributed? [5]	No	Yes	N/A	No	Yes	Yes	No	No	N/A
Minimum	0.000	0.000	0.001	0.000	0.001	0.019	0.019	0.000	0.000
Maximum	0.086	0.004	0.001	0.013	0.012	0.031	0.067	0.000	0.000
Average	0.005	0.002	0.001	0.002	0.005	0.024	0.047	0.000	0.000

[1] Units for emission factors are lb/ton shingles.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.
- PM2.5 test results for which test method 201A only is listed. Method 201A provides filterable PM emissions only. PM2.5 and PM10 factors calculated and proposed are filterable + condensable, so only results based on 201A (filterable) and 202 (condensable) are used.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

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Table A-5.1: Applicators (shingles-based factors, with RTO or DFTO): Coaters - comparison

Source	Units	PM-filt	PM-cond	PM2.5 [1]	SO_2	CO	TOC	TNMOC	H2S
Proposed	Proposed EF (lb/ton shingles)	0.004	0.001	0.001	0.005	0.010	0.014	0.003	0.008
	# data points	31	19	6	2	6	2	4	3
	# plants sampled	3	2	1	1	2	1	2	1
	std deviation	0.004	0.0003	0.0002	0.00006	0.007	0.00	0.004	0.00
	Proposed EF rating	C	C	D	E	C	E	D	E
Change in Factors	Change from 1995 to 2005	--	--	--	--	--	--	--	--
	Change from 2005 to 2019	--	--	--	--	--	--	--	--
	Change from 1995 to 2019	--	--	--	--	--	--	--	--
Trumbore - 2005	Proposed EF (lb/ton shingles) [2]	--	--	--	--	--	--	--	--
	# data points	--	--	--	--	--	--	--	--
	# plants sampled	--	--	--	--	--	--	--	--
	std deviation	--	--	--	--	--	--	--	--
	Proposed EF rating	--	--	--	--	--	--	--	--
AP-42 - 1995	EF (lb/ton shingles) [3]	--	--	--	--	--	--	--	--
	# plants sampled	--	--	--	--	--	--	--	--
	EF rating	--	--	--	--	--	--	--	--

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.

[2] Fiberglass coater emission factors in lb/ton asphalt are provided in Tables 10 and 11 of Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278. However, the paper notes that the factors are for coaters with no post-control. All applicators for which test data was provided for this analysis have post control. Therefore, the Trumbore factors are not comparable and are not included in the table.

[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-5.2: Applicators (shingles-based factors, with RTO or DFTO): Coaters - factor development

Plant	PM-filt	PM-cond	PM2.5	SO_2	CO	TOC	TNMOC	H2S
4	0.009	no data	no data	no data	no data	no data	no data	no data
9	no data	no data	no data	no data	no data	no data	0.002	no data
22	0.000	0.000	0.001	no data	no data	no data	no data	no data
24	no data	no data	no data	no data	0.004	no data	0.004	no data
40	0.002	0.001	no data	0.005	0.016	0.014	no data	0.008
Calculated Emission Factor [1]	0.004	0.001	0.001	0.005	0.010	0.014	0.003	0.008
Propose Factor? [2]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# data points available	31	19	6	3	6	3	4	3
# data points used	31	19	6	2	6	2	4	3
# data points excluded [3]	0	0	0	1	0	1	0	0
# plants sampled based on data used	3	2	1	1	2	1	2	1
Test Method(s) Used	5A	202	201A+202	6C	10	25A	25A+18	15
Control Device(s)	RTO/Fume Filter	RTO/Fume Filter	RTO/Fume Filter	RTO/Fume Filter	RTO, Fume Filter	RTO/Fume Filter	RTO	RTO/Fume Filter
Standard Deviation	0.004	0.000	0.000	0.000	0.007	0.000	0.004	0.000
Anderson-Darling Normality Test p-Value - Test Results [4]	8.43E-13	0.018	0.537	N/A - two data points	0.025	N/A - two data points	0.064	N/A
Is Data Normally Distributed? [5]	No	No	Yes	N/A	No	N/A	Yes	N/A
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.012	0.039	0.601	N/A - two data points	0.017	N/A - two data points	0.096	N/A
Is Data Log-Normally Distributed? [5]	No	No	Yes	N/A	No	N/A	Yes	N/A
Minimum	0.000	0.000	0.001	0.005	0.004	0.014	0.001	0.008
Maximum	0.010	0.001	0.001	0.005	0.017	0.014	0.010	0.008
Average	0.002	0.000	0.001	0.005	0.010	0.014	0.003	0.008

[1] Units for emission factors are lb/ton shingles.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

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Table A-6.1: Applicators (shingles-based factors, without RTO or DFTO): Saturators - comparison

Source	Units	PM-filt
Proposed	Proposed EF (lb/ton shingles) # data points # plants sampled std deviation Proposed EF rating	0.036 107 4 0.04 C
Change in Factors	Change from 1995 to 2005 Change from 2005 to 2019 Change from 1995 to 2019	-- -- --
Trumbore - 2005	Proposed EF (lb/ton shingles) [2] # data points # plants sampled std deviation Proposed EF rating	-- -- -- -- --
AP-42 - 1995	EF (lb/ton shingles) [3] # plants sampled EF rating	-- -- --

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.
[2] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278 does not provide emission factors for this source type.
[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-6.2: Applicators (shingles-based factors, without RTO or DFTO): Saturators - factor development

Plant	PM-filt
4	0.028
30	0.045
31	0.037
43	0.033
Calculated Emission Factor [1]	0.036
Propose Factor? [2]	Yes
# data points available	107
# data points used	107
# data points excluded [3]	0
# plants sampled based on data used	4
Test Method(s) Used	5A
Control Device(s)	Fume Filter
Standard Deviation	0.036
Anderson-Darling Normality Test p-Value - Test Results [4]	1.77E-21
Is Data Normally Distributed? [5]	No
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.117
Is Data Log-Normally Distributed? [5]	Yes
Minimum	0.002
Maximum	0.190
Average	0.034

[1] Units for all emission factors are lb/ton shingles.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

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Table A-7.1: Applicators (shingles-based factors, with RTO or DFTO): Saturators - comparison

Source	Units	PM-filt
Proposed	Proposed EF (lb/ton shingles) # data points # plants sampled std deviation Proposed EF rating	0.004 3 1 0.002 E
Change in Factors	Change from 1995 to 2005 Change from 2005 to 2019 Change from 1995 to 2019	-- -- --
Trumbore - 2005	Proposed EF (lb/ton shingles) [2] # data points # plants sampled std deviation Proposed EF rating	-- -- -- -- --
AP-42 - 1995	EF (lb/ton shingles) [3] # plants sampled EF rating	-- -- --

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.
[2] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278 does not provide emission factors for this source type.
[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

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2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-7.2: Applicators (shingles-based factors, with RTO or DFTO): Saturators - factor development

Plant	PM-filt
28	0.004
Calculated Emission Factor [1]	0.004
Propose Factor? [2]	Yes
# data points available	3
# data points used	3
# data points excluded [3]	0
# plants sampled based on data used	1
Test Method(s) Used	5A
Control Device(s)	DFTO
Standard Deviation	0.002
Anderson-Darling Normality Test p-Value - Test Results [4]	4.87E-01
Is Data Normally Distributed? [5]	Yes
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.582
Is Data Log-Normally Distributed? [5]	Yes
Minimum	0.003
Maximum	0.006
Average	0.004

[1] Units for all emission factors are lb/ton shingles.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

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Table A-8.1: Applicators (shingles-based factors, without RTO or DFTO): Other Coaters/Saturators - comparison

Source	Units	PM-filt
Proposed	Proposed EF (lb/ton shingles) # data points # plants sampled std deviation Proposed EF rating	0.005 6 1 0.003 D
Change in Factors	Change from 1995 to 2005 Change from 2005 to 2019 Change from 1995 to 2019	-- -- --
Trumbore - 2005	Proposed EF (lb/ton shingles) [2] # data points # plants sampled std deviation Proposed EF rating	-- -- -- -- --
AP-42 - 1995	EF (lb/ton shingles) [3] # plants sampled EF rating	-- -- --

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.

[2] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278 does not provide emission factors for this source type.

[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-8.2: Applicators (shingles-based factors, without RTO or DFTO): Other Coaters/Saturators - factor development

Plant	PM-filt
31	0.005
Calculated Emission Factor [1]	0.005
Propose Factor? [2]	Yes
# data points available	6
# data points used	6
# data points excluded [3]	0
# plants sampled based on data used	1
Test Method(s) Used	5A
Control Device(s)	Fume Filter
Standard Deviation	0.003
Anderson-Darling Normality Test p-Value - Test Results [4]	0.53
Is Data Normally Distributed? [5]	Yes
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.55
Is Data Log-Normally Distributed? [5]	Yes
Minimum	0.002
Maximum	0.010
Average	0.005

[1] Units for all emission factors are lb/ton shingles.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

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Table A-9.1: Applicators (shingles-based factors, with RTO or DFTO): Other Coaters/Saturators - comparison

Source	Units	PM-filt
Proposed	Proposed EF (lb/ton shingles) # data points # plants sampled std deviation Proposed EF rating	0.054 2 1 0.03 E
Change in Factors	Change from 1995 to 2005 Change from 2005 to 2019 Change from 1995 to 2019	-- -- --
Trumbore - 2005	Proposed EF (lb/ton shingles) [2] # data points # plants sampled std deviation Proposed EF rating	-- -- -- -- --
AP-42 - 1995	EF (lb/ton shingles) [3] # plants sampled EF rating	-- -- --

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.

[2] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278 does not provide emission factors for this source type.

[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-9.2: Applicators (shingles-based factors, with RTO or DFTO): Other Coaters/Saturators - factor development

Plant	PM-filt
4	0.054
Calculated Emission Factor [1]	0.054
Propose Factor? [2]	Yes
# data points available	2
# data points used	2
# data points excluded [3]	0
# plants sampled based on data used	1
Test Method(s) Used	5A
Control Device(s)	RTO
Standard Deviation	0.025
Anderson-Darling Normality Test p-Value - Test Results [4]	N/A - two data points
Is Data Normally Distributed? [5]	N/A
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	N/A - two data points
Is Data Log-Normally Distributed? [5]	N/A
Minimum	0.036
Maximum	0.072
Average	0.054

[1] Units for all emission factors are lb/ton shingles.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

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Table A-10.1: Wet loopers - comparison

Source	Units	PM-filt
Proposed	Proposed EF (lb/ton shingles) # data points # plants sampled std deviation Proposed EF rating	0.004 9 1 0.004 D
Change in Factors	Change from 1995 to 2005 Change from 2005 to 2019 Change from 1995 to 2019	-- -- --
Trumbore - 2005	Proposed EF (lb/ton shingles) [2] # data points # plants sampled std deviation Proposed EF rating	-- -- -- -- --
AP-42 - 1995	EF (lb/ton shingles) [3] # plants sampled EF rating	-- -- --

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.
[2] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278 does not provide emission factors for this source type.
[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-10.2: Wet loopers - factor development

Plant	PM-filt
28	0.004
Calculated Emission Factor [1]	0.004
Propose Factor? [2]	Yes
# data points available	9
# data points used	9
# data points excluded [3]	0
# plants sampled based on data used	1
Test Method(s) Used	5A
Control Device(s)	Fume Filter
Standard Deviation	0.004
Anderson-Darling Normality Test p-Value - Test Results [4]	0.013
Is Data Normally Distributed? [5]	No
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.121
Is Data Log-Normally Distributed? [5]	Yes
Minimum	0.001
Maximum	0.010
Average	0.004

[1] Units for all emission factors are lb/ton shingles.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

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2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-11.1: Coating Tanks (asphalt-based factors) - comparison

Source	Units	TNMOC
Proposed	Proposed EF (lb/ton asphalt) # data points # plants sampled std deviation Proposed EF rating	0.069 4 1 0.05 E
Change in Factors	Change from 1995 to 2005 Change from 2005 to 2019 Change from 1995 to 2019	-- -- --
Trumbore - 2005	Proposed EF (lb/ton asphalt) [2] # data points # plants sampled std deviation Proposed EF rating	-- -- -- -- --
AP-42 - 1995	EF (lb/ton asphalt) [3] # plants sampled EF rating	-- -- --

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.

[2] Factors for uncontrolled emissions from oxidized asphalt storage tanks, in lb/ton asphalt from Table 8 of Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278. The Trumbore paper does not clarify whether the PM emission factor is PM-filterable or PM-total (filterable + condensable). Test methods used to measure the PM results used to calculate the PM emission factor are not provided. Since the PM factor is compared to the AP-42 factor, which includes filterable only, it is assumed that the PM factor in the Trumbore paper is PM-filterable. The Trumbore paper provides emission factors for formaldehyde and carbonyl sulfide which are not considered in this analysis because test results for these pollutants were not available.

[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type on a lb/ton of asphalt basis.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-11.2: Coating Tanks (asphalt-based factors) - factor development

Plant	**TNMOC**
19	0.069
Calculated Emission Factor [1]	0.069
Propose Factor? [2]	Yes
# data points available	4
# data points used	4
# data points excluded [3]	0
# plants sampled based on data used	1
Test Method(s) Used	25A+18
Control Device(s)	None
Standard Deviation	0.054
Anderson-Darling Normality Test p-Value - Test Results [4]	0.618
Is Data Normally Distributed? [5]	Yes
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.584
Is Data Log-Normally Distributed? [5]	Yes
Minimum	0.014
Maximum	0.132
Average	0.069

[1] Units for all emission factors are lb/ton asphalt.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-12.1: Flux tank - comparison

Source	Units	TNMOC
Proposed	Proposed EF (lb/ton asphalt) # data points # plants sampled std deviation Proposed EF rating	0.022 4 1 0.02 E
Change in Factors	Change from 1995 to 2005 Change from 2005 to 2019 Change from 1995 to 2019	-- -- --
Trumbore - 2005	Proposed EF (lb/ton asphalt) [2] # data points # plants sampled std deviation Proposed EF rating	-- -- -- -- --
AP-42 - 1995	EF (lb/ton asphalt) [3] # plants sampled EF rating	-- -- --

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.
[2] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278 does not provide emission factors for this source type.
[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-12.2: Flux tank - factor development

Plant	TNMOC
19	0.022
Calculated Emission Factor [1]	0.022
Propose Factor? [2]	Yes
# data points available	4
# data points used	4
# data points excluded [3]	0
# plants sampled based on data used	1
Test Method(s) Used	25A+18
Control Device(s)	None
Standard Deviation	0.023
Anderson-Darling Normality Test p-Value - Test Results [4]	0.025
Is Data Normally Distributed? [5]	No
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.127
Is Data Log-Normally Distributed? [5]	Yes
Minimum	0.008
Maximum	0.056
Average	0.022

[1] Units for all emission factors are lb/ton asphalt.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-13.1: Mixers (shingles-based factors) - comparison

Source	Units	PM-filt
Proposed	Proposed EF (lb/ton shingles) # data points # plants sampled std deviation Proposed EF rating	0.001 11 2 2E-19 C
Change in Factors	Change from 1995 to 2005 Change from 2005 to 2019 Change from 1995 to 2019	-- -- --
Trumbore - 2005	Proposed EF (lb/ton shingles) [2] # data points # plants sampled std deviation Proposed EF rating	-- -- -- -- --
AP-42 - 1995	EF (lb/ton shingles) [3] # plants sampled EF rating	-- -- --

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.

[2] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278 provides factors in lb/ton ashpalt for uncontrolled emissions from oxidized asphalt storage tanks.

[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-13.2: Mixers (shingles-based factors) - factor development

Plant	PM-filt
31	0.001
32	0.001
Calculated Emission Factor [1]	0.001
Propose Factor? [2]	Yes
# data points available	12
# data points used	11
# data points excluded [3]	1
# plants sampled based on data used	2
Test Method(s) Used	5A
Control Device(s)	Fume Filter
Standard Deviation	0.000
Anderson-Darling Normality Test p-Value - Test Results [4]	N/A - two data points
Is Data Normally Distributed? [5]	N/A
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	N/A - two data points
Is Data Log-Normally Distributed? [5]	N/A
Minimum	0.001
Maximum	0.001
Average	0.001

[1] Units for all emission factors are lb/ton asphalt.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-14.1: Mixers (asphalt-based factors) - comparison

Source	Units	PM-filt	SO_2	TOC
Proposed	Proposed EF (lb/ton asphalt)	0.135	0.027	0.049
	# data points	2	3	4
	# plants sampled	2	2	1
	std deviation	0.19	0.02	0.04
	Proposed EF rating	D	D	E
Change in Factors	Change from 1995 to 2005	--	--	--
	Change from 2005 to 2019	--	--	--
	Change from 1995 to 2019	--	--	--
Trumbore - 2005	Proposed EF (lb/ton asphalt) [2]	--	--	--
	# data points	--	--	--
	# plants sampled	--	--	--
	std deviation	--	--	--
	Proposed EF rating	--	--	--
AP-42 - 1995	EF (lb/ton asphalt) [3]	--	--	--
	# plants sampled	--	--	--
	EF rating	--	--	--

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.

[2] Factors for uncontrolled emissions from oxidized asphalt storage tanks, in lb/ton asphalt from Table 8 of Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278. The Trumbore paper does not clarify whether the PM emission factor is PM-filterable or PM-total (filterable + condensable). Test methods used to measure the PM results used to calculate the PM emission factor are not provided. Since the PM factor is compared to the AP-42 factor, which includes filterable only, it is assumed that the PM factor in the Trumbore paper is PM-filterable. The Trumbore paper provides emission factors for formaldehyde and carbonyl sulfide which are not considered in this analysis because test results for these pollutants were not available.

[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type on a lb/ton of asphalt basis.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-14.2: Mixers (asphalt-based factors) - factor development

Plant	PM-filt	SO_2	TOC
12	0.270	0.018	no data
39	0.000	0.037	0.049
Calculated Emission Factor [1]	0.135	0.027	0.049
Propose Factor? [2]	Yes	Yes	Yes
# data points available	2	3	4
# data points used	2	3	4
# data points excluded [3]	0	0	0
# plants sampled based on data used	2	2	1
Test Method(s) Used	5A	6C, 15/16	25A
Control Device(s)	Scrubber, Fume Filter/Cartridge Filter	Scrubber, Fume Filter	Fume Filter
Standard Deviation	0.191	0.018	0.040
Anderson-Darling Normality Test p-Value - Test Results [4]	N/A - two data points	0.150	0.436
Is Data Normally Distributed? [5]	N/A	Yes	Yes
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	N/A - two data points	0.251	0.496
Is Data Log-Normally Distributed? [5]	N/A	Yes	Yes
Minimum	0.000	0.018	0.012
Maximum	0.270	0.051	0.096
Average	0.135	0.030	0.049

[1] Units for all emission factors are lb/ton asphalt.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-15.1: Cooling sections (shingles-based factors) - comparison

Source	Units	PM-filt	PM-cond	PM2.5 [1]	TOC
Proposed	Proposed EF (lb/ton shingles)	0.024	0.006	0.010	0.004
	# data points	27	8	4	21
	# plants sampled	3	1	1	2
	std deviation	0.02	0.01	N/A	0.004
	Proposed EF rating	C	D	E	C
Change in Factors	Change from 1995 to 2005	--	--	--	--
	Change from 2005 to 2019	--	--	--	--
	Change from 1995 to 2019	--	--	--	--
Trumbore - 2005	Proposed EF (lb/ton shingles) [2]	--	--	--	--
	# data points	--	--	--	--
	# plants sampled	--	--	--	--
	std deviation	--	--	--	--
	Proposed EF rating	--	--	--	--
AP-42 - 1995	EF (lb/ton shingles) [3]	--	--	--	--
	# plants sampled	--	--	--	--
	EF rating	--	--	--	--

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.

[2] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278 does not provide emission factors for this source type.

[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-15.2: Cooling sections (shingles-based factors) - factor development

Plant	PM-filt	PM-cond	PM2.5	TOC
22	0.021	0.006	0.010	no data
31	0.018	no data	no data	0.003
33	0.033	no data	no data	0.006
Calculated Emission Factor [1]	0.024	0.006	0.010	0.004
Propose Factor? [2]	Yes	Yes	Yes	Yes
# data points available	27	8	4	21
# data points used	27	8	4	21
# data points excluded [3]	0	0	0	0
# plants sampled based on data used	3	1	1	2
Test Method(s) Used	5A	202	201A+202	25A
Control Device(s)	None	None	None	None
Standard Deviation	0.016	0.006	N/A	0.004
Anderson-Darling Normality Test p-Value - Test Results [4]	0.014	0.040	0.615	8.28E-04
Is Data Normally Distributed? [5]	No	No	Yes	No
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.156	0.374	0.613	9.28E-04
Is Data Log-Normally Distributed? [5]	Yes	Yes	Yes	No
Minimum	0.01	0.00	0.00	0.00
Maximum	0.07	0.02	0.02	0.01
Average	0.02	0.01	0.01	0.00

[1] Units for all emission factors are lb/ton shingles.

[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-16.1: Loading racks - comparison

Source	Units	PM10 [1]	SO_2	CO	NO_X	TOC	TNMOC
Proposed	Proposed EF (lb/ton asphalt)	0.002	0.005	0.0005	0.0003	0.021	0.0014
	# data points	3	6	3	2	6	3
	# plants sampled	1	1	1	1	1	1
	std deviation	0.0005	0.003	0.001	2E-05	0.02	0.0002
	Proposed EF rating	E	D	E	E	D	E
Change in Factors	Change from 1995 to 2005	--	--	--	--	--	--
	Change from 2005 to 2019	--	--	--	--	--	--
	Change from 1995 to 2019	--	--	--	--	--	--
Trumbore - 2005	Proposed EF (lb/ton asphalt) [2]	--	--	--	--	--	--
	# data points	--	--	--	--	--	--
	# plants sampled	--	--	--	--	--	--
	std deviation	--	--	--	--	--	--
	Proposed EF rating	--	--	--	--	--	--
AP-42 - 1995	EF (lb/ton asphalt) [3]	--	--	--	--	--	--
	# plants sampled	--	--	--	--	--	--
	EF rating	--	--	--	--	--	--

[1] PM10 and PM2.5 emission factors, if provided, include filterable and condensable particulate emissions.
[2] Trumbore, et. al., "Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing," Environmental Progress, Volume 24, Issue 3, October 2005, pp. 268-278 does not provide emission factors for this source type.
[3] AP-42 Table 11.2-2 (1/95) does not provide emission factors for this source type.

Asphalt Roofing Manufacturing Association
2019 Emission Factors for Asphalt-Related Emissions in Roofing Manufacturing

Table A-16.2: Loading racks - factor development

Plant	PM10	SO_2	CO	NO_X	TOC	TNMOC
16	0.002	0.005	0.001	0.000	0.021	0.001
Calculated Emission Factor [1]	0.002	0.005	0.001	0.0003	0.021	0.0014
Propose Factor? [2]	Yes	Yes	Yes	Yes	Yes	Yes
# data points available	3	6	3	3	6	3
# data points used	3	6	3	2	6	3
# data points excluded [3]	0	0	0	1	0	0
# plants sampled based on data used	1	1	1	1	1	1
Test Method(s) Used	201A+202	6C	10	7E	25A	25A+18
Control Device(s)	RTO/Fume Filter	RTO/Fume Filter	RTO/Fume Filter	RTO/Fume Filter	RTO/Fume Filter	RTO/Fume Filter
Standard Deviation	0.000	0.003	0.001	0.000	0.018	0.000
Anderson-Darling Normality Test p-Value - Test Results [4]	0.487	0.874	0.068	N/A - two data points	0.097	0.269
Is Data Normally Distributed? [5]	Yes	Yes	Yes	N/A	Yes	Yes
Anderson-Darling Normality Test p-Value - LN(Test Results) [4]	0.373	0.481	0.122	N/A - two data points	0.059	0.303
Is Data Log-Normally Distributed? [5]	Yes	Yes	Yes	N/A	Yes	Yes
Minimum	0.001	0.001	0.000	0.000	0.005	0.001
Maximum	0.002	0.009	0.001	0.000	0.044	0.002
Average	0.002	0.005	0.001	0.000	0.021	0.001

[1] Units for all emission factors are lb/ton asphalt.

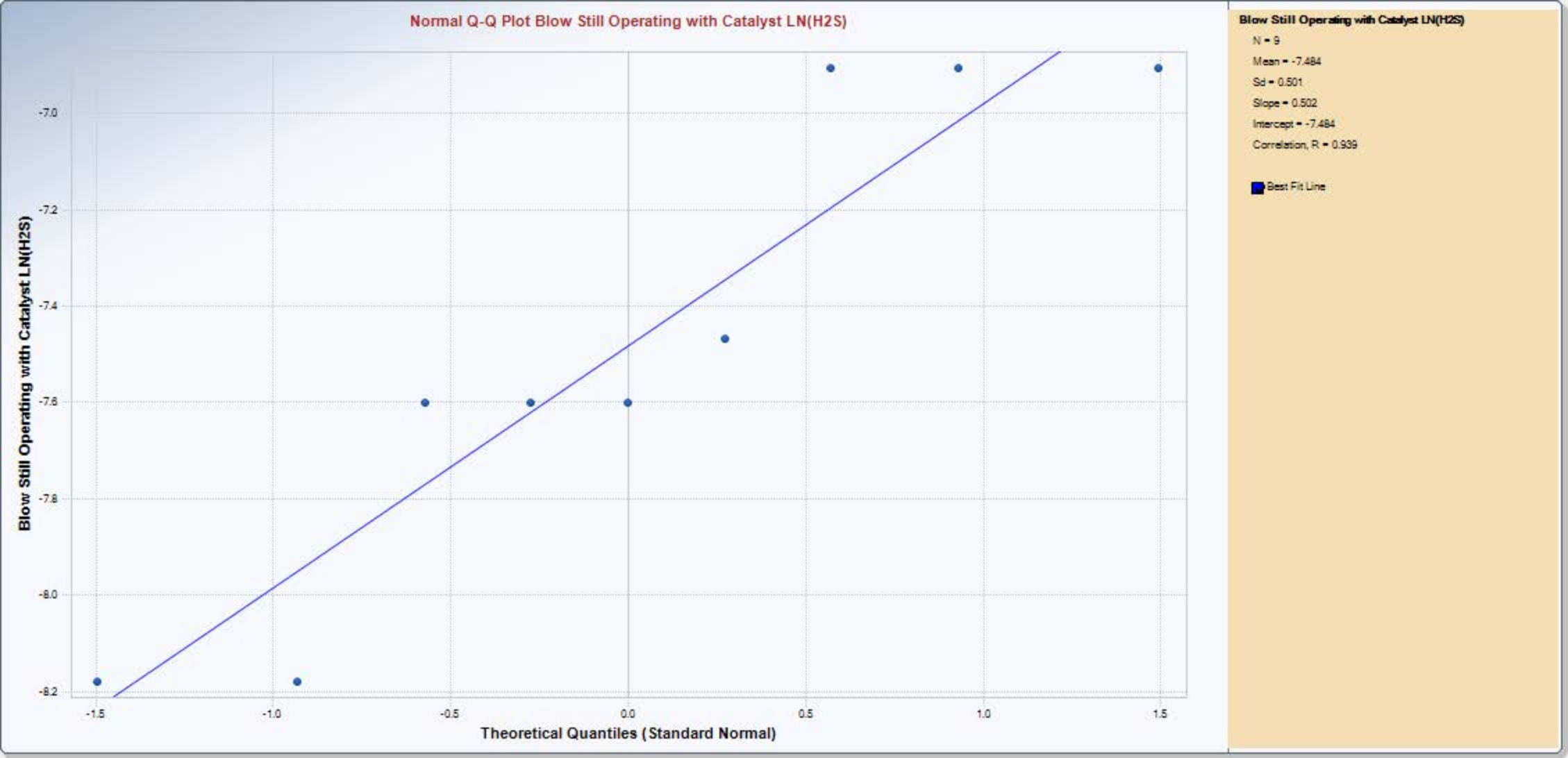
[2] A factor is not proposed for the following:
- Any pollutants which have no test results.
- Any pollutants which have only one test result. Sufficient data to calculate these factors is not available.

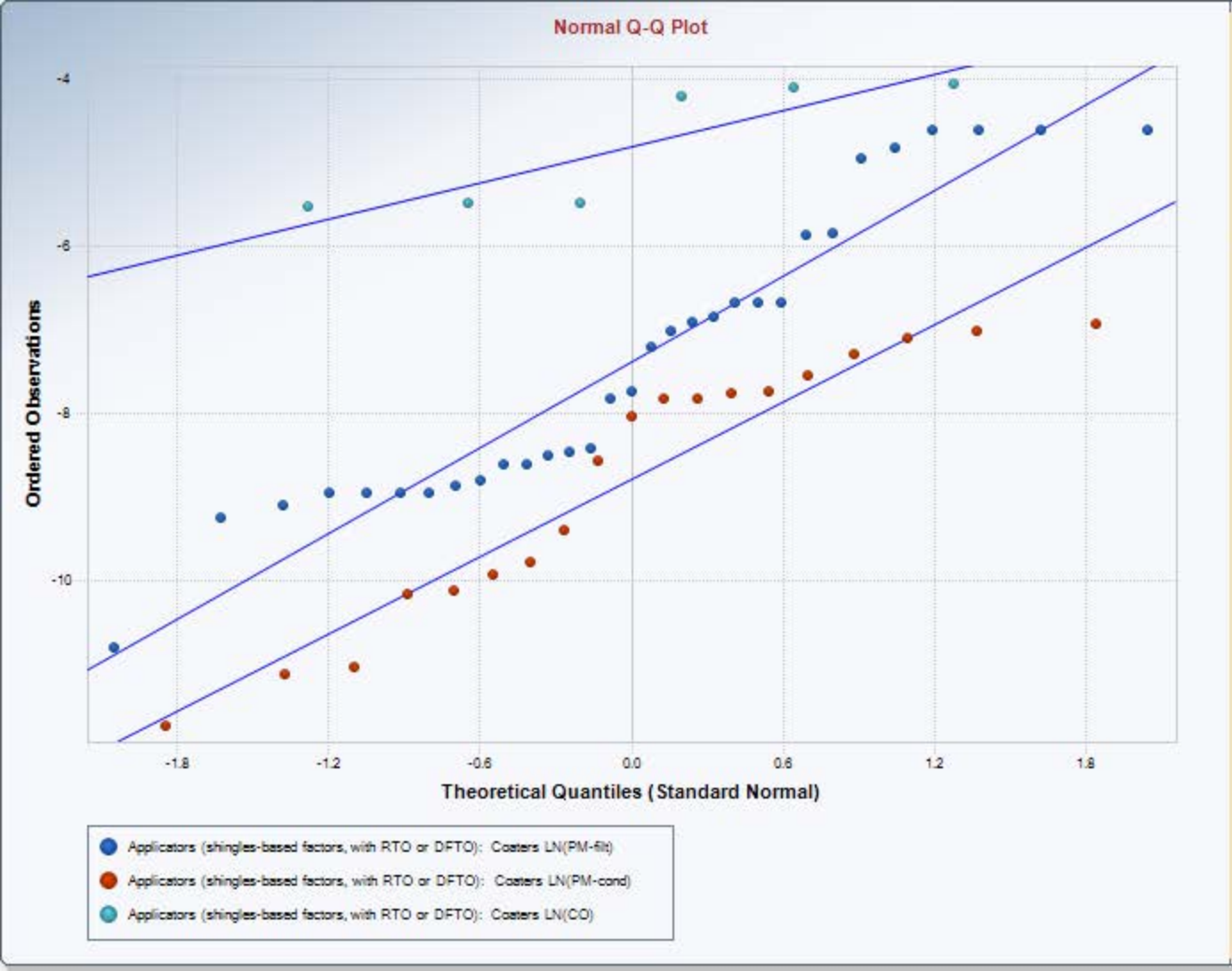
[3] Data points are excluded for the following reasons:
- Test result identified as an outlier in accordance with Rosner's Outlier Test (for data sets containing greater than 24 results) or Dixon's Outlier Test (for data sets containing less than or equal to 24 results).
- Test result is blank or zero.

[4] SPC for Excel Anderson Darling test spreadsheet (June 2011), developed by BPI Consulting, LLC is used to calculate a p-value for each data set and log-transformed data set. Spreadsheet available here: https://www.spcforexcel.com/knowledge/basic-statistics/anderson-darling-test-for-normality.

[5] Data is normally / log-normally distributed if the corresponding p-value is greater than 0.05.

APPENDIX B: Q-Q PLOTS FOR NON-NORMALLY OR NON-LOG-NORMALLY DISTRIBUTED DATA SETS


Normal Q-Q Plot Blow Still Operating with Catalyst LN(H2S)
Blow Still Operating with Catalyst LN(H2S)
N = 9
Mean = -7.484
Sd = 0.501
Slope = 0.502
Intercept = -7.484
Correlation, R = 0.939
Best Fit Line
Blow Still Operating with Catalyst LN(H2S)
-7.0
-7.2
-7.4
-7.6
-7.8
-8.0
-8.2
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)



Applicators (shingles-based factors, with RTO or DFTO): Coaters LN(PM-filt)

N = 31
Mean = -7.382
Sd = 1.726
Slope = 1.706
Intercept = -7.382
Correlation, R = 0.962

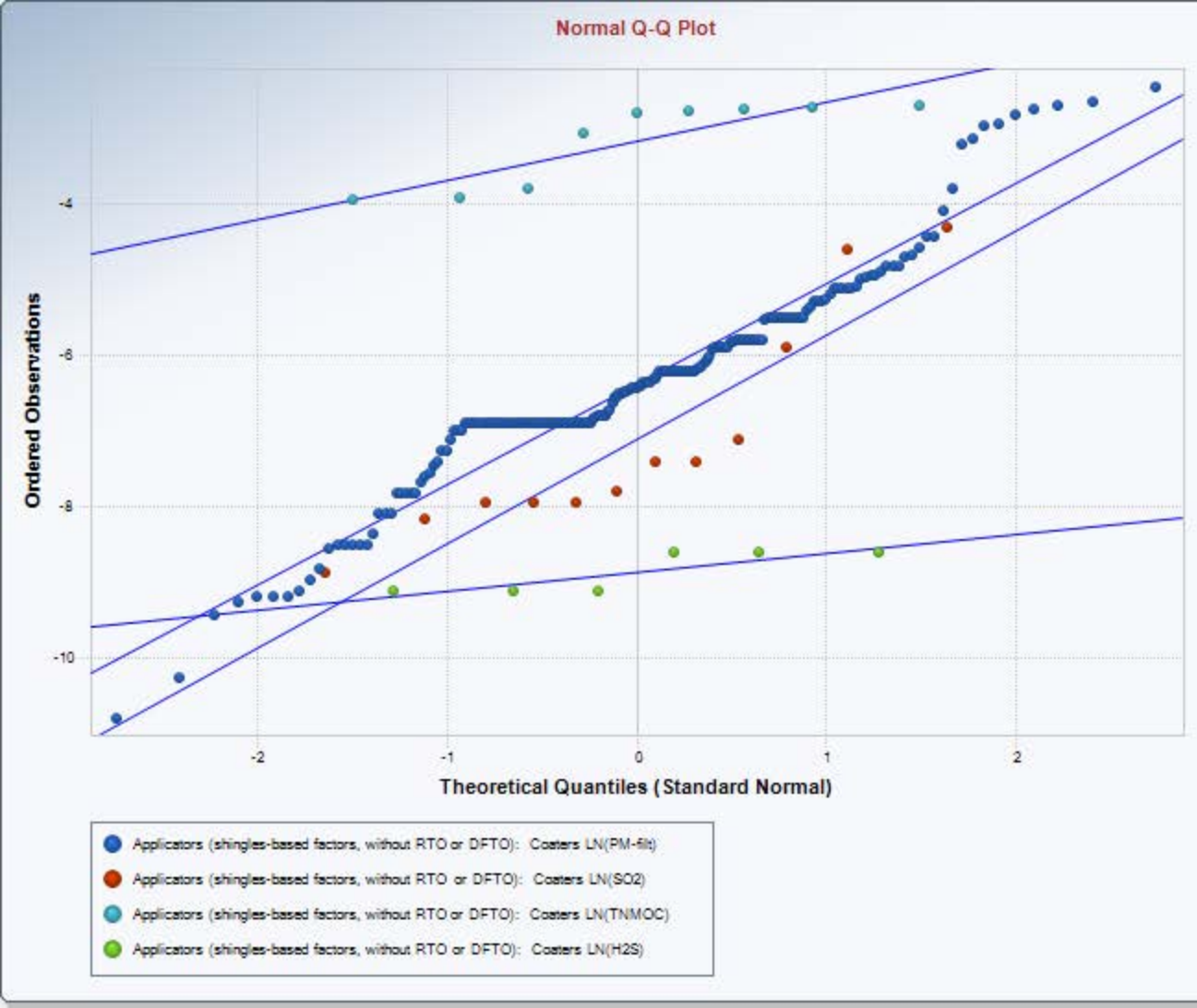
Applicators (shingles-based factors, with RTO or DFTO): Coaters LN(PM-cond)

N = 19
Mean = -8.791
Sd = 1.555
Slope = 1.547
Intercept = -8.791
Correlation, R = 0.957

Applicators (shingles-based factors, with RTO or DFTO): Coaters LN(CO)

N = 6
Mean = -4.806
Sd = 0.757
Slope = 0.722
Intercept = -4.806
Correlation, R = 0.874

Best Fit Line



Applicators (shingles-based factors, without RTO or DFTO): Coaters LN(PM-filt)

N = 199
Mean = -6.374
Sd = 1.355
Slope = 1.329
Intercept = -6.374
Correlation, R = 0.975

Applicators (shingles-based factors, without RTO or DFTO): Coaters LN(SO2)

N = 12
Mean = -7.128
Sd = 1.432
Slope = 1.387
Intercept = -7.128
Correlation, R = 0.918

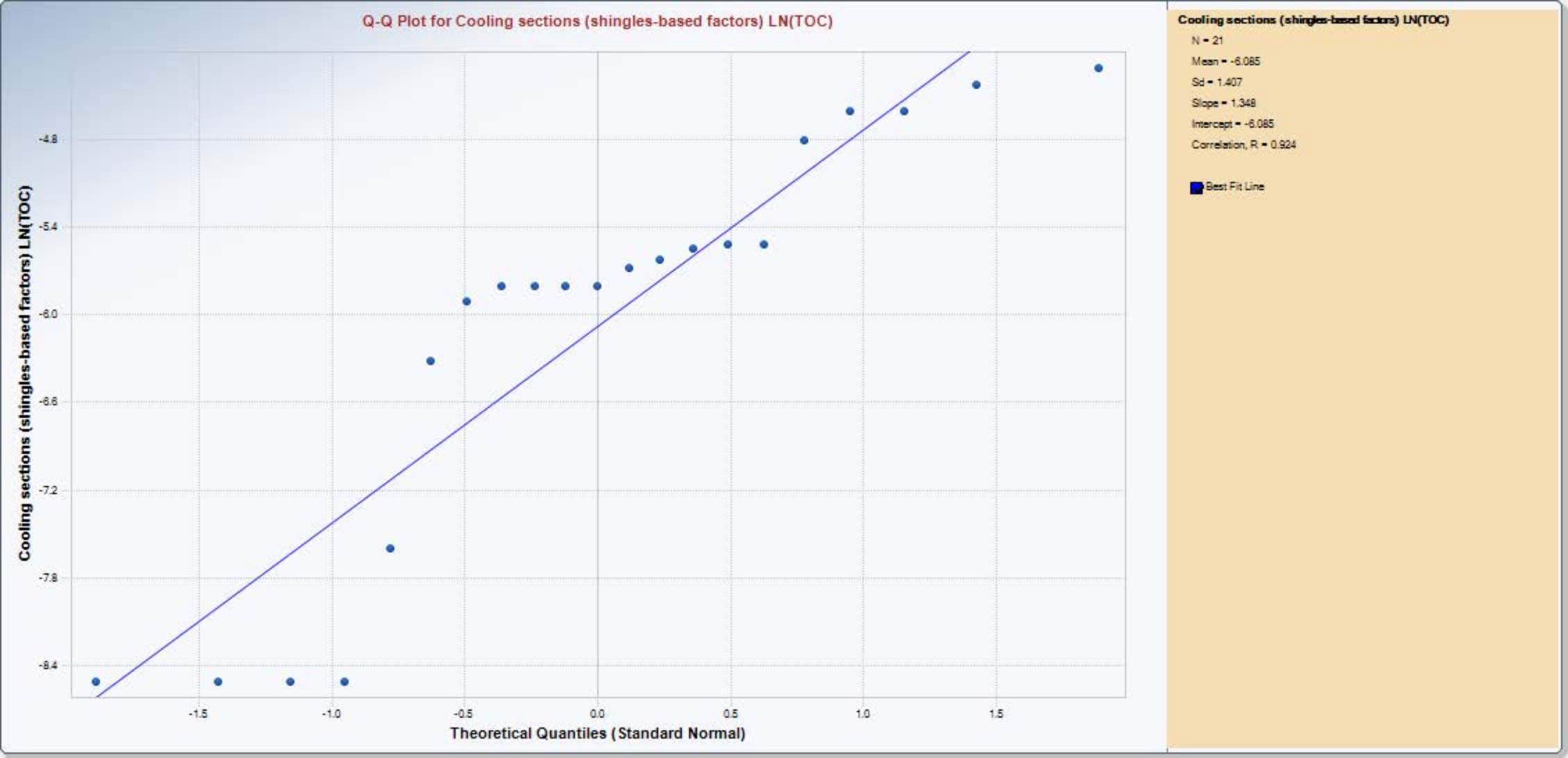
Applicators (shingles-based factors, without RTO or DFTO): Coaters LN(TNMOC)

N = 9
Mean = -3.17
Sd = 0.554
Slope = 0.522
Intercept = -3.17
Correlation, R = 0.881

Applicators (shingles-based factors, without RTO or DFTO): Coaters LN(H2S)

N = 6
Mean = -8.869
Sd = 0.27
Slope = 0.25
Intercept = -8.869
Correlation, R = 0.848

Best Fit Line


Q-Q Plot for Cooling sections (shingles-based factors) LN(TOC)
Cooling sections (shingles-based factors) LN(TOC)
-4.8
-5.4
-6.0
-6.6
-7.2
-7.8
-8.4
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)
Cooling sections (shingles-based factors) LN(TOC)
N = 21
Mean = -6.085
Sd = 1.407
Slope = 1.348
Intercept = -6.085
Correlation, R = 0.924
Best Fit Line

APPENDIX C: DATASETS CONTAINING A SINGLE DATA POINT

The test data in Table C-1 were excluded from the emission factor development calculations as they were the only data available for a given source type and pollutant.

Source Type	Units	Pollutant	Stack Testing Result
Blowstills Operating with Catalyst	lb/ton asphalt	PM_{10}	0.034
		$PM_{2.5}$	0.011
		1,3-Butadiene	5.9E-6
		Benzene	3.0E-4
		Chlorine	0.31
		Formaldehyde	1.0E-4
Applicators (shingles-based factors, without RTO or DFTO): Laminators	lb/ton shingle	PM-filt	3.0E-3
Applicators (asphalt-based factors, without RTO or DFTO): Other Saturators/Coaters	lb/ton asphalt	PM-filt	5.2E-3
Mixers (asphalt-based factors)	lb/ton asphalt	Carbonyl sulfide	0.011
		Dimethyl disulfide	4.8E-3
		Dimethyl sulfide	0.013
		Methyl mercaptan	8.5E-3
		H_2S	6.0E-3
Cooling Sections (asphalt-based factors)	lb/ton asphalt	PM-filt	0.063
		PM_{10}	0.042
		$PM_{2.5}$	0.034
		TNMOC	0.041

APPENDIX D: LIST OF ACRONYMS

AP-42	*Volume I, Stationary Point and Area Sources*, or the *Compilation of Air Pollutant Emission Factors*
ARMA	Asphalt Roofing Manufacturers Association
cfm	cubic feet per minute
CO	Carbon Monoxide
DFTO	Direct-fired Thermal Oxidzer
EPA	United States Environmental Protection Agency
°F	Degrees Fahrenheit
H_2S	Hydrogen Sulfide
HAPs	Hazardous Air Pollutants
HCl	Hydrochloric Acid
HEAF	High Efficiency Air Filters
lb/hr	pounds per hour
lb/ton asphalt	pounds of emissions per short ton of asphalt throughput
lb/ton shingles	pounds of emissions per short ton of shingle production
mg/dscfm	milligram per dry standard cubic feet per minute
NO_X	Nitrogen Oxides
PM_{10}	Particulate Matter with an Aerodynamic Diameter Less Than 10 microns
$PM_{2.5}$	Particulate Matter with an Aerodynamic Diameter Less Than 2.5 microns
PM	Particulate Matter
PM-cond	Condensable Particulate Matter
PM-filt	Filterable Particulate Matter
PM-tot	Total Particulate Matter
RTO	Regenerative Thermal Oxidizer
SO_2	Sulfuric Dioxide
TNMOC	Total Non-Methane Organic Compounds
TOC	Total Organic Compounds
VOC	Volatile Organic Compounds