Proposed Emission Factors For Criteria Pollutants and Hazardous Air Pollutants from Asphalt Roofing Manufacturing

Prepared for:
Asphalt Roofing Manufacturers Association

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Executive Summary

This document contains proposed emission factors for criteria air pollutants and hazardous air pollutants (HAPs) emitted from various asphalt roofing manufacturing industry sources. These factors were developed from data collected by the Asphalt Roofing Manufacturers Association (ARMA) and ARMA member companies. Where AP-42 emission factors or other published factors are available, these are compared to the proposed emission factors developed from the ARMA data. This document will form the basis of a request to revise the factors currently published by EPA based on data collected in the 1970s.

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1.0 Introduction and Summary of Emission Factors

This document contains proposed emission factors for asphalt processing and roofing manufacturing production units and compares these to factors published in the U. S. Environmental Protection Agency's (EPA's) emission factor document (commonly referred to as AP-42[1]) and to emission factors from other published literature.

1.1 Background

The proposed emission factors presented in this document are for certain criteria air pollutants, criteria pollutant precursors (described below), and hazardous air pollutants. The emission factors were developed from data available to the Asphalt Roofing Manufacturers Association (ARMA).

- *Available Data includes:*
  - *Data collected by ARMA in 1998 and 1999* as a part of a joint EPA-industry emissions study conducted to support the U.S. EPA's maximum achievable control technology (MACT) rulemaking. Without exception, these data meet EPA's criteria for an "A" rating[2]. ("A" rating data quality means that the tests were 1) performed using EPA reference methods, or when not applicable, a sound methodology and 2) that the tests are reported in enough detail for adequate validation, and 3) raw data are provided that can be used to duplicate the emission results presented in the report.)
  - *Data provided by ARMA member companies*. These data generally meet the criteria for an "A" or "B" rating. ("B" rating data quality means that the tests were performed using a sound methodology, but may be lacking enough detail for adequate validation.)
  - *Data provided by ARMA Member Company Owens Corning.* These data also meet EPA's criteria for an "A" or "B" rating.

These data are compared to the data from the original AP-42 document.

In order to allow users of these emission factors to understand whether each proposed emission factor is reliable and representative, each emission factor is rated using the system devised by EPA for factors in their AP-42 document[3]. Note that in the discussion immediately above, the "A" or "B" ratings referred to the quality of the *data*. In the following discussion (also from EPA's AP-42), the ratings rank the quality of the *emission factors,* not of individual emission tests.

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[1] U. S. Environmental Protection Agency, Chapter 11 of the 5th edition of AP-42 Emission Factors, U. S. EPA, "Mineral Products Industry, Section 2, Asphalt Roofing" January 1995.
[2] U. S. Environmental Protection Agency, Chapter 4 of AP-42 Emission Factors, U. S. EPA; EPA-454/R95-015, November 1997, p.4-11.
[3] Chapter 4 of AP-42 Emission Factors, pp.4-24 and 4-25.

Proposed Emission Factors

Emission Factor Rating	Description (From AP-42, pp. 4-24 and 4-25)
A	Excellent. Emission factor developed is primarily from A- and B-rated source test data taken from randomly chosen facilities from the industry population. The source category population is sufficiently specific to minimize variability.
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, 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.
C	Average. Emission factor is developed primarily from A-, B-, or 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.
D	Below Average. Emission factor is developed primarily from A-, B-, or 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 category population.
E	Poor. Emission factor is developed primarily from C- and D-rated test data from a very few 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 variability within the source category population.

This document is accompanied by an Excel Spreadsheet **EFforARMA5-12-03.xls**. The spreadsheet contains all of the raw data used to develop the emission factors.

Proposed Emission Factors

This document is organized in five sections and three appendices containing emissions data.

Section

1.0 Introduction. This section contains background information and a summary of the recommended criteria pollutant and HAP emission factors for each source.

2.0 Sources Tested to Develop the Emission Factors. This section describes the sources tested to develop the ARMA emissions factors, including data collected by ARMA, AP-42 data and other data including a relatively large database developed by Owens Corning.

3.0 Methodology for Calculation of Emission Factors. This section describes the statistical approach used in developing the emissions factors.

4.0 Emission Factors. This section contains detailed emission factors for each type of process unit and provides information on the original sources from which each factor is derived.

5.0 Conclusion.

Appendices

1 Appendix A contains a summary of the emissions data used to develop the proposed emissions factors. It is a printout of five worksheets from **EFforARMA5-12-03.xls**.

2 Appendix B contains significant additional data for uncontrolled asphalt roofing manufacturing sources. For most of these source types, an insufficient number of sources were sampled to develop reliable emission factors. In such cases, the data have been averaged using the same statistical approach described in Section 3, but no emissions factors have been recommended. It is a printout of worksheets from **EFforARMA5-12-03.xls**.

3 Appendix C contains significant additional data for controlled asphalt roofing manufacturing sources. Identical to the approach taken for the data contained in Appendix B, these data have been averaged using the Section 3 statistical approach; no emissions factors have been recommended. Appendix C is also a printout of worksheets from **EFforARMA5-12-03.xls**.

1.2 Recommended Criteria Pollutant Emissions Factors

There are six criteria air pollutants regulated by the Clean Air Act: sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), lead (Pb), particulate matter less than ten microns in diameter (PM_{10}), and ozone (O_3). Ozone is not typically emitted from stacks, but is formed (in part) due to emissions of its precursors: NO_X, CO, and volatile organic compounds (VOCs). Particulate matter (PM) has been sampled for rather than PM_{10}. As PM includes all PM_{10}, the PM factors can be considered overestimates of PM_{10} emissions. In general, Total Organic Carbon as determined by Method 25a has been sampled for as opposed to Volatile Organic Compounds. As TOC includes some compounds that are not VOCs, TOC factors can be considered overestimates of VOC emissions. This document contains proposed emission factors for SO_2, NO_X, CO, PM and TOC. No data are available for lead (Pb); thus no emission factors have been developed for lead.

Proposed Emission Factors

Table 1 shows a summary of proposed ARMA criteria pollutant emissions factors for asphalt blowing stills operating with and without catalyst, oxidized asphalt tanks, and coaters. Note that asphalt blowing stills are sometimes called asphalt convertors or oxidizers.

Note: Throughout this document "--" will be used to indicate there are no data available. NR indicates that no Emission Factor is recommended.

Table 1 Proposed Criteria Pollutant Emission Factors For Asphalt Processing and Asphalt Roofing Manufacturing Operations
(Pounds of pollutant per ton of asphalt produced)

		PM	SO_2	CO	NO_X	TOC
Blowing Still without Catalyst						
Controlled by a Thermal Oxidizer	Proposed Factor	8.3 E-02	8.8 E-01	6.6 E-01	5.7E-02	4.1 E-02
	Sources Tested	17	11	14	10	13
	Proposed EF Rating	A	A	B	A	A
Blowing Still with Catalyst						
Controlled by a Thermal Oxidizer	Proposed Factor	7.2E-02	4.5E-01	NR	NR	NR
	Sources Tested	3	2	1	1	1
	Proposed EF Rating	C	C	--	--	--
Oxidized Asphalt Tank						
Emissions sampled prior to any control device	Proposed Factor	--	--	2.4E-02	--	4.0E-01
	Sources Tested	0	0	3	0	2
	Proposed EF Rating	--	--	C	--	C
Coater						
Emissions sampled prior to any control device	Proposed Factor	5.9E-01	NR	6.0E-02	--	2.9E-01
	Sources Tested	3	1	4	0	4
	Proposed EF Rating	C	--	C	--	C

Proposed Emission Factors

Table 2 shows the original AP-42 factors for the same Table 1 sources.

Table 2 AP-42 Criteria Pollutant Emission Factors For Asphalt Processing and Asphalt Roofing Manufacturing Operations
(Pounds of pollutant per ton of asphalt produced)

		PM	SO_2	CO	NO_X	TOC
Blowing Still without Catalyst, Coating Asphalt						
Controlled by an After-burner	AP-42 Factor	8.1 E-01	--	--	--	1.7 E-02*
	Sources Tested	1	0	0	0	1
	EF Rating	D				D
Blowing Still with Catalyst						
	No comparable factors					
Oxidized Asphalt Tank						
	No comparable factors					
Uncontrolled Coater						
	No comparable factors					

*Note: There is apparently a conversion error in the TOC values for Controlled Blowing Stills in AP-42. Process SCC 3-05-001-02 is Asphalt Blowing of Coating Asphalt. In Table 11.2-3, the metric emissions factor is 0.085 kg/Mg. The English factor is given as 0.017 lbs/ton. The English units (lbs/ton of product) should be twice the metric ones (in kg/Mg of product), not 0.2 times the metric ones. This can be corrected when AP-42 is revised. (A review of the original data would be necessary in order to determine which value is correct. Such a review was not conducted for this report.)

1.3 Recommended HAP Emissions Factors

The Clean Air Act identifies 188 HAPs. The following summary tables show the organic HAPs present in the emission sources tested. The data shown represent only those factors that were considered adequate for generation of emission factors. Significant additional data are available and are presented in Appendices A, B, and C. Tests for inorganic HAPs have not been conducted. When the program to sample emissions for the purposes of MACT was developed, it was agreed by ARMA and EPA that inorganic HAPs (other than HCl) would be expected to be present only in trace quantities. Accordingly, sampling for inorganic HAPs was not required. Trumbore 1998[4], does contain data on inorganic HAP emissions from blowing stills. Emissions of these substances are very low, generally two orders of magnitude below emissions for organic HAPs. For a complete discussion of the sources sampled in developing these emission factors, see Section 4 and the Appendices.

Table 3 presents HAP data for the four sources for which emission factors have been developed. Note that the values for HAPs that were not detected have been assumed to be 50% of the detection limit for the method. (See Section 3.0 for a full discussion of the statistical treatment of the data.) Table 3 shows the proposed hazardous air pollutant emission factors for asphalt roofing and asphalt processing sources. The individual data from the emission sources used to develop these factors are provided in Sections 4.1 through 4.4.

[4] Trumbore, David C., The Magnitude and Source of Air Emissions from Asphalt Blowing Operations", Environmental Progress, Spring 1998.

Proposed Emission Factors

Table 3 Proposed Hazardous Air Pollutant Emission Factors Asphalt Roofing Manufacturing Operations
(Pounds of pollutant per ton of asphalt throughput)

Hazardous Air Pollutants	Asphalt Blowing Still, No Catalyst See Section 4.1			Asphalt Blowing Still with Catalyst See Section 4.2			Oxidized Tanks See Section 4.3			Coaters See Section 4.4		
	Emission Factor (lb/ton)	# of plants	EF Rating	Emission Factor (lb/ton)	# of plants	EF Rating	Emission Factor (lb/ton)	# of plants	EF Rating	Emission Factor (lb/ton)	# of plants	EF Rating
HCl	5.6E-03	3	B	2.3E-01	4	B						
Benzene	3.3E-03	5	B									
Toluene	1.3E-04	2	C									
Ethyl Benzene	6.5E-03	2	C									
Formaldehyde							2.1E-03	3	C	9.1E-03	3	C
Carbonyl Sulfide							1.8E-03	3	C	8.1E-03	3	C
Phenol	5.1E-06	2	C									
2-methyl phenol	2.4E-06	2	C									
4-methyl phenol	4.0E-06	2	C									
Naphthalene	1.1E-05	5	B	8.0E-05	2	C						
2-Methylnaphthalene	3.8E-06	4	B									
Acenaphthene	1.3E-06	4	B									
Fluorene	3.4E-06	2	C									
Phenanthrene	3.0E-06	4	B									
Anthracene	7.6E-08	2	C									
Pyrene	1.2E-06	4	C									
Chrysene	5.8E-08	2	C									
Di-n-butylphthalate	3.1E-06	2	C									
Bis(2-ethylhexyl)phthalate	6.3E-06	2	C									
Acenaphthalene	6.4E-08	3	B									
Fluoranthene	8.8E-07	3	C									
Benz(a)anthracene	1.3E-08	2	C									
Benzo(b)fluoranthene	1.2E-08	2	C									
Benzo(e)pyrene	1.5E-08	2	C									

Proposed Emission Factors

The blowing stills in Table 3 were sampled after their thermal oxidizers. The oxidized tanks and coaters were sampled prior to any control equipment. The Sources shown in Table 3 are discussed in Sections 4.1 – 4.4. Complete data for these sources are presented in worksheets A-1 through A-5 of the spreadsheet **EFforARMA5-12-03.xls** and summarized in Appendix A.

There are some additional data available. The additional data for uncontrolled sources are discussed in Section 4.5.1. Additional data for controlled sources are discussed in Section 4.5.2. Complete data for these sources are presented in worksheets B-1 through B-8 and C-1 through C-7 of the spreadsheet **EFforARMA5-12-03.xls** and summarized in Appendices B and C.

2.0 Sources Tested to Develop the Emission Factors

2.1 Test Methods

Much of the data contained in this document was gathered during a sampling program conducted in 1998 and 1999. ARMA and the EPA's Industrial Studies Branch, Emission Standards Division collaborated on the design of the program. It was funded by ARMA and conducted in accordance with state-of-the-art quality assurance and quality control protocols. Test methods used included:

- Particulate Matter: U.S. EPA Method 5A
- Sulfur oxides: U.S. EPA Method 3A
- Carbon Monoxide: U.S. EPA Method 10, or Fourier Transform Infrared Spectroscopy (FTIR)
- Nitrogen Oxides: U.S. EPA Method 7E
- Total Organic Compounds: U.S. EPA Method 25A. These are expressed as TOC as carbon. The Owens Corning data were reported as TOC as propane. They have been converted to TOC as Carbon.
- Hydrochloric Acid: U.S. EPA Method 26 or 26A
- Hazardous Air Pollutants: Fourier Transform Infrared Spectroscopy or approved U.S. EPA methods

Accordingly, the data meet permit-required quality control standards and data quality is "A" or "B". (See discussion in Section 1.1 of this report.)

2.2 Data Sources

This section describes the sources sampled and test methods used to develop the emission factors for both criteria pollutants and HAPs. Section 2.2.1 describes ARMA's dataset. Section 2.2.2 describes the AP-42 dataset.

2.2.1 ARMA Data Sources used to Develop Emission Factors

The emission factors were developed from data available to the Asphalt Roofing Manufacturers Association (ARMA).

- *Data collected by ARMA in 1998 and 1999* as a part of a joint EPA-industry emissions study conducted to support the U.S. EPA's maximum achievable control technology (MACT) rulemaking. Without exception, these data meet EPA's criteria for an "A" rating[5]. ("A" rating data quality means that the tests were performed using EPA reference methods, or when not applicable, a sound methodology and that the tests are reported in enough detail for adequate validation, and, raw data are provided that can be used to duplicate the emission results presented in the report.) Because the primary intent of the joint sampling effort was to gather data on HAPs, criteria pollutant data were not consistently collected. Thus, this database contains fewer criteria pollutant samples.

[5] U. S. Environmental Protection Agency, Chapter 4 of AP-42 Emission Factors, U. S. EPA; EPA-454/R95-015, November 1997, p.4-11.

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- *Data provided by ARMA Member Owens Corning.* These data were collected by Owens Corning for the purpose of understanding their emissions as well as meeting permit-imposed sampling requirements. Most of these data have been published in two peer-reviewed papers[6,7] and meet EPA's criteria for an "A" rating.
- *Confidential data provided by ARMA member companies*. These data were generally collected over the last five or six years for the purpose of permit-required compliance testing. They were contributed to this report with the understanding that the identities of the individual locations would be kept confidential. Each of the plants sampled is identified by a name such as "Confidential [Unique Letter/Number]." These data generally meet the criteria for an "A" or "B" rating. ("B" rating data quality means that the tests were performed using a sound methodology, but may be lacking enough detail for adequate validation.)

These data are compared to the data from the original AP-42 document.

Using the ARMA data collected in 1998 and 1999, the Owens Corning Data and the confidential ARMA data, emission factors have been developed for the following asphalt roofing processes:

1. A blowing still controlled by a thermal oxidizer operating without catalyst,
2. A blowing still controlled by a thermal oxidizer operating with catalyst,
3. Asphalt storage in oxidized asphalt tanks, and
4. A fiberglass coater.

The emission factors for each process are calculated in pounds of pollutant per ton of asphalt throughput. These emission factors can then be multiplied by the line's asphalt throughput (in tons per year) in order to calculate total annual pounds of emissions for each pollutant.

[6] Trumbore, David C., *The Magnitude and Source of Air Emissions from Asphalt Blowing Operations",* Environmental Progress, Spring 1998.
[7] Trumbore, David C., *Estimates of Air Emissions from Asphalt Storage Tanks and Truck Loading*, Environmental Progress, Winter 1999.

Figure 1 Sources Used to Develop ARMA Emission Factors

Asphalt Blowing Still					Oxidized Asphalt Tanks	Coaters
Without Catalyst			With Catalyst			
Thermal Oxidizer			Thermal Oxidizer		Uncontrolled	Uncontrolled
ARMA/EPA MACT Program	Owens Corning Data	Other ARMA Data	ARMA/EPA MACT Program	Owens Corning Data	ARMA/EPA MACT Program	ARMA/EPA MACT Program
Oxford Plant J	Plant A Plant B Plant C Plant D Plant F Plant H Plant I Plant J Plant K Plant L Plant M Plant N Plant P Plant S	Confidential D1 Confidential E1 Confidential P1 Confidential T1	Oxford	Plant L Plant M Plant M	Plant J Minneapolis Fremont	Fremont Minneapolis Frederick Shakopee

Data were gathered from more than twenty individual sampling sources to characterize the four types of asphalt processing and asphalt roofing sources. During most sampling events, two or three replicates were collected, although there were sometimes as many as five replicates and occasionally only one. Note that not every sampling site was sampled for every constituent. The tables in Section 4 of this document show the locations tested to produce the proposed emission factor for each emission source.

2.2.2 Additional ARMA Data Sources

Figures 2 and 3 show additional sources for which ARMA has gathered emissions data. These data are presented in Appendix B and Appendix C. For these emission sources, an insufficient number of sites and samples were collected to develop reliable emission factors. In such cases, the data have been averaged using the same statistical approach described in Section 3, but no emissions factors have been recommended. See Section 4.5 for additional discussion.

Proposed Emission Factors

Figure 2 Additional Uncontrolled Sources Sampled

(Data are found in Appendix B. No emission factors have been developed.)

Asphalt Loading Operations	Asphalt Flux Tank	Asphalt Tank Sources		Fiberglass Shingle Line Sources		Organic Shingle Line Sources	Mod Bit Line Sources
Table B-1	Table B-2	Laminant Table B-3	Sealant Table B-4	Mixer Table B-5	Surge Tank Table B-6	Saturator Table B-7	Tanks and Coaters Table B-8
Plant J	Plant J	Fremont Laminator Fremont Day Tank	Fremont Seal Down Exh Fremont Seal Down Day Tank	Fremont Hori-zontal Mixer	Fremont Vertical Mixer	Frederick Shakopee	Port Arthur

Figure 3 Additional Controlled Sources Sampled

(Data are found in Appendix C. No emission factors have been developed.)

Controlled Coaters			Controlled Asphalt Shingle Line	Controlled Saturator	Mod Bit Line	
Controlled by a Fume Filter Table C-1	Controlled by a HEAF + Mist Eliminator Table C-2	Controlled by a Thermal Oxidizer Table C-3	Controlled by n Thermal Oxidizer + Mist Eliminator Table C-4	Fume Filter or Mist Eliminator Table C-5	Mist Eliminator Table C-6	Thermal Oxidizer Table C-7
Confidential G1 Confidential P1 Confidential N1	Confidential A1 Confidential C1 Confidential S1	Minneapolis	Confidential B1 Confidential F1	Confidential G1 Confidential H1	Confidential I	Port Arthur

2.2.3 AP-42 Factors for Criteria Pollutants

There are AP-42 factors for some criteria pollutants for emission sources including a blowing still operating without catalyst and coaters from asphalt shingle lines. The complete AP-42 emissions database contains a few additional sources. Those sources which are relevant to current roofing operations have been included in this document for comparison.

Figure 4
Potential Sources of Emissions Data in the AP-42 Database

(Note: not all sources were tested for each pollutant)

Asphalt Blowing Still Controlled by an Afterburner	Controlled Coaters
Stephens (1977)	Fairfield (1976) Shakopee (1977) Waukegan (1976)

3.0 Methodology for Calculation of Emission Factors

This section explains the methodology used to calculate the emission factors. Note that the statistical treatment of the data presented here differs somewhat from the treatment of the HAP data described in the document titled *MACT Analysis for the Asphalt Roofing Manufacturing Category* (Jankousky 2001). The approach used here is generally consistent with that described in EPA-454/R-95-015, the EPA's *Procedures for Preparing Emission Factor Documents* (hereinafter, "the EPA's procedures document"). The emission factors are calculated from averages of the data. One exception is described in Section 3.3. As with the earlier document, no standard deviations have been added to the calculated averages. However, the standard deviation has been calculated for each emission factor. If an individual user of the **EFforARMA5-12-03.xls** spreadsheet wishes to add one or more standard deviations to the data, this can be accomplished by changing "multiple," a named variable in the spreadsheet, to the desired number of standard deviations.

3.1 Emission Factors for Each Sampling Event: EF_{A1}

The emission factor for a sampling event (1) for Plant (A) is denoted EF_{A1} and is calculated from the average of a set of replicate samples. That is, for each individual pollutant, an emission factor (EF_{A1}) is

$$EF_{A1} = \text{Average } (EF_i, EF_{ii}, \ldots)$$

Where: EF_i is the emission factor (in pounds of the pollutant/tons of asphalt throughput) calculated from a single replicate, i.

EF_{A1} is the emission factor (in pounds of the pollutant/tons of asphalt throughput) calculated for the sampling event 1 at Plant A.

3.2 Emission Factors for Each Type Source: EF_{Source}

In most cases, sampling events from more than one plant are available to calculate the emission factor for each particular type of emission source (such as coaters). In cases where multiple sampling events are available, the emission factor for the source was calculated using the following equation:

$$EF_{Source} = \text{Average } (EF_A, EF_B, \ldots)$$

Thus if plant A was sampled twice (sampling events A1 and A2), and plant B was sampled three times (B1, B2, and B3), the emission factor is calculated as [the sum of EF_A (the average of two samples taken on plant A) + EF_B (the average of three samples taken on plant B)] divided by two (the number of plants) rather than the sum of the five samples divided by five. This ensures that each plant sampled (rather than each sampling event) is treated as equivalent in the database.

3.3 Treatment of Values Not Detected

The value of the calculated emissions for constituents not detected has been assumed to be 50% of the detection limit. This is referred to as a below detection limit (BDL) value. This is consistent with the approach recommended in the EPA's procedures document.

If the dataset includes a BDL value and other actually detected values of similar or greater magnitude, the BDL value was averaged with the other values.

However, a special procedure was used if the less than the detection limit value is higher than all other values in the database. In a few cases, one BDL sample in the database had a high detection limit, but several other data points with actually detected (and lower than the other BDL) values were available. In such cases, the BDL value with the high detection limit has been omitted from the data used to calculate the recommended emission factor. For example, there are three toluene samples available to calculate emission factors for blowing stills operating without catalyst. Their values are 8.8E-05, 1.8E-04, and <1.7E-03. In this case, the <1.7E-03 value has been omitted from the dataset as an outlier. The proposed emission factor is 1.3 E-04, the average of 8.8E-05 and 1.8E-04.

4.0 Detailed Emission Factors

This section presents a summary of the emission factors developed from the data. All emission factors are given in pounds of pollutant per ton of asphalt throughput. Throughput is defined as the amount of asphalt that ends up on the product. All emission factors are for coating grade asphalts; asphalts with lower softening points would be expected to have lower emissions.

Sections 4.1 and 4.2 contain emission factors for asphalt blowing stills operating without and with ferric chloride catalyst, respectively. Section 4.3 contains emission factors for oxidized asphalt tanks. Section 4.4 contains emission factors for coaters. There is a significant amount of data for various uncontrolled and controlled sources. However, as fewer individual sources of each of these types of sources were sampled, these data were judged to be insufficient to develop emission factors. They are discussed in Section 4.5. The uncontrolled source data are presented in Appendix B and the controlled source data are presented in Appendix C.

4.1 Asphalt Blowing Still not using a Catalyst

This section develops emission factors for asphalt blowing stills not using a catalyst. Section 4.1.1 contains criteria pollutant emission factors and Section 4.1.2 contains HAP emission factors. Complete data used to develop these emissions factors is found in Table A-1 of Appendix A and in the corresponding worksheet in **EFforARMA5-12-03.xls**.

4.1.1 Criteria Pollutant Emissions Factors

The ARMA database contains criteria pollutant data from five blowing stills operating without catalyst; each one is controlled by a thermal oxidizer. Although the blowing still at Oxford was sampled for the 1998-1999 MACT effort, no criteria pollutant emissions data were obtained. All samples were collected downstream of the thermal oxidizer and all were collected and analyzed using EPA approved methods. The stills include:

- The blowing still at Plant J (operated by Owens Corning) which was sampled as a part of the MACT effort. The thermal oxidizer was operating at a temperature of 1600^{o}F and a residence time of ≥ 0.5 seconds.
- A blowing still designated Confidential D1. It is controlled by a thermal oxidizer operating at >1200^{o}F.
- A blowing still designated Confidential E1. It is controlled by a thermal oxidizer operating at >1200^{o}F.
- A blowing still designated Confidential T1. It is controlled by a thermal oxidizer operating at 1350^{o}F.
- A blowing still designated Confidential P1. It is controlled by a thermal oxidizer operating at 1525^{o}F.

The second resource for criteria pollutant data is Owens Corning database. Note that Plant J is included in both the ARMA database and the Owens Corning database. The Owens Corning data set consists of samples taken at 14 Owens Corning asphalt blowing

stills over a period of 15 years. All of the sources are controlled by thermal oxidizers. At most plants, the source was sampled several times.

There is one only source of criteria pollutant data in the AP-42 document: the Elk Corporation blowing still at Stephens, Arkansas. These data were collected in 1977; this source is no longer operating. It was controlled by an afterburner, and is unlikely to be representative of blowing stills controlled by thermal oxidizers operating at greater than 1200^{o}F. EPA gave this emission factor a rating of "D."

The Stephens data have been omitted from the database used to calculate the ARMA proposed emissions factors for the following reasons: these data are quite old, the control device on the source is not representative of control devices currently in use, and the emissions do not appear to be representative of the current sources.

Table 4 presents ARMA-recommended criteria pollutant emissions factors for a blowing still operating without catalyst. The emissions factors have been calculated by averaging the average value for each of the plants. As described in Section 3.2, multiple emissions values exist for several of the 17 blowing stills in the dataset. A separate emissions factor is generated for each plant by averaging all of the data from that plant. The emission factor for this source type (blowing still without catalyst) is calculated as the average of the emission factors for each of the 17 plants.

Proposed Emission Factors

Table 4 Proposed ARMA Criteria Pollutant Emissions Factors for a Blowing Still Operating without Catalyst

Pounds per ton of asphalt produced

Plant	PM	SO_X	CO	NO_X	TOC[8]
Blowing Still Operating without catalyst					
Plant A	0.02	0.63	0.43	0.06	0.07
Plant B	0.17	--	0.72	--	0.00
Plant C	0.07	0.88	0.09	0.08	0.02
Plant D	0.07	--	0.95	--	--
Confidential D1	0.04	0.38	0.61	--	0.14
Confidential E1	0.04	--	--	--	--
Plant F	0.07	--	--	--	--
Plant H	0.18	0.84	0.09	0.02	0.01
Plant I	0.10	0.66	0.00	0.08	0.08
Plant J	0.11	--	0.01	--	0.00
Plant K	0.08	--	--	--	--
Plant L	0.12	0.82	0.48	0.06	0.01
Plant M	0.13	0.90	1.2	0.03	0.03
Plant N	0.04	0.95	0.01	0.02	0.06
Plant P	0.03	0.93	0.21	0.12	0.00
Confidential P1	0.06	--	--	--	--
Plant S	--	1.2	2.00	0.04	0.05
Stephens	0.8* omitted	--	--	--	0.017 omitted
Confidential T1	0.09	1.51	2.46	0.07	0.08
# of Data Points	112	14	22	13	17
Standard Deviation	0.05	0.29	0.58	0.03	0.04
Proposed EF	**8.3 E-02**	**8.8E-01**	**6.6E-01**	**5.7E-02**	**4.1E-02**
# of Plants Sampled	17	11	14	10	13
Proposed EF Rating	A	A	B	A	A

The emission factors found in Table 4 are based on a significant amount of data. All of the samples were collected and analyzed using EPA-approved methods. The emissions factor is based on A- and B- rated source data. Although the sources sampled were not randomly chosen, there is no apparent bias in this large data base. ARMA believes that it is appropriate to assign the emission factors for PM, SO_X, NO_X, and TOC a rating of A. The emissions factors are each based on 10 or more samples. The emission factor for CO has been assigned a rating of B. The amount of CO emitted will be strongly dependent on thermal oxidizer operation. To achieve complete combustion (to CO_2 rather than CO), the unit must be operated at an adequate temperature, with adequate oxygen, sufficient turbulence and a sufficient residence time.

[8] Note Owens Corning Data have been converted from TOC as propane to TOC as carbon.

4.1.2 HAP Emissions Factors

There are two sources of data for HAPs from blowing stills operating without catalyst: 1) the data collected by ARMA in 1998 and 1999 as a part of a joint EPA-industry emissions study and 2) the Owens Corning database. During the ARMA study, HAP data were collected from two blowing stills operating without catalyst: the Owens-Corning blowing still at Plant J and the CertainTeed blowing still at Oxford. The Oxford sampling concentrated on polycyclic organic matter (POM) and chlorinated HAPs. At Plant J, a broad suite of analyses was conducted. However, the detection limits for some constituents were relatively high. Using the 50% of detection limit approach (see Section 3.3) the emissions calculated for xylene, carbonyl sulfide, 1,3 butadiene, and toluene are on the order of 2 E-03. However, as none of these constituents was actually detected, and as none of these constituents was detected in any other blowing stills tested, no emissions factors have been developed for these constituents. Accordingly, they have been omitted from Table 5.

The Owens Corning data set for HAPs from blowing stills operating without catalyst consists of seven sampling events conducted at six Owens Corning asphalt blowing stills over a period of 3 years. All of the sources are controlled by thermal oxidizers. The data shown in Table 5 below are excerpted from Table 9 (Trumbore, 1998). Complete analytical results can be found in **EFforARMA5-12-03.xls**.

Table 5 HAP Emission Factors, Blowing Still Operating without Catalyst
(Pounds of pollutant per ton of asphalt produced)

Organic HAPs	Recommended. Emission Factor	# of Plants Sampled	Proposed EF Rating	Plant C	Plant O	Plant P	Plant L	Plant Q	Oxford		Plant J	Standard Deviation
Hydrochloric Acid	5.6E-03	3	B			8.2E-03	omitted	8.1E-03	--	<	6.8E-04	4.3E-03
Benzene	3.3E-03	5	B	2.6E-04	1.3E-02	--	1.5E-03	4.6E-04	--	<	1.5E-03	5.4E-03
Toluene	1.3E-04	2*	C	--	--	--	8.8E-05	1.8E-04	--	<	1.7E-03	6.2E-05
Ethyl Benzene	6.5E-03	2	C	--	--	--	--	1.1E-02	--	<	2.0E-03	6.4E-03
Phenol	5.1E-06	2	C	--	--	--	7.4E-06	--	--		2.7E-06	3.3E-06
2-methyl phenol	2.4E-06	2	C	--	--	--	2.5E-06	--	--	<	2.4E-06	8.8E-08
4-methyl phenol	4.0E-06	2	C	--	--	--	5.7E-06	--	--	<	2.4E-06	2.4E-06
Naphthalene	1.1E-05	5	B	5.9E-06	--	--	2.5E-05	9.4E-07	2.2E-05	<	2.4E-06	1.1E-05
2-Methylnaphthalene	3.8E-06	4	B	--	--	--	4.7E-06	6.4E-08	7.9E-06	<	2.4E-06	3.3E-06
Acenaphthene	1.3E-06	4	B	--	--	--	2.5E-06	1.8E-07	1.2E-07	<	2.4E-06	1.3E-06
Fluorene	3.4E-06	2	C	--	--	--	--	--	3.9E-07		6.4E-06	4.3E-06
Phenanthrene	3.0E-06	4	B	--	--	--	6.9E-06	3.5E-07	2.3E-06	<	2.4E-06	2.8E-06
Anthracene	7.6E-08	2*	C	--	--	--	--	2.9E-08	1.2E-07	<	2.4E-06	6.7E-08
Pyrene	1.2E-06	4	C	--	--	--	2.5E-06	1.3E-08	1.0E-07	<	2.4E-06	1.4E-06
Chrysene	5.8E-08	2*	C	--	--	--	--	1.2E-08	1.0E-07	<	2.4E-06	1.3E-06
Di-n-butylphthalate	3.1E-06	2	C	--	--	--	3.0E-06	--	--		3.2E-06	1.3E-07
Bis(2-ethylhexyl)phthalate	6.3E-06	2	C	--	--	--	8.4E-06	--	--		4.3E-06	2.9E-06
Acenaphthalene	6.4E-08	3	C	6.7E-09	--	--	--	1.6E-08	1.7E-07		--	9.2E-08
Fluoranthene	8.8E-07	3	C	--	--	--	2.5E-06	1.3E-08	1.3E-07		--	1.4E-06
Benz(a)anthracene	1.3E-08	2	C	--	--	--	--	7.1E-09	1.8E-08		--	8.0E-09
Benzo(b)fluoranthene	1.2E-08	2	C	--	--	--	--	7.5E-09	1.7E-08		--	6.4E-09
Benzo(e)pyrene	1.5E-08	2	C	--	--	--	--	2.1E-08	9.7E-09		--	8.0E-09

Plants C, O, P, L, and Q are from Trumbore, David C., The Magnitude and Source of Air Emissions from Asphalt Blowing Operations", Environmental Progress, Spring 1998. Oxford and Plant J are ARMA data.

* Plant J data omitted from average; the detection limit was too high. See Section 3.3.

4.2 Asphalt Blowing Still using a Ferric Chloride Catalyst

4.2.1 Criteria Pollutant Emission Factors

During the ARMA sampling effort, the blowing still at Oxford was sampled for HAPs, but no criteria pollutant data were collected. The criteria pollutant data shown below for blowing stills operating with catalyst were made available to ARMA by Owens Corning and CertainTeed:

Table 6 Criteria Pollutant Emissions from Blowing Stills Operating with Catalyst

Asphalt Blowing Still with Catalyst					
	PM	SO_2	CO	NO_X	TOC
Plant L (OC)	9.5E-02	5.3E-01	1.2E+00	4.5E-02	2.5E-02
Oxford (CertainTeed)	2.02E-02	--	--	--	--
Plant M (OC)	1.00E-01	3.7E-01	--	--	--
Proposed Factor	**7.2E-02**	**4.5E-01**	**--**	**--**	**--**
# of Sources Tested	3	2	1	1	1
Proposed EF Rating	C	C	NR	NR	NR

Studies conducted on blowing still emissions have shown that with the exception of hydrogen chloride emissions, pollutant emissions from blowing stills operating with ferric chloride catalyst are similar (on a pounds per hour basis) to the same blowing still operating without ferric chloride catalyst. However, the time required for the blow is significantly reduced due to the use of the catalyst[9]. Accordingly, as an alternative to using the factors in Table 6, companies may wish to use the emission factors for criteria pollutant emissions without catalyst (see Tables 4 and 5) and multiply these factors by the ratio of the blowing time with catalyst to the blowing time without catalyst. For example, if the use of ferric chloride catalyst reduces the blowing time by one-third, the emissions of PM would be expected to be two-thirds of the emissions predicted by Table 4.

There are no data contained in AP-42 for blowing stills operating with ferric chloride catalyst.

[9] David C. Trumbore, personal communication.

4.2.2 HAP Emission Factors

Table 7 contains the proposed emission factor for HAPs developed from the ARMA data. Table 2 of Appendix A contains a listing of all criteria pollutants and HAPs sampled.

Table 7 HAP Emission Factors Developed From All Data Available To ARMA For Asphalt Blowing Still Operating With Catalyst
(Pounds of pollutant per ton of asphalt produced)

Asphalt Blowing Still Operating with Catalyst		
Source Tested	HCl	Naphthalene
Plant L[10]	2.5E-01	5.30E-05
Medina[11]	1.9E-01	--
Minneapolis[22]	2.5E-01	--
Oxford[12]	1.9E-01	1.1E-04
Proposed EF	**2.3 E-01**	**8.0E-05**
# of Plants sampled	4	2
Proposed EF Rating	B	C

As was noted in Section 4.2.1, with the exception of hydrogen chloride emissions, pollutant emissions from blowing stills operating with ferric chloride catalyst are similar (on a pounds per hour basis) to the same blowing still operating without ferric chloride catalyst. However, the time required for the blow is significantly reduced due to the use of the catalyst. Because the HAP data for blowing stills operating without ferric chloride catalyst (Table 5) is more complete than those shown in Table 7, companies may wish to use those factors, reduced by a factor proportionate to the reduction in blowing time.

[10] Trumbore, 1998.
[11] The Medina and Minneapolis data were provided by Owens Corning, personal communication from David C. Trumbore.
[12] Data provided by CertainTeed, personal communication from Martha Bixby, dated 2-24-01.

4.3 Oxidized Asphalt Storage Tanks

4.3.1 Asphalt Storage Criteria Pollutant Data

The oxidized asphalt tanks sampled to develop the emission factors were at Owens Corning Plant J, the Celotex Minneapolis plant and the Celotex Fremont plant.

Table 8 ARMA Criteria Pollutant Emission Factors for Asphalt Storage

Source Tested	PM	SO_2	CO	NO_X	TOC
	Pounds per ton of asphalt throughput				
Oxidized Asphalt Tanks					
Plant J	--	--	4.13E-02	--	2.43E-01
Minneapolis	--	--	2.94E-02	--	5.62E-01
Fremont	--	--	6.48E-04	--	--
Proposed EF	**--**	**--**	**2.4E-02**	**--**	**4.0E-01**
# of Sources Tested	0	0	3	0	2
Proposed EF Rating			C		C

4.3.2 Asphalt Storage Hazardous Air Pollutant Data

Table 9 shows concentrations of the HAPs from the sampling of the asphalt storage tanks. Data on additional HAPs may be found in Table 3 of Appendix A.

Table 9 ARMA HAP Emission Factors for Oxidized Asphalt Storage Tanks

Source of Data	Formaldehyde	Carbonyl Sulfide
	Pounds per ton of asphalt throughput	
Oxidized Asphalt Tanks		
Plant J	3.60E-03	3.63E-03
Minneapolis	2.50E-03	1.77E-03
Fremont	1.12E-04	5.09E-05
Proposed EF	**2.1E-03**	**1.8E-03**
# of Sources Tested	3	3
Proposed EF Rating	C	C

4.4 Coaters

4.4.1 Fiber Glass Coater Criteria Pollutant Data

There are four sources of coater data: Minneapolis, Frederick, Fremont and Shakopee.

Table 10 ARMA Emission Factors for Fiber Glass Coaters
(Pounds per ton of asphalt in product)

Source Tested	PM	SO_2	CO	NO_X	TOC
Uncontrolled Coaters					
Minneapolis	1.8E-01	--	2.01E-01	--	4.8E-01
Fremont	--	--	1.21E-02	--	2.49E-01
Frederick	1.52E+00	--	1.26E-02	--	3.49E-01
Shakopee	6.74E-02	1.86E-02	1.50E-02	--	7.33E-02
Proposed EF	**5.9E-01**	**NR**	**6.0E-02**	**--**	**2.9E-01**
# of Sources	3		4	0	4
Proposed EF Rating	C		C		B

ARMA Member Companies also submitted emissions data for coaters controlled by various emissions abatement devices. Those data are presented in Appendix C.

4.4.2 Coater HAP Data

The ARMA database contains HAP data for the same shingle line sources identified in Table 10 above. However, the Shakopee HAP data have not been used in the calculation of emission factors. These data were collected in August 1995, early in the development of the Fourier Transform Infrared (FTIR) sampling and analytical methods. The following problems were noted in the analysis of the 1995 Shakopee data: 1) the FTIR had difficulty in handling the wide range of similar hydrocarbons and the resultant interferences; 2) due to difficulties experienced by the sampling contractor, the protocol for sample conditioning was not followed; 3) compounds in the hexane through isooctane chain lengths were not actually measured due to interferences; 4) there was strong interference between the formaldehyde peak and the aliphatic hydrocarbons. Table 11 contains a summary of the HAPs identified in the highest quantities for the fiber glass shingle line. Complete data are found in **EFforARMA5-12-03.xls**. The data are summarized in Table 4 of Appendix A.

Proposed Emission Factors

Table 11 ARMA HAP Emission Factors for Fiber Glass Coaters
(Pounds per ton of asphalt in product)

Source Tested	Formaldehyde	Carbonyl Sulfide
O. Minneap	1.59E-03	1.89E-02
P. Fremont	1.37 E-02	1.03 E-03
Q. Frederick	1.22 E-02	<4.3 E-03
Proposed EF	**9.1E-03**	**8.1E-03**
# of Sources	3	3
Proposed EF Rating	C	C

As can be seen from Table 4 in Appendix A, calculated emission factors of hydrochloric acid, benzene, toluene, ethyl benzene, xylene and 1,3 butadiene were in the 1 E-03 to 7 E-03 range. However, these values have been omitted from Table 11 because none of these constituents was actually detected at the laboratory detection limit.

4.5 Emissions Data from Additional Sources

4.5.1 Emissions Data from Additional Uncontrolled Sources

In addition to the emission factor data presented for the sources presented in Sections 4.1 through 4.4, Appendix B: Tables B-1 through B-8 contain emissions data from the sources shown on Figure 3 (Section 2.2.2). The data have been averaged using the same statistical approach discussed in Section 3.0. However, because the data are generally from just one or two sources, the data averages are not recommended as emission factors. Complete data are found in **EFforARMA5-12-03.xls**.

4.5.2 Emissions Data from Additional Controlled Sources

Appendix C: Tables C-1 through C-7 contain emissions data from the sources shown on Figure 4 (page 12). The data have been averaged using the same statistical approach discussed in Section 3.0. However, because the data are generally from just one or two sources, the data averages are not recommended as emission factors. Complete data are found in **EFforARMA5-12-03.xls**.

5.0 Conclusion

The data represented here have been subjected to a high degree of quality assurance. The number and representativeness of samples in the data set has been considered in determining the recommended rating of each emission factor. These factors are expected to be more reliable than the factors found in AP-42.

Bibliography

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Appendices

Note: the tables in the appendices contain summaries of data from Excel Spreadsheet titled **EFforARMA5-12-03.xls**. The Tables are not complete printouts of the worksheets. The entire worksheets can be viewed from the Spreadsheet. Shading of any value indicates that it was not detected at the detection limit for the sample. The shaded values are 50% of the detection limit.