Emission Factor Documentation for AP-42 Section 11.2

Asphalt Roofing

Final Report

For U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Inventory Branch

EPA Contract No. 68-D2-0159
Work Assignment No. I-01

MRI Project No. 4601-01

May 20, 1994

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For U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Inventory Branch
Research Triangle Park, NC 27711

Attn: Mr. Ron Myers (MD-14)

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PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U.S. Environmental Protection Agency (EPA), under Contract No. 68-D2-0159, Assignment No. I-01. Mr. Ron Myers was the requester of the work. The report was prepared by Brian Shrager and Richard Marinshaw.

Approved for:

MIDWEST RESEARCH INSTITUTE

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May 20, 1994

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1. INTRODUCTION

The document Compilation of Air Pollutant Emission Factors (AP-42) has been published by the U.S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of areawide emissions;
2. Estimates of emissions for a specific facility; and
3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from test reports and other information to support preparation of AP-42 Section 11.2, Asphalt Roofing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the asphalt roofing industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from asphalt roofing. Section 3 is a review of emission data collection and laboratory analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details revisions to the existing AP-42 section narrative and pollutant emission factor development. It includes the review of specific data sets and the results of data analysis. Section 5 presents the AP-42 Section 11.2, Asphalt Roofing.

2. INDUSTRY DESCRIPTION[1]

The asphalt roofing industry manufactures asphalt-saturated felt rolls, fiberglass and organic (felt-based) shingles, and surfaced and smooth roll roofing. Most of these products are used in roof construction, but small quantities are used in walls and other building applications.

2.1 CHARACTERIZATION OF THE INDUSTRY[6]

Approximately 266 asphalt roofing plants operate in the United States. Table 2-1 lists the States in which more than 150 people were employed in the asphalt roofing industry in 1987. The total value of shipments for the asphalt roofing industry was about $3.4 billion in 1987.

TABLE 2-1. LEADING ASPHALT ROOFING PRODUCING STATES

Alabama	Louisiana	Ohio
Arkansas	Maryland	Oklahoma
California	Massachusetts	Oregon
Florida	Minnesota	Pennsylvania
Georgia	Missouri	South Carolina
Illinois	New Jersey	Tennessee
Indiana	New York	Texas
Kansas	North Carolina	

2.2 PROCESS DESCRIPTION[1-4]

The production of asphalt roofing products consists of six major operations: (1) felt saturation, (2) coating, (3) mineral surfacing (top and bottom), (4) cooling and drying, (5) product finishing (seal-down strip application, cutting and trimming, and laminating of laminated shingles), and (6) packaging. There are six major production support operations: (1) asphalt storage, (2) asphalt blowing, (3) back surfacing and granule storage, (4) filler storage, (5) filler heating, and (6) filler and coating asphalt mixing. There are two primary roofing substrates: organic (paper felt) and fiberglass. Production of roofing products from the two substrates differ mainly in the elimination of the saturation process when using fiberglass.

Preparation of the asphalt is an integral part of the production of asphalt roofing. This preparation, called "blowing," involves the oxidation of asphalt flux by bubbling air through liquid asphalt flux at 260°C (500°F) for 1 to 10 hours. The amount of time depends on the desired characteristics of the roofing asphalt, such as softening point and penetration rate. Blowing results in an exothermic reaction that requires cooling. Water sprays are applied either internally or externally to the shell of the blowing vessel. A typical plant blows four to six batches per 24-hour day. Blowing may be done in either vertical vessels or in horizontal chambers (both are frequently referred to as "blowing stills"). Inorganic salts such as ferric chloride ($FeCl_3$) may be used as catalysts to achieve desired properties and to increase the rate of reaction in the blowing still, decreasing the time required for each blow. Blowing operations may be located at oil refineries, asphalt processing plants, or asphalt roofing plants. Figure 2-1 illustrates an asphalt blowing operation.

The most basic asphalt roofing product is asphalt-saturated felt. Figure 2-2 shows a typical line for the manufacture of asphalt-saturated felt. It consists of a dry felt feed roll, a dry looper section, a saturator spray section (seldom used today), a saturator dipping section, heated drying-in drums, a wet looper, cooling drums, a finish floating looper, and a roll winder.

Organic felt may weigh from approximately 20 to 55 pounds (lb) per 480 square feet (ft^2) (a common unit in the paper industry), depending upon the intended product. The felt is unrolled from the unwind stand onto the dry looper, which maintains a constant tension on the material. From the dry looper, the felt may pass into the spray section of the saturator (not used in all plants), where asphalt at 205° to 250°C (400° to 480°F) is sprayed onto one side of the felt through several nozzles. In the saturator dip section, the saturated felt is drawn over a series of rollers, with the bottom rollers submerged in hot asphalt at 205° to 250°C (400° to 480°F). During the next step, heated drying-in drums and the wet looper provide the heat and time, respectively, for the asphalt to penetrate the felt. The saturated felt then passes through water-cooled rolls, onto the finish floating looper, and then is rolled and cut to product size on the roll winder. Three common weights of asphalt felt are approximately 12, 15, and 30 lb per 108 ft^2 (108 ft^2 of felt covers exactly 100 ft^2 of roof).

The typical process arrangement for manufacturing asphalt shingles, mineral-surfaced rolls, and smooth rolls is illustrated in Figure 2-3. For organic products the initial production steps are similar to the asphalt-saturated felt line. For fiberglass (polyester) products the initial saturation operation is eliminated although the dry looper is utilized. A process flow diagram for fiberglass shingle and roll manufacturing is presented in Figure 2-4. After the saturation process, both organic and fiberglass (polyester) products follow essentially the same production steps, which include a coater, a granule and sand or backing surface applicator, a press section, water-cooled rollers and/or water spray cooling, finish floating looper, and a roll winder (for roll products), or a seal-down applicator and a shingle cutter (for shingles), or a laminating applicator and laminating operation (for laminated shingles), a shingle stacker, and a packaging station.

Saturated felt (from the saturator) or base fiberglass (polyester) substrate enters the coater. Filled asphalt coating at 180° to 205°C (355° to 425°F) is released through a valve onto the top of the mat just as it passes into the coater. Squeeze rollers in the coater apply filled coating to the backside and distribute it evenly to form a thick base coating to which surfacing materials will adhere. Filled asphalt coating is prepared by mixing coating asphalt or modified asphalt at approximately 250°C (480°F) and a mineral stabilizer (filler) in approximately equal proportions. Typically, the filler is dried and preheated at about 120°C (250°F) in a filler heater before mixing with the coating asphalt. Asphalt modifiers can include rubber polymers or olefin polymers. When modified asphalt is used to produce fiberglass roll roofing, the process is similar to the process depicted in Figure 2-4 with the following exception: instead of a coater, an impregnation vat is used, and preceding this vat, asphalt, polymers, and mineral stabilizers are combined in mixing tanks.

EMISSION SOURCE	SCC
ASPHALT BLOWING: SATURANT	3-05-001-01
ASPHALT BLOWING: COATING	3-05-001-02
ASPHALT BLOWING: (GENERAL)	3-05-001-10
FIXED ROOF ASPHALT STORAGE TANKS	3-05-001-30, -31
FLOATING ROOF ASPHALT STORAGE TANKS	3-05-001-32, -33

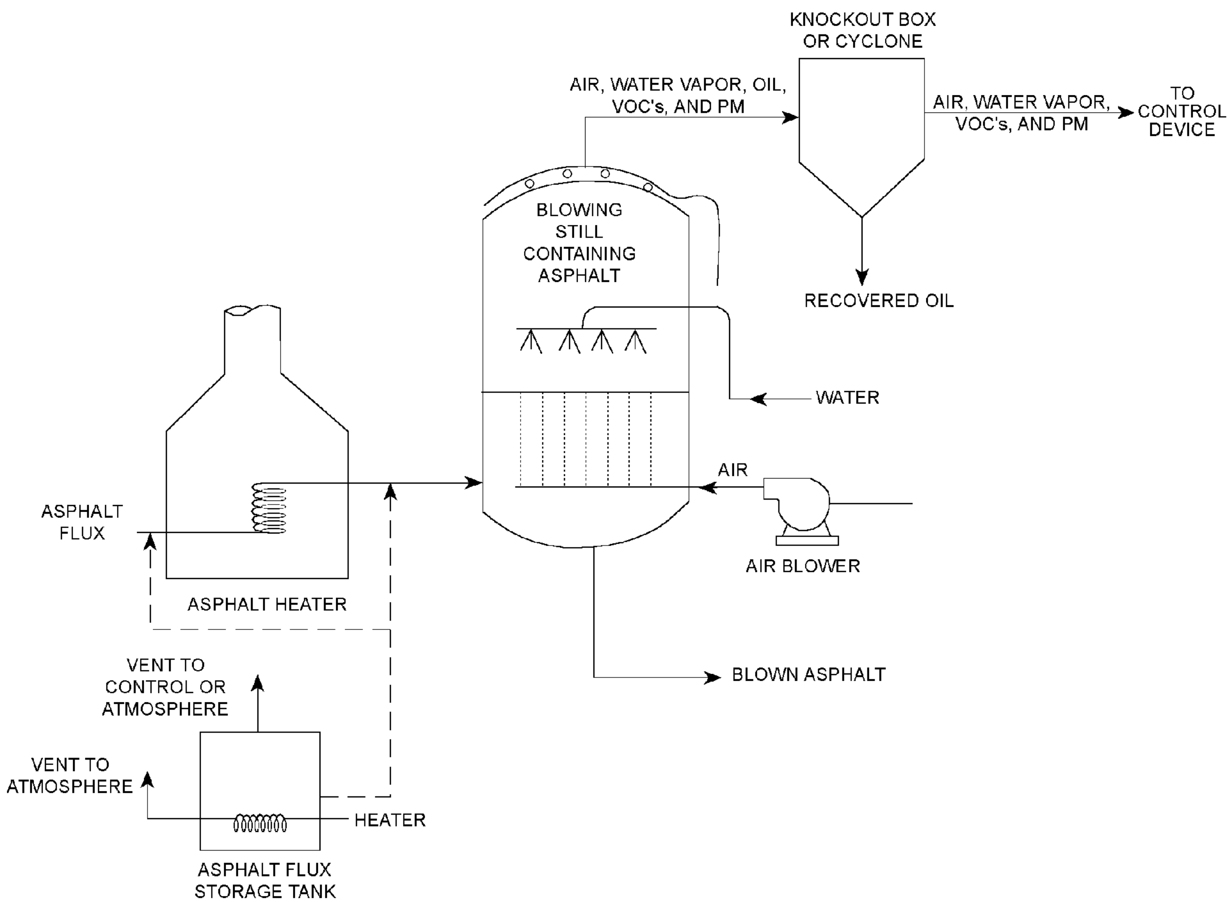

Figure 2-1. Asphalt blowing process flow diagram.[1,4]
(SCC = Source Classification Code)

EMISSION SOURCE	SCC
DIPPING ONLY	3-05-001-11
SPRAYING ONLY	3-05-001-12
DIPPING/SPRAYING	3-05-001-13
DIP SATURATOR, DRYING-IN DRUM, WET LOOPER, AND COATER	3-05-001-16
DIP SATURATOR, DRYING-IN DRUM, AND COATER	3-05-001-17
DIP SATURATOR, DRYING-IN DRUM, AND WET LOOPER	3-05-001-18
SPRAY/DIP SATURATOR, DRYING-IN DRUM, WET LOOPER, COATER, AND STORAGE TANKS	3-05-001-19
FIXED ROOF ASPHALT STORAGE TANKS	3-05-001-30, -31
FLOATING ROOF ASPHALT STORAGE TANKS	3-05-001-32, -33

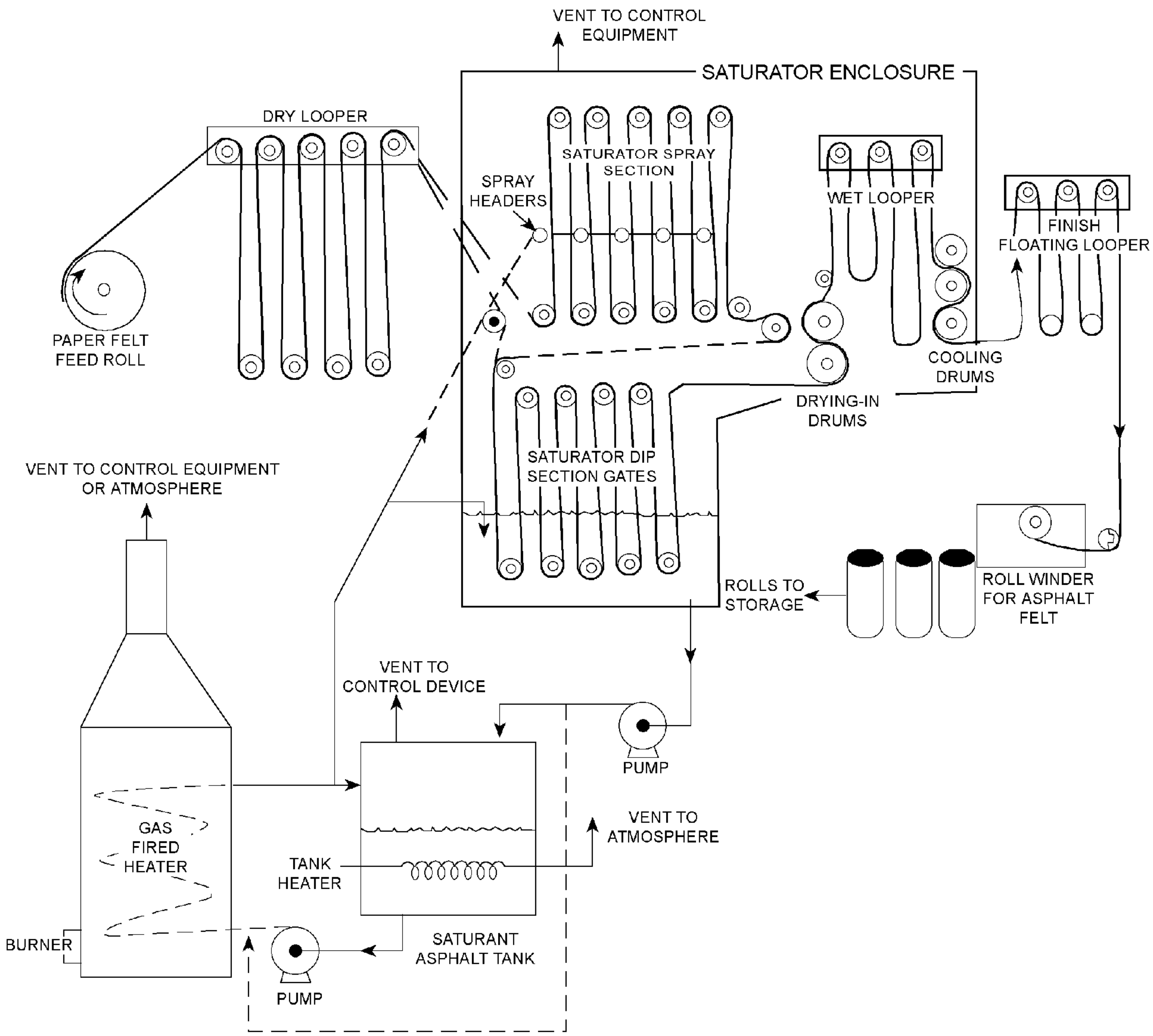

Figure 2-2. Asphalt-saturated felt manufacturing process.[1,2]
(SCC = Source Classification Code)

EMISSION SOURCE	SCC
FELT SATURATION: DIPPING ONLY	3-05-001-03
FELT SATURATION: DIPPING/SPRAYING	3-05-001-04
DIPPING ONLY	3-05-001-11
SPRAYING ONLY	3-05-001-12
DIPPING/SPRAYING	3-05-001-13
DIP SATURATOR, DRYING-IN DRUM, WET LOOPER, AND COATER	3-05-001-16
DIP SATURATOR, DRYING-IN DRUM, AND COATER	3-05-001-17
DIP SATURATOR, DRYING-IN DRUM, AND WET LOOPER	3-05-001-18
SPRAY/DIP SATURATOR, DRYING-IN DRUM, WET LOOPER, COATER, AND STORAGE TANKS	3-05-001-19
FIXED ROOF ASPHALT STORAGE TANKS	3-05-001-30, 31
FLOATING ROOF ASPHALT STORAGE TANKS	3-05-001-32, -33

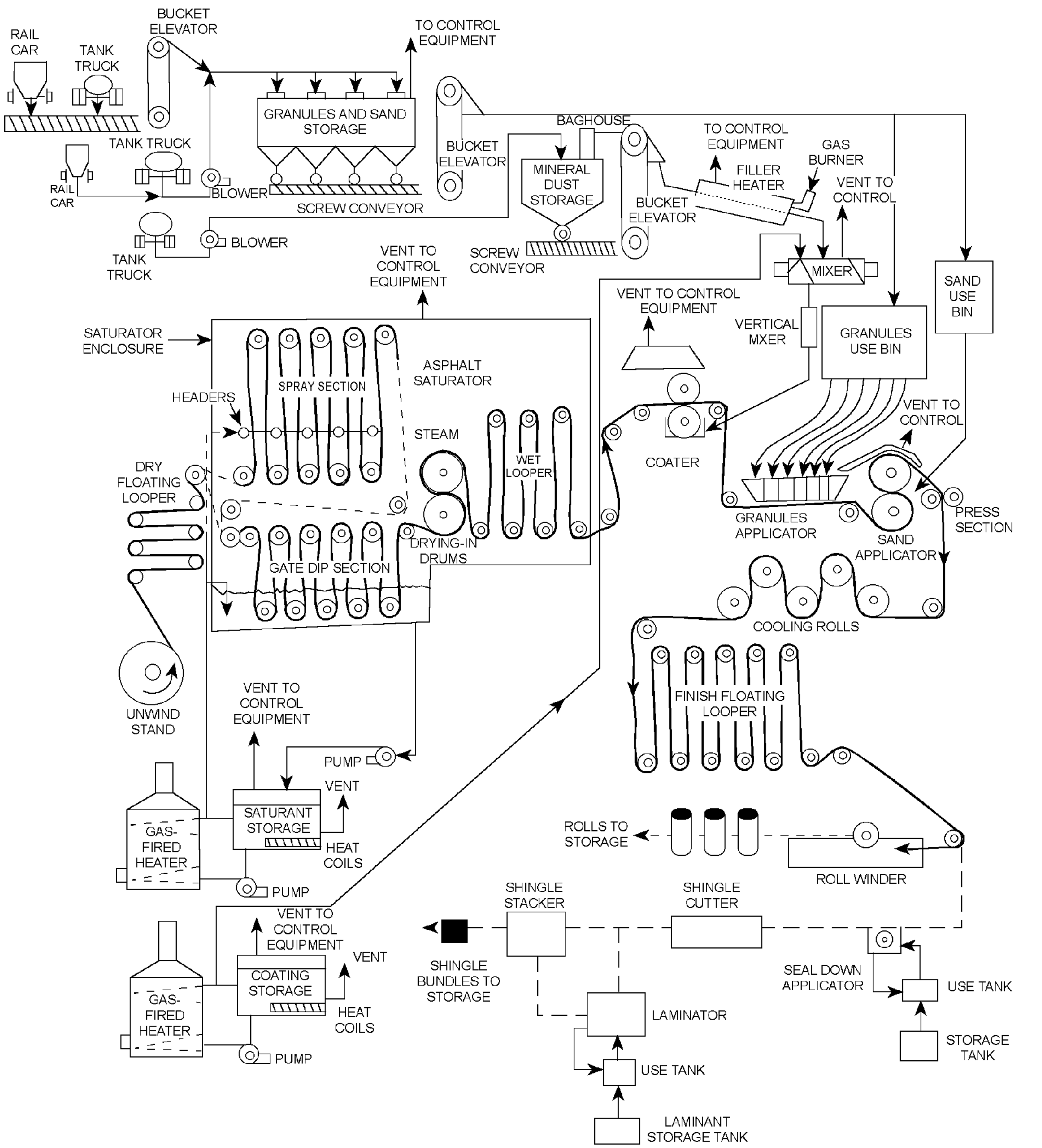

Figure 2-3. Organic shingle and roll manufacturing process flow diagram.[1,2]
(SCC = Source Classification Code)

EMISSION SOURCE	SCC
FELT SATURATION: DIPPING ONLY	3-05-001-03
FELT SATURATION: DIPPING/SPRAYING	3-05-001-04
DIPPING ONLY	3-05-001-11
SPRAYING ONLY	3-05-001-12
DIPPING/SPRAYING	3-05-001-13
DIP SATURATOR, DRYING-IN DRUM, WET LOOPER, AND COATER	3-05-001-16
DIP SATURATOR, DRYING-IN DRUM, AND COATER	3-05-001-17
DIP SATURATOR, DRYING-IN DRUM, AND WET LOOPER	3-05-001-18
SPRAY/DIP SATURATOR, DRYING-IN DRUM, WET LOOPER, COATER, AND STORAGE TANKS	3-05-001-19
FIXED ROOF ASPHALT STORAGE TANKS	3-05-001-30-31
FLOATING ROOF ASPHALT STORAGE TANKS	3-05-001-32, 33

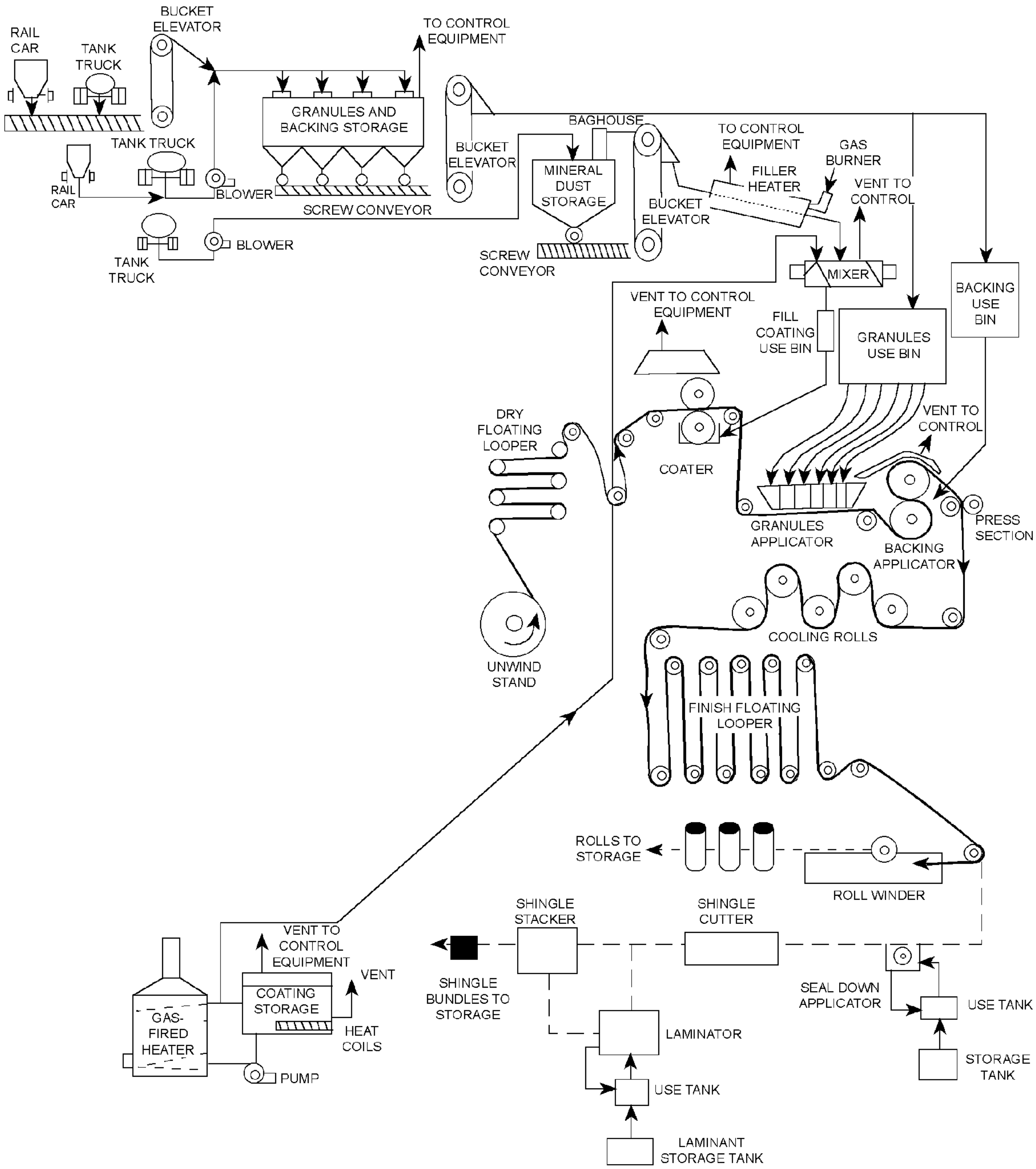

Figure 2-4. Fiberglass shingle and roll manufacturing process flow diagram.[1,2]
(SCC = Source Classification Code)

After leaving the coater, the coated sheet to be made into shingles or mineral surfaced rolls passes through the granule applicator, where granules are fed onto the hot, coated surface. The granules are pressed into the coating as the mat passes around a press roll, where it is reversed, exposing the bottom side. Sand, talc, or mica is applied to the back surface and is also pressed into the coating.

After application of the mineral surfacing, the mat is cooled rapidly by water cooled rolls and/or water sprays and is passed through air pressure operated press rolls used to embed the granules firmly into the filled coating. The mat then passes through a drying section where it is air dried. After drying, a strip of adhesive (normally asphalt) is applied to the roofing surface. The strip will act to seal the loose edge of the roofing after application to a roof. A finish looper in the line allows continuous movement of the sheet through the preceding operations and serves to further cool and dry the roofing sheet. Roll roofing is completed at this point is and moves to a winder where rolls are formed. Shingles are passed through a cutter, which cuts the sheet into individual shingles. (Some shingles are formed into laminated products by layering the shingle pieces and binding them together with a laminating material, normally a modified asphalt. The laminant is applied in narrow strips to the backside of the sheet). The finished shingles are stacked and packaged for shipment.

There are several operations that support the asphalt roofing production line. Asphalt (coating and saturant) is normally delivered to the facility by truck and rail and stored in heated storage tanks. Filler (finely divided mineral) is delivered by truck and normally is pneumatically conveyed to storage bins that supply the filler heater. Granules and back surfacing material are brought in by truck or rail and mechanically or pneumatically conveyed to storage bins.

2.3 EMISSIONS

Emissions from the asphalt roofing industry consist primarily of particulate matter (PM) and volatile organic compounds (VOC). Both are emitted from asphalt storage tanks, blowing stills, saturators, coater-mixer tanks, and coaters. The PM from these operations is primarily recondensed asphalt fume. Sealant strip and laminant applicators are also sources of small amounts of PM and VOC. Mineral surfacing operations and materials handling are additional sources of PM. Small amounts of polycyclic organic matter (POM) are also emitted from blowing stills and saturators. Asphalt and filler heaters are sources of typical products of combustion from natural gas or the fuel in use.

2.4 CONTROL TECHNOLOGY

A common method for controlling emissions from the saturator, including the wet looper, is to enclose them completely and vent the enclosure to a control device. The coater may be partially enclosed, normally with a canopy type hood that is vented to a control device. Full enclosure is not always practical due to operating constraints. Fugitive emissions from the saturator or coater may pass through roof vents and other building openings if not captured by enclosures or hoods. Control devices for saturator/coater emissions include low-voltage electrostatic precipitators (ESP's), high-energy air filters (HEAF), coalescing filters (mist eliminators), afterburners (thermal oxidation), fabric filters, and wet scrubbers. Blowing operations are controlled by thermal oxidation (afterburners).

Particulate matter (PM) associated with mineral handling and storage operations is captured by enclosures, hoods, or pickup pipes and controlled by fabric filtration (baghouses) with removal efficiencies of approximately 95-99 percent. Other control devices that may be used with mineral handling and storage operations are wet scrubbers and cyclones.

In the industry, closed silos and bins are used for mineral storage, so open storage piles are not an emission source. To protect the minerals from moisture pickup, all conveyors that are outside the buildings are covered or enclosed. Fugitive mineral emissions may occur at unloading points, depending on the type of equipment used and the mineral handled. The discharge from conveyor to the silos and bins is normally controlled by a fabric filter (baghouse).

REFERENCES FOR SECTION 2

1. Written communication from Russel Snyder, Asphalt Roofing Manufacturers Association, Rockville, MD, to Richard Marinshaw, Midwest Research Institute, Cary, NC, May 2, 1994.

2. J. A. Danielson, *Air Pollution Engineering Manual (2nd Ed.)*, AP-40, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1973. Out of print.

3. *Atmospheric Emissions from Asphalt Roofing Processes*, EPA Contract No. 68-02-1321, Pedco Environmental, Cincinnati, OH, October 1974.

4. L. W. Corbett, "Manufacture of Petroleum Asphalt," *Bituminous Materials: Asphalts, Tars, and Pitches, 2(I)*, Interscience Publishers, New York, 1965.

5. *Background Information for Proposed Standards Asphalt Roofing Manufacturing Industry*, EPA 450/3-80-021a, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1980.

6. *1987 Census of Manufacturers*, U.S. Department of Commerce, Washington D.C., April 1990.

3. GENERAL DATA REVIEW AND ANALYSIS

3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The AP-42 Background Files located in the Emission Inventory Branch (EIB) were reviewed for information on the industry, processes, and emissions. The Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF) and VOC/PM Speciation Data Base Management System (SPECIATE) data bases were searched by Source Classification Code for identification of the potential pollutants emitted and emission factors for those pollutants. A general search of the Air CHIEF CD-ROM also was conducted to supplement the information from these two data bases.

Information on the industry, including number of plants, plant location, and annual production capacities, was obtained from the *Census of Manufactures* and other sources. The Aerometric Information Retrieval System (AIRS) data base also was searched for data on the number of plants, plant location, and estimated annual emissions of criteria pollutants.

A number of sources of information were investigated specifically for emission test reports and data. A search of the Test Method Storage and Retrieval (TSAR) data base was conducted to identify test reports for sources within the asphalt roofing industry. Copies of these test reports were obtained from the files of the Emission Measurement Branch (EMB). The EPA library was searched for additional test reports. A list of plants that have been tested within the past 5 years was compiled from the AIRS data base. Using this information and information obtained on plant location from the *Census of Manufactures*, State and Regional offices were contacted about the availability of test reports. However, the information obtained from these offices was limited. Publications lists from the Office of Research and Development (ORD) and Control Technology Center (CTC) were also searched for reports on emissions from the asphalt roofing industry. In addition, representative trade associations, including the Asphalt Institute, the Asphalt Recycling and Reclaiming Association, and the Asphalt Roofing Manufacturers Association, were contacted for assistance in obtaining information about the industry and emissions.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission data must be from a primary reference:
    a. Source testing must be from a referenced study that does not reiterate information from previous studies.
    b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.
2. The referenced study must contain test results based on more than one test run.
3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., 1-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:

1. Test series averages reported in units that cannot be converted to the selected reporting units;
2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front half with EPA Method 5 front and back half);
3. Test series of controlled emissions for which the control device is not specified;
4. Test series in which the source process is not clearly identified and described; and
5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EIB for preparing AP-42 sections. The data were rated as follows:

A--Multiple tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B--Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C--Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

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

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. In such cases, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth

of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM

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

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

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

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

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

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

The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Chapter 4 of this report.

REFERENCES FOR SECTION 3

1. *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*, EPA-454/B-93-050. Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 1993.

4. AP-42 SECTION DEVELOPMENT

4.1 REVISION OF SECTION NARRATIVE

The existing section narrative was revised to reflect comments provided by the Asphalt Roofing Manufacturers Association (ARMA). The section was also edited for punctuation and grammar.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

Nine references were documented and reviewed in the process of revising the section on asphalt roofing. References 1 through 5 are emission test reports from EMB-sponsored emission tests that were conducted for the purpose of developing new source performance standards (NSPS) for the asphalt roofing manufacturing industry. Data from these same tests were used to calculate the emission factors shown in the existing section, but only a secondary reference containing these data was cited. Reference 6 is an emission test report from an EMB-sponsored emission test that was conducted to help establish testing methodology for the asphalt roofing industry. Reference 7 is a secondary reference containing emission data from three plants, and the test reports that contain these data were not located. The data in Reference 7 was used only for sources and pollutants for which other documented test data were not available. The results of the analysis of test data from References 1 through 6 is presented in Section 4.2.4. Reference 8 is an EPA report documenting the results of an emission test on a simulated asphalt roofing kettle for installing built-up roofing. Emission factors developed from Reference 8 data are not representative of the asphalt roofing industry but may give an indication of possible emissions from blowing stills or saturators. Therefore, these emission factors are presented in this background report but were not included in the revised AP-42 Section 11.2. Reference 9 is a series of emission tests on asphalt saturators, but the reports do not contain any production data, process descriptions, or details on control devices. Therefore, Reference 9 was not used for emission factor development.

4.2.1 Review of Specific Data Sets

4.2.1.1 Reference 1. This EMB-sponsored test measured controlled and uncontrolled emissions from a dip saturator, strike-in drum section, hot looper, and coater that were all ducted to two parallel ESP's. Filterable PM, total organic compounds (TOC), polycyclic organic matter (POM), CO, and CO_2 emissions were measured at the inlet to both ESP's and at the two outlets. Filterable PM and TOC emissions were measured using EPA Methods 5A and 25A, respectively. A single test run was used to quantify POM emissions, so these data were not used for emission factor development. In addition, a particle size analysis was performed, but the discussion of the results stated that the data were considered questionable. Orsat analyses of the outlet gases indicated that CO and CO_2 emissions were negligible.

A rating of A was assigned to the data for filterable PM and TOC. The report included adequate detail, the testing methodology was sound, and no problems were reported during the valid test runs. Data for the other pollutants were not rated and were not included in the AP-42 section.

4.2.1.2 Reference 2. This EMB-sponsored test measured controlled and uncontrolled emissions from a dip saturator, drying-in drum section, coater, and storage tanks ducted to two parallel afterburners. Emissions from the storage tanks were only ducted to one of the afterburners during Run 2 and did not appear to be significant. Filterable PM, TOC, CO, trace metal, POM, aldehydes, sulfur dioxide (SO_2), and NO_x emissions were measured at the afterburner inlets and outlets. Filterable PM and TOC emissions were measured using EPA Methods 5A and 25A, respectively. Carbon monoxide emissions were measured using a nondispersive infrared analyzer (NDIR). Trace metal, POM, and aldehyde emissions were quantified using optical emission spectroscopy, a modified Method 5 train with a POM collection column, and the Los Angeles Wet Chemistry Method, respectively. Because of uncertainty in the POM test method and the fact that only a single test run was used to quantify POM emissions, these data were not used for emission factor development. Emission factors for trace metals were developed but are not presented in the AP-42 section because only one test run was performed. Nitrogen oxide emissions were not detected at the afterburner inlets but were quantified at the outlets using NO_x analyzers. The test contractor was unable to directly monitor the stack due to adverse conditions and the sensitivity of the NO_x analyzers. Therefore, Teflon bags were used to sample the stack gases, and analysis was performed in the laboratory. Sulfur dioxide was not detected at any test location. In addition, a particle size analysis was performed, but the discussion of the results stated that the data were considered questionable. The afterburner outlet emission data could not be used to develop emission factors because dilution air was added to the gas stream after combustion. The volumetric flow rate at the outlets was double the inlet flow rates, thereby biasing the calculated emissions. An indication of this bias is that the TOC measurement was higher at the afterburner outlets than at the inlets.

A rating of A was assigned to the data for uncontrolled filterable PM, TOC, and CO emissions. The report included adequate detail, the testing methodology was sound, and no problems were reported during the valid test runs. Data for the other pollutants were not rated and were not included in the AP-42 section.

4.2.1.3 Reference 3. This EMB-sponsored test measured controlled and uncontrolled emissions from a spray/dip saturator, strike-in drum section, looper, coater, and asphalt storage tanks ducted to a high energy air filter (HEAF). Filterable PM, TOC, CO and CO_2 (outlet only), POM, and SO_2 (outlet only) emissions were measured at the HEAF inlet and outlet. Filterable PM and TOC emissions were measured using EPA Methods 5A and 25A, respectively. Outlet gases were analyzed for CO and CO_2 using an Orsat analyzer, but neither gas was detected. Polycyclic organic matter emissions were quantified using an experimental sampling train (modified Method 5 train with a POM collection column). Because of uncertainty in the POM test method and the fact that only a single test run was used to quantify POM emissions, these data were not used for emission factor development. Because a single run was performed to determine SO_2 concentrations in the outlet gases, these data were not used for emission factor development. In addition, a particle size test was performed, but the analysis was not completed because the data were considered questionable.

A rating of A was assigned to the data for filterable PM and TOC. The report included adequate detail, the testing methodology was sound, and no problems were reported during the valid test runs. Data for the other pollutants were not rated and were not included in the AP-42 section.

4.2.1.4 Reference 4. This EMB-sponsored test measured controlled and uncontrolled emissions from a dip saturator, strike-in drum section, and hot looper that were all ducted to a HEAF. Filterable PM, CO, and CO_2 emissions were measured at the HEAF inlet and outlet, and TOC emissions were measured at the HEAF outlet. Filterable PM and TOC emissions were measured using EPA Methods 5A and 25A, respectively. Orsat analyses of the inlet and outlet gases indicated that CO and CO_2 emissions were negligible.

A rating of A was assigned to the data for filterable PM and TOC. The report included adequate detail, the testing methodology was sound, and no problems were reported during the valid test runs.

4.2.1.5 Reference 5. This EMB-sponsored test measured controlled and uncontrolled emissions from two asphalt blowing stills ducted to an afterburner. Saturant asphalt and coating asphalt were each blown by one of the stills, and emissions from the saturant and coating blows were measured separately. Filterable PM, TOC, CO_2, POM, aldehyde, SO_2, and NO_x emissions were measured at the afterburner inlet and outlet, and CO emissions were measured at the afterburner outlet. Neither of the inlet tests were performed isokinetically, causing data from the six inlet test runs to be downrated. Filterable PM and TOC emissions were measured using EPA Methods 5A and 25A, respectively. Carbon monoxide emissions were measured using an NDIR. Polycyclic organic matter and aldehyde emissions were quantified using a modified Method 5 train with a POM collection column and the Los Angeles Wet Chemistry Method, respectively. Because of uncertainty in the POM test method and the fact that only a single test run was used to quantify POM emissions, these data were not used for emission factor development. Data from the SO_2 and NO_x tests were considered invalid due to a variety of problems encountered during testing.

A rating of A was assigned to the data for controlled filterable PM, TOC, and CO_2 emissions. A rating of C was assigned to the data for uncontrolled filterable PM, TOC, and CO_2 emissions because the test runs were not conducted isokinetically. The report included adequate detail, the testing methodology was sound, and no problems were reported during the valid test runs. Data for the other pollutants were not rated and were not included in the AP-42 section.

4.2.1.6 Reference 6. This EMB-sponsored test was performed to establish source testing methodology for the asphalt roofing industry. No production rates were recorded during the testing, and the test data that were recorded were incomplete. Therefore, the test data could not be used for emission factor development.

4.2.1.7 Reference 7. This document summarizes emission test data from three tests performed at asphalt roofing plants. These tests were performed before the testing methodology for PM emissions from the asphalt roofing industry was developed. Emission factors were developed for CO emissions from blowing stills at two plants, measured before and after the afterburners that were used to control emissions at these plants. Additional data were presented in this document but were not used for emission factor development because of inadequate test methodology and the availability of data for similar sources from other references cited in this section.

A rating of C was assigned to the data for CO emissions. The document included some detail, the testing methodology was sound, and no problems were reported during the valid test runs. However, the data were downrated because they were not obtained from primary references.

4.2.1.8 Reference 8. This test measured VOC emissions from a simulated asphalt roofing kettle for installing built-up roofing. The data from this report were not included in the revised AP-42 section on asphalt roofing because they do not represent actual emissions from asphalt roofing manufacturing processes. However, they may give an indication of possible emissions from blowing stills or saturators. Emission measurements were made for 23 compounds using a modified volatile organic sampling train

TABLE 4-1. SUMMARY OF TEST DATA FOR ASPHALT ROOFING MANUFACTURING[a]

Source	Type of control	Pollutant	No. of test runs	Data rating	Emission factor range, kg/Mg (lb/ton)[a]	Average emission factor, kg/Mg (lb/ton)[a]	Ref. No.
Dip saturator, drying-in drum section, hot looper, and coater	None	Filterable PM	4	A	0.19-0.30 (0.37-0.60)	0.24 (0.47)	1
Dip saturator, drying-in drum section, hot looper, and coater	None	TOC	4	A	0.039-0.047 (0.078-0.094)	0.045 (0.089)	1
Dip saturator, drying-in drum section, hot looper, and coater	ESP	Filterable PM	4	A	0.0075-0.035 (0.012-0.070)	0.016 (0.032)	1
Dip saturator, drying-in drum section, hot looper, and coater	ESP	TOC	4	A	0.042-0.055 (0.083-0.11)	0.049 (0.098)	1
Dip saturator, drying-in drum section, and coater	None	Filterable PM	3	A	0.41-3.5 (0.81-7.0)	1.4 (2.8)	2
Dip saturator, drying-in drum section, and coater	None	TOC	3	A	0.040-0.050 (0.080-0.10)	0.047 (0.093)	2
Dip saturator, drying-in drum section, and coater	None	CO	2	A	0.0085-0.011 (0.017-0.022)	0.0095 (0.019)	2
Spray/dip saturator, drying-in drum section, looper, coater, and storage tanks	None	Filterable PM	2	A	1.5-1.7 (3.1-3.3)	1.6 (3.2)	3
Spray/dip saturator, drying-in drum section, looper, coater, and storage tanks	None	TOC	3	A	0.10-0.17 (0.19-0.33)	0.13 (0.26)	3

TABLE 4-1. (continued)

Source	Type of control	Pollutant	No. of test runs	Data rating	Emission factor range, kg/Mg (lb/ton)[a]	Average emission factor, kg/Mg (lb/ton)[a]	Ref. No.
Spray/dip saturator, drying-in drum section, looper, coater, and storage tanks	HEAF	Filterable PM	3	A	0.010-0.043 (0.020-0.086)	0.027 (0.053)	3
Spray/dip saturator, drying-in drum section, looper, coater, and storage tanks	HEAF	TOC	3	A	0.15-0.19 (0.29-0.37)	0.16 (0.32)	3
Dip saturator, drying-in drum section, and hot looper	None	Filterable PM	3	A	0.11-0.25 (0.22-0.49)	0.17 (0.33)	4
Dip saturator, drying-in drum section, and hot looper	HEAF	Filterable PM	3	A	0.032-0.038 (0.063-0.075)	0.035 (0.071)	4
Dip saturator, drying-in drum section, and hot looper	HEAF	TOC	3	A	0.046-0.048 (0.092-0.096)	0.047 (0.094)	4
Blowing stills: saturant asphalt	None	Filterable PM	3	C	2.4-4.3 (4.8-8.5)	3.3 (6.6)	5
Blowing stills: saturant asphalt	None	TOC	3	C	0.55-0.75 (1.1-1.5)	0.66 (1.3)	5
Blowing stills: saturant asphalt	Afterburner	Filterable PM	2	A	0.12-0.15 (0.24-0.30)	0.14 (0.27)	5
Blowing stills: saturant asphalt	Afterburner	TOC	2	A	0.0015-0.0028 (0.0030-0.0056)	0.0022 (0.0043)	5
Blowing stills: coating asphalt	None	Filterable PM	3	C	12-13 (24-26)	12 (24)	5
Blowing stills: coating asphalt	None	TOC	3	C	1.6-1.9 (3.2-3.8)	1.7 (3.4)	5
Blowing stills: coating asphalt	Afterburner	Filterable PM	3	A	0.31-0.50 (0.61-1.0)	0.41 (0.81)	5
Blowing stills: coating asphalt	Afterburner	TOC	3	A	0.026-0.14 (0.052-0.28)	0.085 (0.17)	5
Blowing stills	None	CO	3	C	0.00065-0.027 (0.0013-0.053)	0.011 (0.022)	7[b]
Blowing stills	Afterburner	CO	3	C	0.0021-0.70 (0.0042-1.4)	0.24 (0.47)	7[b]

TABLE 4-1. (continued)

Source	Type of control	Pollutant	No. of test runs	Data rating	Emission factor range, kg/Mg (lb/ton)[a]	Average emission factor, kg/Mg (lb/ton)[a]	Ref. No.
Blowing stills	None	CO	4	C	0.041-2.1 (0.082-4.1)	0.26 (0.52)	7[c]
Blowing stills	Afterburner	CO	4	C	0.34-7.5 (0.68-15)	3.5 (6.9)	7[c]

[a]Emission factors in units of kg/Mg (lb/ton) of shingles produced unless noted.
[b]Plant B. Emission factors in units of kg/Mg (lb/ton) of saturated felt produced.
[c]Plant C. Emission factors in units of kg/Mg (lb/ton) of saturated felt produced.

TABLE 4-2. SUMMARY OF EMISSION FACTORS FOR ASPHALT ROOFING MANUFACTURING[a]

Source	Type of control	Pollutant	No. of plants tested	Average emission factor, kg/Mg (lb/ton)	Emission factor rating	Ref. Nos.
Dip saturator, drying-in drum section, hot looper, and coater	None	Filterable PM	3	0.60 (1.2)	D	1,2,4
Dip saturator, drying-in drum section, hot looper, and coater	None	TOC	2	0.046 (0.091)	D	1,2
Dip saturator, drying-in drum section, hot looper, and coater	ESP	Filterable PM	1	0.016 (0.032)	D	1
Dip saturator, drying-in drum section, hot looper, and coater	ESP	TOC	1	0.049 (0.098)	D	1
Dip saturator, drying-in drum section, and coater	None	CO	1	0.0095 (0.019)	D	2
Spray/dip saturator, drying-in drum section, looper, coater, and storage tanks	None	Filterable PM	1	1.6 (3.2)	D	3
Spray/dip saturator, drying-in drum section, looper, coater, and storage tanks	None	TOC	1	0.13 (0.26)	D	3
Spray/dip saturator, drying-in drum section, looper, coater, and storage tanks	HEAF	Filterable PM	1	0.027 (0.053)	D	3
Spray/dip saturator, drying-in drum section, looper, coater, and storage tanks	HEAF	TOC	1	0.16 (0.32)	D	3
Dip saturator, drying-in drum section, and hot looper	HEAF	Filterable PM	1	0.035 (0.071)	D	4
Dip saturator, drying-in drum section, and hot looper	HEAF	TOC	1	0.047 (0.094)	D	4
Blowing stills: saturant asphalt	None	Filterable PM	1	3.3 (6.6)	E	5
Blowing stills: saturant asphalt	None	TOC	1	0.66 (1.3)	E	5
Blowing stills: saturant asphalt	Afterburner	Filterable PM	1	0.14 (0.27)	D	5
Blowing stills: saturant asphalt	Afterburner	TOC	1	0.0022 (0.0043)	D	5
Blowing stills: coating asphalt	None	Filterable PM	1	12 (24)	E	5

TABLE 4-2. (continued)

Source	Type of control	Pollutant	No. of plants tested	Average emission factor, kg/Mg (lb/ton)	Emission factor rating	Ref. Nos.
Blowing stills: coating asphalt	None	TOC	1	1.7 (3.4)	E	5
Blowing stills: coating asphalt	Afterburner	Filterable PM	1	0.41 (0.81)	D	5
Blowing stills: coating asphalt	Afterburner	TOC	1	0.085 (0.17)	D	5
Blowing stills	None	CO	2	0.14[b] (0.27)	E	7
Blowing stills	Afterburner	CO	2	1.9[b] (3.7)	E	7

[a]Emission factors in units of kg/Mg (lb/ton) of shingles produced unless noted.
[b]Emission factors in units of kg/Mg (lb/ton) of saturated felt produced.

TABLE 4-3. EMISSION FACTOR SUMMARY FOR ASPHALT KETTLES[a]

(Factors represent uncontrolled emissions unless otherwise noted)

Pollutant	Emission factor, kg/Mg (lb/ton) of asphalt lost (type 1 asphalt)[b]	Emission factor, kg/Mg (lb/ton) of asphalt lost (type 2 asphalt)[b]	Emission factor, kg/Mg (lb/ton) of asphalt lost (type 3 asphalt)[b]	Test data rating	Emission factor rating
Benzaldehyde	11 (22)	18 (36)	14 (28)	C	E
Benzene	8.4 (17)	2.1 (4.2)	26 (52)	A	D
Benzene, dimethyl	0.5 (1.0)	1.9 (3.8)	3.8 (7.6)	C	E
Benzene, methyl	2.8 (5.6)	5.2 (10)	8.7 (17)	C	E
Benzene, tetramethyl	5.0 (10)	2.3 (4.6)	0.60 (1.2)	C	E
Benzene, trimethyl	BDL	BDL	1.6 (3.2)	C	E
Decane	5.6 (11)	2.1 (4.2)	4.0 (8.0)	C	E
Dodecane	7.8 (16)	11 (22)	6.7 (13)	C	E
Ethanone, 1-phenyl	BDL	4.5 (9.0)	14 (28)	C	E
Heptadecane	BDL	3.1 (6.2)	BDL	C	E
Heptane	0.40 (0.80)	0.40 (0.80)	3.0 (6.0)	C	E
Hexadecane	4.1 (8.2)	10 (20)	BDL	C	E
Methane, dichloro	[c]	22 (44)	63 (130)	C	E
Naphthalene	BDL	0.80 (1.6)	1.8 (3.6)	C	E
Naphthalene, dimethyl	1.9 (3.8)	3.6 (7.2)	1.1 (2.2)	C	E
Naphthalene, trimethyl	1.2 (2.4)	5.4 (11)	BDL	C	E
Nonane	0.50 (1.0)	0.60 (1.2)	3.5 (7.0)	C	E
Octane	0.40 (0.80)	0.40 (0.80)	2.6 (5.2)	C	E
Pentadecane	5.8 (12)	4.1 (8.2)	2.7 (5.4)	C	E
Tetradecane	1.2 (2.4)	8.8 (18)	3.4 (6.8)	C	E
Tridecane	28 (56)	9.1 (18)	12 (24)	C	E
Undecane	3.4 (6.8)	8.5 (17)	6.7 (13)	C	E
Undecane, dimethyl	BDL	0.40 (0.80)	1.0 (2.0)	C	E

BDL = Below detection limit.
[a]Reference 8. Emission factors are calculated from the average of three pairs of VOST tubes.
[b]Types 1, 2, and 3 asphalt make up 90 percent of roofing asphalt.
[c]Sample was contaminated.

TABLE 4-4. TRACE METAL EMISSION FACTORS FOR ASPHALT ROOFING MANUFACTURING[a]

Pollutant	Afterburner inlet concentration (ppm)	Uncontrolled emission factor, lb x 10^{-6}/ton of asphalt lost	Afterburner outlet concentration (ppm)	Controlled emission factor, lb x 10^{-6}/ton, of asphalt lost	Storage tank outlet concentration (ppm)	Storage tank: uncontrolled emission factor lb x 10^{-6}/ton of asphalt
Beryllium	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium	6.5	5.3	303	29	BDL	BDL
Arsenic	BDL	BDL	BDL	BDL	BDL	BDL
Vanadium	11	8.9	192	18	2	0.19
Manganese	55	45	530	50	24	2.3
Nickel	135	110	30,410	2,900	53	5.0
Antimony	BDL	BDL	BDL	BDL	BDL	BDL
Chromium	26.5	21	5,073	481	16	1.5
Zinc	707.5	570	1,310	120	39	3.7
Copper	92	75	2,580	240	7	0.66
Lead	47	38	69	6.5	BDL	BDL
Boron	1,033	840	2,620	248	115	11
Lithium	113	92	845	80	10	0.95
Silver	BDL	BDL	81	7.7	6	0.57
Selenium	910	740	345	33	131	12
Iron	365	300	16,690	1,600	95	9.0
Strontium	6	4.9	72	6.8	BDL	BDL
Sodium	670	540	11,600	1,100	140	13
Potassium	BDL	BDL	BDL	BDL	BDL	BDL
Calcium	BDL	BDL	BDL	BDL	BDL	BDL
Silicon	BDL	BDL	BDL	BDL	BDL	BDL
Magnesium	BDL	BDL	BDL	BDL	BDL	BDL
Barium	148	120	660	63	152	14

[a]Reference 2. Data are based on a single test run at each sampling point and therefore are not rated.
BDL = below detection limit.

(VOST). Three different types of asphalt were tested during the program, and emission factors were developed for each type. All of the emission factors represent uncontrolled emissions.

A rating of A was assigned to benzene data because the VOST has been validated for this compound (See Reference 10). All other pollutants were rated C since the VOST has not been validated for these pollutants. The report included adequate detail, and no problems were reported during the valid test runs.

4.2.2 Review of XATEF and SPECIATE Data Base Emission Factors

The XATEF and SPECIATE data bases were searched for emission factors pertaining to asphalt roofing manufacturing. Although emission factors for asphalt roofing manufacturing were presented in both data bases, the references for the emission factors contained only surrogate data and were not suitable for inclusion in AP-42.

4.2.3 Review of Test Data in AP-42 Background File[1,2]

All of the references cited in the existing AP-42 section were reviewed, and the data from these references are presented in the preceding sections of this document and in Tables 4-1 and 4-2.

4.2.4 Results of Data Analysis

The data from References 1 through 5, and 7 are shown in Table 4-1. These data were used to develop new emission factors (shown in Table 4-2) for uncontrolled and controlled emissions of filterable PM, TOC and CO from several different processes and control devices associated with asphalt roofing manufacturing. Emission factors were developed for uncontrolled VOC emissions from asphalt kettles (heating process), as shown in Table 4-3, but these emission factors were not presented in the revised AP-42 section because they do not represent actual emissions from asphalt roofing manufacturing processes. Table 4-4 presents emission factors for trace metal emissions from a combination of sources including a dip saturator, wet looper, coater, and asphalt storage tanks. These trace metal emission factors were developed from data from a single test run (Reference 2) and are not rated or included in the revised AP-42 section.

The emission factors from the existing section are currently rated A for PM and D for CO and TOC. The new filterable PM emission factors were rated D because the data came from a small number of plants and may not represent a random sample for the industry.

REFERENCES FOR SECTION 4

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3. *Air Pollution Emission Test, Celotex Corporation, Los Angeles, California*, EMB Report No. 75-ARM-8, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1976.

4. *Air Pollution Emission Test, Johns Manville Corporation, Waukegan, Illinois*, EMB Report No. 76-ARM-13, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1976.

5. *Air Pollution Emission Test, Elk Roofing Company, Stephens, Arkansas*, EMB Report No. 76-ARM-11, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1977.

6. *Air Pollution Emission Test, Source Testing Methodology for the Asphalt Roofing Industry, Celotex Corporation, Cincinnati, Ohio*, EMB Report No. 75-ARM-10, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1977.

7. *Atmospheric Emissions from Asphalt Roofing Processes*, EPA Contract No. 68-02-1321, Pedco Environmental, Cincinnati, OH, October 1974.

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10. Fuerst, R.G., T.J. Logan, M.R. Midgett et al., "Validation Studies of the Protocol for the Volatile Organic Sampling Train," *JAPCA* 37(4):388 (1987).

5. AP-42 SECTION 11.2

AP-42 Section 11.2 can be downloaded from the CHIEF Web site at http://www.epa.gov/ttn/chief/.