Emission Factor Documentation for AP-42 Section 9.10.2

Salted and Roasted Nuts and Seeds

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-08

MRI Project No. 4601-08

May, 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

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Emission Factor and Methodologies

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NOTICE

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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. 005 and I-08. The EPA work assignment manager for this project is Mr. Dallas Safriet.

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May 17, 1994

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SECTION 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 issued 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 emission factors reported in AP-42 are used by air pollution professionals for widely varied purposes that include:

1. Estimating areawide emissions;

2. Estimating emissions for a specific facility; and

3. Evaluating emissions relative to ambient air quality.

This emission factor documentation report supports the creation of a new AP-42 Section 9.10.2, Salted and Roasted Nuts and Seeds. The intent of this section is to address air emissions from all operations associated with nut meat production from post harvest processing of the raw nuts through finished roasted and salted nut products. The section will not address processing of other nut products such as oils and peanut butter. While the intent is ultimately to provide complete coverage of the industry, quantified air emissions data related to the processing of nuts and seeds are currently limited to almond post-harvest processing, so that is the primary focus of this document. However, as additional air emissions data become available, both on further aspects of almond processing such as almond shelling and roasting, and on processing of other nuts, Section 9.10.2 will be expanded. Therefore, this background report includes a discussion of the peanut industry and a description of peanut processing, as well as the almond industry and almond processing, in anticipation of future expansion of the AP-42 section to include emission factors for peanut processing.

This background report contains five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the salted and roasted nut industry. It includes a characterization of the industry, an overview of the different processes, a description of emissions, and a description of the technology used to control emissions resulting from nut processing. Section 3 is a review of process/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 emission factor development for almond processing operations. Section 5 presents the proposed AP-42 Section 9.10.2, Salted and Roasted Nuts and Seeds. Original data are presented in the Appendix.

SECTION 2

INDUSTRY DESCRIPTION

This section gives a brief review of trends in the peanut and almond industries. The processes of peanut harvesting, processing, shelling, and roasting, as well as almond harvesting, hulling, shelling, and processing, are described. The remainder of the section and also of the report deals only with almond processing, since reliable emissions data are available only for this aspect of the industry. Sources of particulate matter (PM) and other emissions from almond processing are discussed and a brief description of emission control technology is given.

2.1 INDUSTRY CHARACTERIZATION[1-4]

The overall production of finished salted and roasted nuts and seeds has two primary components. Typically nuts undergo post harvest processing such as hulling and shelling either on the farm or at contract facilities on or near the farm that are classified as crop preparation services facilities (SIC 0723). The salted and roasted nuts and seeds industry (SIC 2068) primarily includes establishments that manufacture salted, roasted, dried, cooked, or canned nuts or that similarly process grains and seeds for snack use. Establishments primarily manufacturing candy-coated nuts are classified in industry 2064, and those manufacturing peanut butter are classified in industry 2099. These latter operations are not addressed in this section. A single SCC, 3-02-017-99, has been assigned for peanut processing. No SCC's have been assigned to specific peanut processing operations. Seven SCC's have been assigned to almond processing operations, including; (1) 3-02-017-11 (unloading of almonds to receiving pit), (2) 3-02-017-12 (precleaning of orchard debris from almonds), (3) 3-02-017-13 (hull removal and separation from in-shell almonds), (4) 3-02-017-14 (hulling and shelling of almonds), (5) 3-02-017-15 (classifier screen deck), (6) 3-02-017-16 (air leg), and (7) 3-02-017-17 (almond roaster--direct-fired rotating drum). Table 2-1 shows the number of salted and roasted nuts and seeds plants in the United States by State in 1987.

2.1.1 The Peanut Industry

Peanuts are cleaned and cured (dried) at mills (SIC 0723) located in peanut producing regions. Peanut wholesalers (SIC 5159) market unprocessed or shelled peanuts to salted and roasted nuts and seeds processors (SIC 2068), candy manufacturers (SIC 2064), peanut butter manufacturers (SIC 2099), and peanut oil mills (SIC 2076).

Peanuts are a popular food item in the United States. Unlike other nations that use peanuts primarily for oil production, the United States processes a significant proportion of peanuts into peanut butter and whole salted and roasted nuts. In 1988, approximately 40 percent of U.S. peanut consumption was in the form of edible peanuts (peanut butter, salted and roasted peanuts, and peanut candy). Peanut oil and by-products are also used in a variety of industrial products such as paints, lubricants, and soaps. Peanut shells can be used in abrasives, and furfural, xylose, cellulose, and

TABLE 2-1. NUMBER OF SALTED AND ROASTED NUTS AND SEEDS PLANTS IN THE UNITED STATES BY STATE, 1987

State	Number of plants
Alabama	3
Arkansas	1
California	15
Georgia	8
Hawaii	1
Illinois	6
Massachusetts	3
Minnesota	5
North Carolina	6
Ohio	5
Pennsylvania	4
Texas	5
Virginia	5

Source: Reference 3.

mucilage can be derived from peanut shells. Peanut meal, the crushed peanut solids remaining after oil extraction, is used as an animal feed and fertilizer.

Peanuts are produced on farms largely in the Southeast and Mid-South regions of the nation. Table 2-2 shows the leading peanut producing States.

2.1.2 The Almond Industry

The United States produces approximately 71 percent of all almonds grown for the world market. Almond growers and processors within the United States are located almost exclusively in California. The industry includes facilities involved in post harvest processing operations (SIC 0723) and finished nut production (SIC 2068).

The U.S. consumption of nuts has been increasing. Between 1980 and 1988, per capita consumption of nuts rose from 0.83 kg to 1.14 kg (1.83 lb to 2.51 lb). Production of almonds has increased with the rising consumption of nuts in general. The 1990 season in California had 297,900 megagrams (Mg) (656.2 million lb) of almonds produced on 166,300 hectares (411,000 acres) compared to 146,100 Mg (321.8 million lb) of almonds produced on 131,500 hectares (325,000 acres) 10 years earlier. Although over 41 varieties of almonds are produced in the United States, 7 varieties

TABLE 2-2. LEADING PEANUT PRODUCING STATES, 1988 ACREAGE AND PRODUCTION DATA

State	Area cultivated, hectares (acres)	Peanut production, Megagrams (tons)
Georgia	257,000 (635,000)	839,000 (925,000)
Alabama	97,000 (240,000)	244,000 (269,000)
North Carolina	63,000 (155,000)	191,000 (210,000)
Texas	107,000 (265,000)	190,000 (209,000)
Virginia	37,000 (92,000)	120,000 (132,000)
Florida	40,000 (98,000)	103,000 (114,000)
Oklahoma	40,000 (99,000)	103,000 (113,000)
South Carolina	5,300 (13,000)	15,000 (16,000)
New Mexico	5,400 (13,400)	14,000 (15,000)

Source: *Agricultural Statistics 1990*, USDA, National Agricultural Statistics Service: Washington, DC, 1990; Table 160, page 118.

(Carmel, Merced, Ne Plus Ultra, Nonpareil, Peerless, Price Cluster, and Texas/Mission) make up 90 percent of the almonds produced.

2.2 PROCESS DESCRIPTION[5-7,11-13]

The production and processing of peanuts and almonds are described in the following subsections.

2.2.1 Peanut Harvesting and Processing[5]

2.2.1.1 Growing and Harvesting—

Peanuts (also known as groundnuts or goobers, *Arachis hypogaea*) are an annual leguminous herb native to South America. The peanut peduncle or peg (the stalk that holds the flower) elongates after flower fertilization and bends down into the ground where the peanut seed matures. Peanuts have a growing period of approximately 5 months; seeding typically occurs in mid-April to mid-May, and harvesting during August in the United States.

Light, sandy loam soils are preferred for peanut production. Moderate rainfall of between 51 and 102 centimeters (cm) (20 and 40 inches [in.]) annually is also necessary. The leading peanut producing States are Georgia, Alabama, North Carolina, Texas, Virginia, Florida, and Oklahoma.

Harvesting typically begins with the mowing of peanut vines. Then the peanut plants are inverted using specialized machines, peanut inverters, that dig, shake, and place the peanut plants (inverted with the peanut pods on top of the plant) into windrows for field curing. The inverted peanuts are allowed to mature and dry before harvesting. Mature peanuts are picked up from the windrow with combines that separate the peanut pods from the plant using various thrashing operations. The peanut plants are deposited back onto the fields and the pods are accumulated in hoppers. Peanuts are also harvested without field curing by using combines that dig and separate the vines and stems from the peanut pods in one step. Peanuts harvested by this method are cured in storage. Some small producers use traditional harvesting methods in which the plants are plowed from the ground and manually stacked onto wires supported by poles for field curing.

Harvesting is normally followed by mechanical drying. Moisture in peanuts is usually kept below 12 percent to prevent aflatoxin molds from growing. This low moisture content is difficult to achieve under normal field conditions without overdrying vines and stems which reduces combine efficiency (less foreign material is separated from the pods). On-farm dryers usually consist of storage trailers with air channels along the floor or storage bins with air vents. Fans blow heated air (approximately 35°C [95°F]) through the air channels and up through the peanuts. Peanuts are dried to moistures of roughly 7 to 10 percent.

Peanuts from the farm are processed at local peanut mills that further cure (if necessary), clean, store, and process the peanuts for various uses (oil production, roasting, peanut butter production, etc.). Major processes include processing peanuts for in-shell consumption and shelling peanuts for other uses. In-shell processing and shelling are described further.

2.2.1.2 In-Shell Processing—

Some peanuts are processed for in-shell roasting. Figure 2-1 presents a typical flow diagram for in-shell peanut processing. Processing begins with separating foreign material (primarily soil, vines, stems, and leaves) from the peanut pods using a series of screens and blowers. The pods are then washed in wet, coarse sand that removes stains and discoloration. The sand is screened from the peanuts for reuse. The nuts are then dried and powdered with talc or kaolin to whiten the shells. Excess talc/kaolin is shaken from the peanut shells.

2.2.1.3 Shelling—

A typical shelled peanut processing flow diagram is shown in Figure 2-2. Shelling begins with separating the foreign material using a series of screens, blowers, and magnets. The cleaned peanuts are then sized using screens (size graders) to separate desired sizes. Sizing is required so that peanut pods can be crushed without also crushing the peanut kernels.

Next, the shells of the sized peanuts are typically crushed by passing the peanuts between rollers that have been adjusted for peanut size. The gap between rollers must be narrow enough to crack the peanut hulls, but wide enough to prevent damage to the kernels. A horizontal drum with a perforated and ridged bottom and rotating beater is also used to hull peanuts. The rotating beater crushes the peanuts against the bottom ridges pushing both the shells and peanuts through the perforations. The beater is adjusted for different sizes of peanuts to avoid damaging the peanut kernels. Shells are aspirated from the peanut kernels as they fall from the drum. The crushed shells

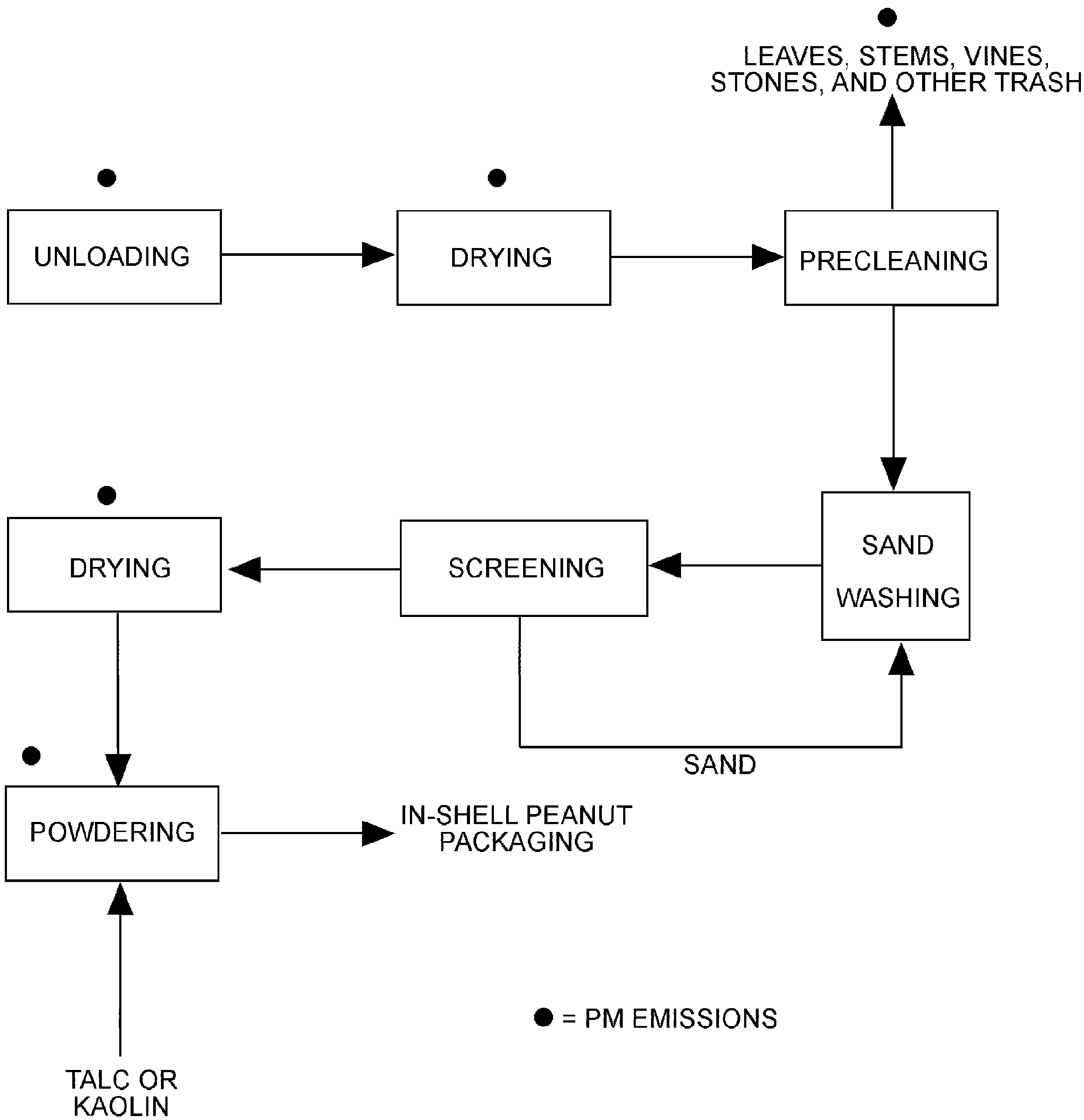

Figure 2-1. Typical in-shell peanut processing flow diagram.

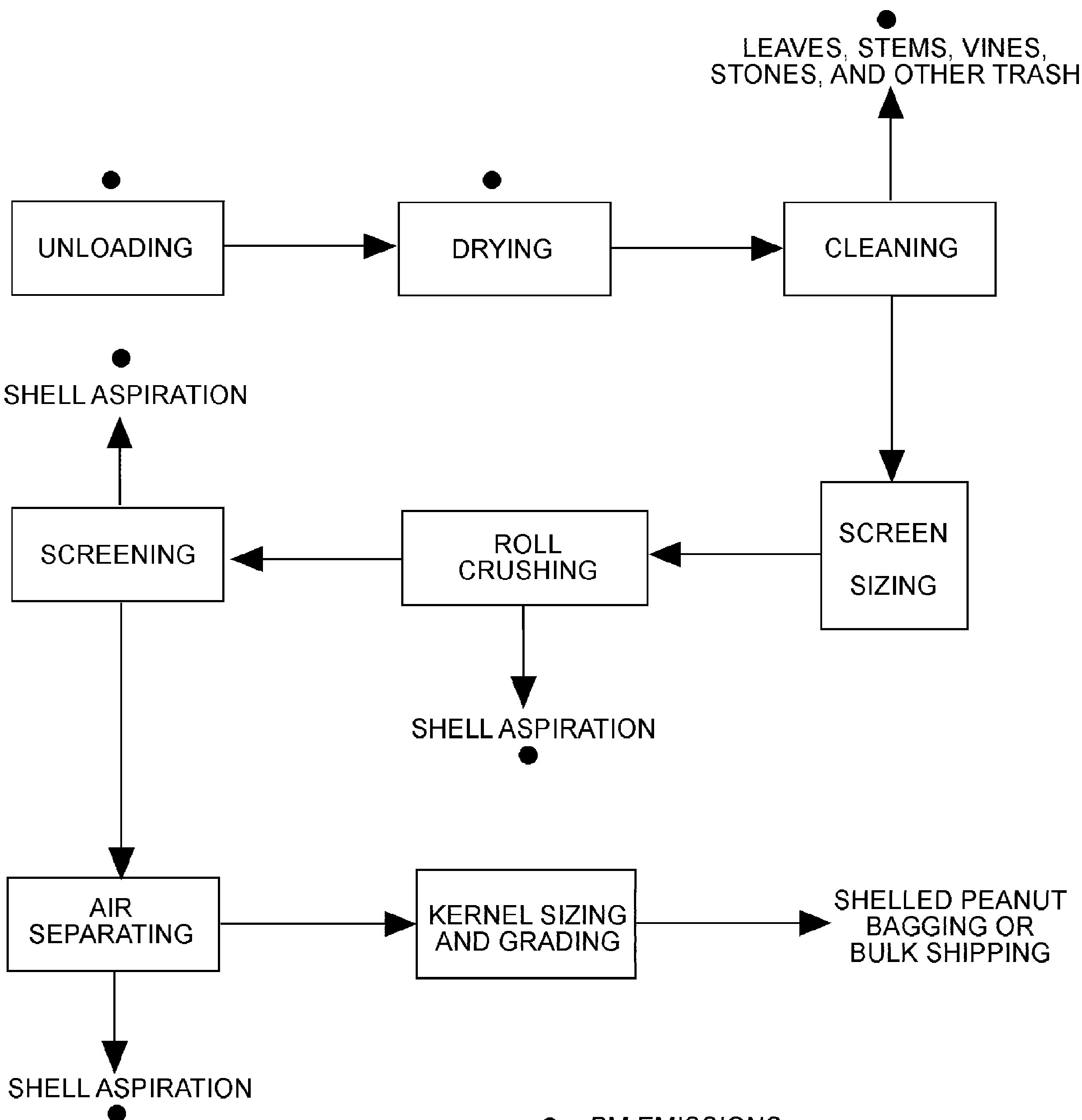

Figure 2-2. Typical shelled peanut processing flow diagram.

and peanut kernels are then separated using oscillating shaker screens and air separators. The separation process also removes undersized kernels and split kernels.

Following crushing and hull/kernel separation, peanut kernels are sized and graded. Sizing and grading can be done by hand, but most mills use screens to size kernels and electric eye sorters for grading. Electric eye sorters detect discoloration and separate peanuts by color grades. The sized and graded peanuts are bagged in 45.4-kg (100-lb) bags for shipment to end users, such as peanut butter plants and nut roasters. Some peanuts are shipped in bulk in rail hopper cars.

2.2.1.4 Roasting—

Roasting imparts the typical "peanut" flavor many people associate with peanuts. During roasting, amino acids and carbohydrates react to produce tetrahydrofuran derivatives. Roasting also further dries the peanuts and causes them to turn brown as a result of peanut oil staining the peanut cell walls. Following roasting, peanuts are prepared for packaging or for further processing into candies or peanut butter. Typical peanut roasting processes are shown in Figure 2-3.

There are two primary methods for roasting peanuts: dry roasting and oil roasting.

Dry roasting—Dry roasting is done on either a batch or continuous basis. Batch roasters offer the advantage of adjusting for differences in moisture content of different peanut lots from storage. Batch roasters are typically natural gas-fired, revolving ovens (drum-shaped). The rotation of the oven continuously stirs the peanuts to produce an even roast. Oven temperatures are approximately 430°C (800°F), and peanut temperature is raised to approximately 160°C (320°F) for 40 to 60 min. Actual roasting temperatures and times vary depending on the condition of the peanut batch and the desired end characteristics.

Continuous dry roasters vary considerably. Continuous roasting reduces labor, ensures a steady flow of peanuts for other processes (packaging, candy production, peanut butter production, etc.), and decreases spillage. Continuous roasters move peanuts through an oven on a conveyor or by gravity feed. In one type of roaster, peanuts are fed by a conveyor into a stream of countercurrent, hot air that roasts the peanuts. The peanuts are agitated in this system to ensure air passes around the individual kernels to promote an even roast.

Dry roasted peanuts are cooled and blanched. Cooling occurs in cooling boxes or on conveyors that blow large quantities of air over the peanuts immediately following roasting. Cooling is necessary to stop the roasting process in the peanuts so that a uniform quality is achieved. Blanching removes the skin of the peanut as well as dust, molds, and other foreign material. There are several blanching methods including dry, water, spin, and air impact.

Dry blanching is primarily used in peanut butter production because it removes the kernel heart which is typically not desired in peanut butter due to flavor. Dry blanching heats the peanuts to a temperature of approximately 138°C (280°F) for 25 min to crack and loosen the skins. The heated peanuts are then cooled and passed through either brushes or ribbed rubber belting to rub off the skins. Screening is used to separate the hearts from the cotyledons.

Water blanching passes the peanuts on conveyors past stationary blades that slit the peanut skins. The skins are then loosened with hot water sprayers and removed by passing the peanuts under oscillating canvas-covered pads on knobbed conveyor belts. Water blanching requires drying the peanuts to a moisture content of 6 to 12 percent.

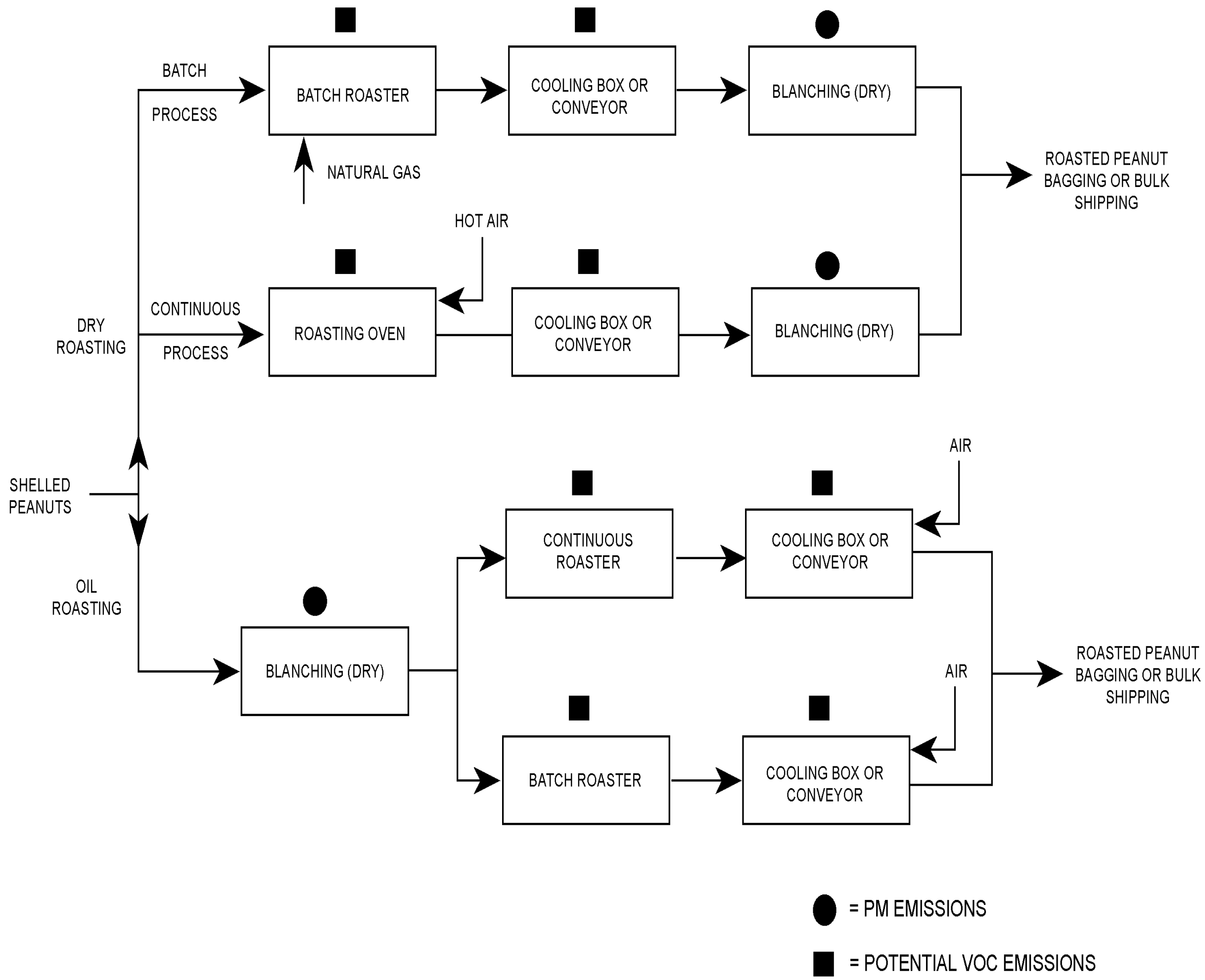

Figure 2-3. Typical shelled peanut roasting processing flow diagram.

Spin blanching loosens the skins of the peanuts with steam. Steaming is followed by spinning the peanuts on revolving spindles as the peanuts move single file down a grooved conveyor. The spinning unwraps the peanut skins.

Air impact blanching uses a horizontal drum (cylinder) in which the peanuts are placed and rotated. The inner surface of the drum has an abrasive surface that aids in the removal of the skins as the drum rotates. Inside the drum are air jets that blow the peanuts counter to the rotation of the drum creating air impact which loosens the skin. The combination of air impacts and the abrasive surface of the drum results in skin removal. Air impact blanching can be conducted on either a batch or continuous basis.

Oil roasting—Oil roasting is also done on a batch or continuous basis. Before roasting, the peanuts are blanched to remove the skins. Continuous roasters move the peanuts through a long tank of heated oil on a conveyor. In both batch and continuous roasters, oil is heated to temperatures of approximately 138° to 143°C (280° to 290°F), and roasting times vary from 3 to 10 min depending on desired characteristics and peanut quality. Oil roasters have heating elements on the sides of the roasting tank to prevent charring of the peanuts on the bottom. Oil is constantly monitored for quality and frequent filtration, neutralization, and replacement is necessary to maintain quality. Coconut oil is preferred, but other oils such as peanut and cottonseed are frequently used.

Cooling also follows oil roasting so that a uniform roast can be achieved. Cooling is achieved by blowing large quantities of air over the peanuts on either conveyors or in cooling boxes.

2.2.2 Almond Processing[6,7,11-13]

After almonds are collected from the field they undergo two processing phases, post-harvest processing and finish processing. These phases are typically conducted at two different facilities. There are two basic types of almond post-harvest processing facilities: those that produce hulled, in-shell almonds as a final product (known as hullers), and those that produce hulled, shelled, almond meats as a final product (known as huller/shellers). Almond precleaning, hulling, and separating operations are common to both types of facilities. The huller/sheller includes additional steps to remove the almond meats from their shells. A typical almond hulling operation is shown in Figure 2-4. A typical almond huller/sheller is depicted in Figure 2-5. The hulled, shelled almond meats are shipped to large production facilities where the almonds may undergo further processing into various end products. Almond harvesting, along with precleaning, hulling, shelling, separating, and final processing operations are discussed in more detail in the following paragraphs.

Almond harvesting and processing is a seasonal industry, typically beginning in August and running from two to four months. However, the beginning and duration of the season varies with the weather and with the size of the crop. The almonds are harvested either manually by knocking the nuts from the tree limbs with a long pole or mechanically by shaking them from the tree. Typically the almonds remain on the ground for 7 to 10 days to dry. The fallen almonds are then swept into rows. Mechanical pickers gather the rows for transport to the almond huller or huller/sheller. Some portion of the material in the gathered rows includes orchard debris, such as leaves, grass, twigs, pebbles, and soil. The fraction of debris is a function of farming practices (tilled versus untilled), field soil characteristics, and age of the orchard, and it can range from less than 5 to 60 percent of the material collected. Average debris fractions of 12 to 14 to approximately 25 percent have been reported, but the farm-to-farm variability within a region is so large, that the average has little meaning for a particular facility.

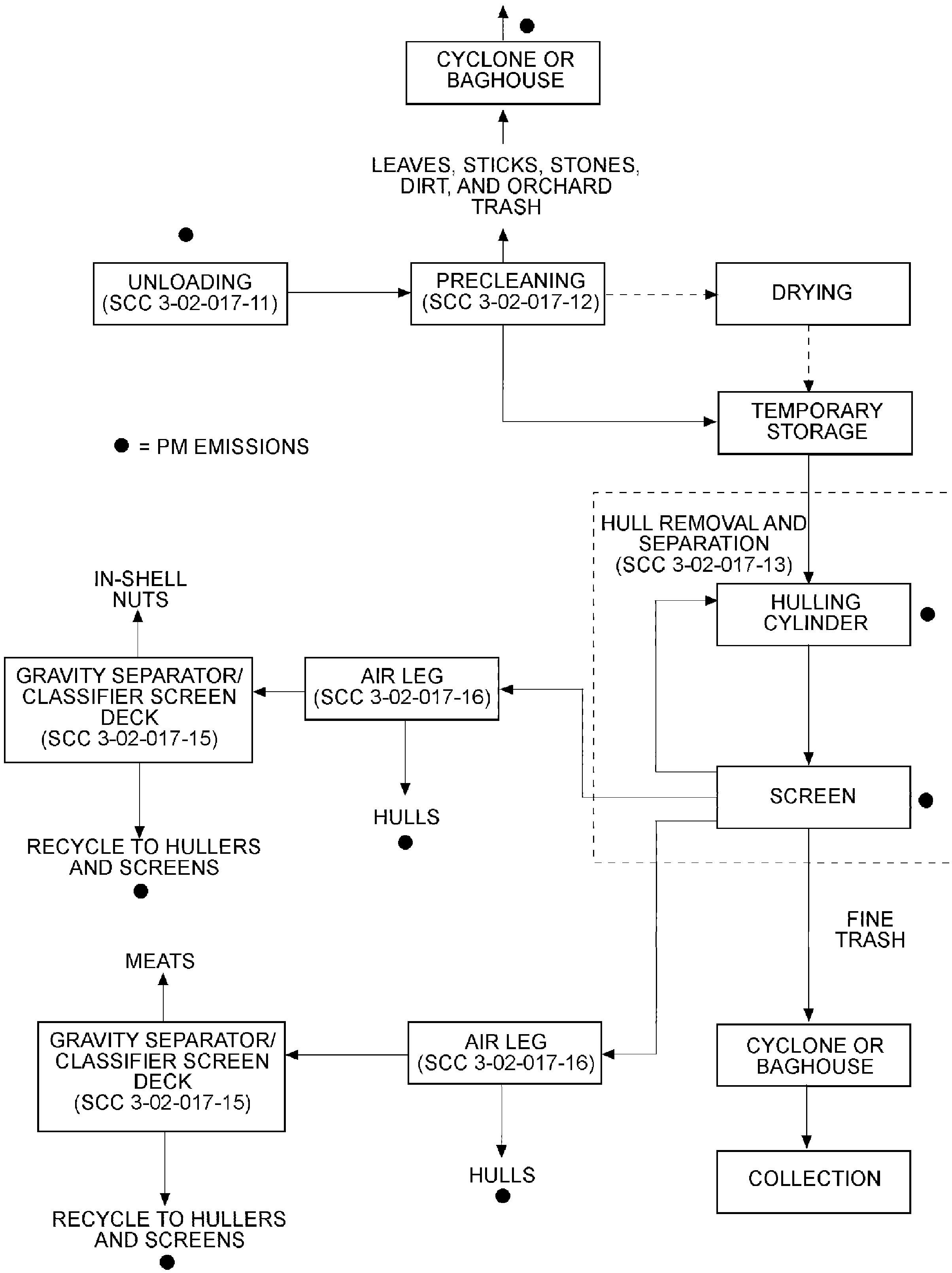

Figure 2-4. Representative almond hulling process flow diagram.

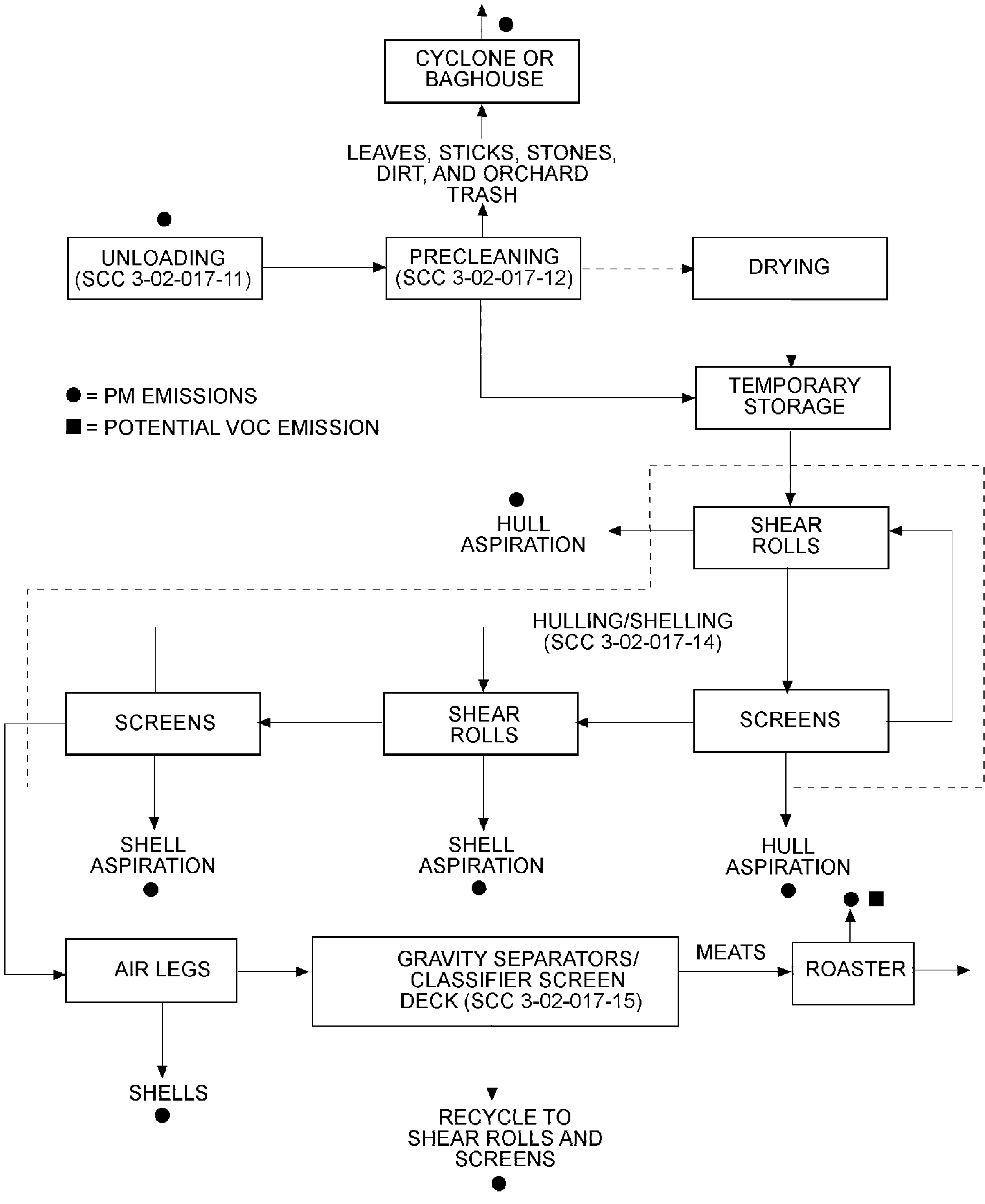

Figure 2-5. Representative almond huller/sheller process flow diagram.

The almonds are delivered to the processing facility and are dumped into a receiving pit. The almonds are conveyed by screw conveyors and bucket elevators to a series of vibrating screens. The screens selectively remove orchard debris including leaves, soil, and pebbles. A destoner removes stones, dirt clods, and other larger debris. A detwigger removes twigs and small sticks. The air streams from the various screens, destoners, and detwiggers are ducted to cyclones or baghouses for particulate matter removal. The recovered soil and fine debris such as leaves and grass is disposed by spreading on surrounding farmland. The recovered twigs may be chipped and used as fuel for co-generation plants. The precleaned almonds are transferred from the precleaner area by another series of conveyors and elevators to storage bins to await further processing. (In some instances, the precleaned almonds may be conveyed to a dryer prior to storage. However, field drying is used in most operations.)

Almonds are conveyed on belt and bucket conveyors to a series of hulling cylinders or shear rolls which crack the almond hulls. Hulling cylinders are typically used in almond huller facilities. Series of shear rolls are generally used in huller/shellers. The hulling cylinders have no integral provision for aspiration of shell pieces. Shear rolls, on the other hand, do have integral aspiration to remove shell fragments from loose hulls and almond meats. The cracked almonds are then discharged to a series of vibrating screens or a gravity table which separates the hulls and unhulled almonds from the in-shell almonds, almond meats, and fine trash. The remaining unhulled almonds pass through additional hulling cylinders or shear rolls and screen separators. The number of passes and the combinations of equipment vary among facilities. The hulls are conveyed to storage for sale as an ingredient in the manufacture of cattle feed. The fine trash is ducted to a cyclone or baghouse for collection and disposal.

In the case of the hulling facility, the hulled, in-shell almonds are separated from any remaining hull pieces in a series of air legs and are then graded, collected, and sold as finished product, along with the inevitable small percentage of almond meats. In the case of the huller/sheller, the in-shell almonds continue through more shear rolls and screen separators.

As the in-shell almonds make additional passes through sets of shear rolls, the almond shells are cracked or sheared away from the meat. More sets of vibrating screens separate the shells from the meats and small shell pieces. The separated shells are aspirated and collected in a fabric filter or cyclone and then conveyed to storage for sale as fuel for co-generation plants. The almond meats and small shell pieces are conveyed on vibrating conveyor belts and bucket elevators to air classifiers and air legs (a counter-flow forced air gravity separator) that separate the small shell pieces from the meats. The number of these air separators varies among facilities. The shell pieces removed by these air classifiers are also collected and stored for sale as fuel for co-generation plants. The revenues generated from the sale of hulls and shells are generally sufficient to offset the costs of operating the almond processing facility.

The almond meats are then conveyed to a series of gravity tables or separators which sort the meats by lights, middlings, goods, and heavies. Lights, middlings, and heavies, which still contain hulls and shells, are returned to various points in the process. Goods are conveyed to the finished meats box for storage. Any remaining shell pieces are aspirated and sent to shell storage.

The almond meats are now ready for either sales as raw product or for further processing, typically at a separate facility. The meats may be blanched, sliced, diced, roasted, salted, or smoked. Small meat pieces may be ground into meal or pastes for bakery products. Almonds are roasted by gradual heating in a rotating drum. They are heated slowly to prevent the skins and outer layers from burning. The roasting develops a flavor which corresponds with a color change in the meats. To obtain almonds with a light brown color and a medium roast requires a 500-pound roaster fueled with natural gas about 1.25 hours at 118°C (245°F).

2.3 EMISSIONS[7,9-13]

Particulate matter (PM) is the primary air pollutant emitted from almond post harvest processing operations. All operations in an almond processing facility involve dust generation from the movement of trash, hulls, shells, and meats. The quantity of PM emissions varies depending on the type of facility, harvest method, trash content, climate, production rate, and the type and number of controls used by the facility. Fugitive PM emissions are attributable primarily to unloading operations, but some fugitive emissions are generated from precleaning operations and subsequent screening operations.

Because products collected during harvest typically contain some residual dirt, which includes trace amounts of metals, it stands to reason that some amount of these metals will be emitted along with the dust from the various operations. California Air Resources Board (CARB) data indicate that metals emitted from almond processing include arsenic, beryllium, cadmium, copper, lead, manganese, mercury, and nickel in quantities on the order of 5×10^{-11} to 5×10^{-4} kilograms (kg) of metal per kg of PM emissions (5×10^{-11} to 5×10^{-4} pounds [lb] of metal per lb of PM emissions). It has been suggested that other sources of these metals other than the inherent trace metal content of soil may include fertilizers, other agricultural sprays, and groundwater.

In the final processing operations, almond roasting is a potential source of volatile organic compound (VOC) emissions. However, no chemical characterization data are available to hypothesize what compounds might be emitted, and no emission source test data are available to quantify these potential emissions.

No information is currently available on emissions or emission control devices for the peanut processing industry. However, due to the similarities of some of the processes with those in the almond processing industry it is reasonable to assume that the types of emissions would be comparable. No data are available, however, to make any comparison as to the relative quantities of these emissions.

2.4 EMISSION CONTROL TECHNOLOGY[7,9-13]

Emission control systems at almond post harvest processing facilities include ventilation systems to capture the dust generated during handling and processing of almonds, shells, and hulls, and an air pollution control device to collect the captured PM. Cyclones formerly served as the principal air pollution control devices for PM emissions from almond post harvest processing operations. However, fabric filters or a combination of fabric filters and cyclones are becoming common. Practices of combining and controlling specific exhaust streams from various operations vary considerably among facilities. The exhaust stream from a single operation may be split and ducted to two or more control devices. Conversely, exhaust streams from several operations may be combined and ducted to a single control device. According to one source within the almond processing industry, out of approximately 350 almond hullers and huller/shellers, no two are alike.

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10. Private communication. Wendy Eckley of Eckley Engineering, Fresno, CA, with Lance Henning, Midwest Research Institute, August-September 1992, March 1993.

11. Written communication from Darin Lundquist, Manager, Central California Almond Growers Association, to Dallas Safriet, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 9, 1993.

12. Written communication from Jim Ryals, Manager, Almond Hullers and Processors Association, to Dallas Safriet, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 7, 1993.

13. Written communication from Wendy Eckley, Eckley Engineering, to Dallas Safriet, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 7, 1993.

SECTION 3

GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

This section describes the literature search to collect emissions data and the EPA quality rating systems applied to data and to any emissions factors developed from those data.

3.1 LITERATURE SEARCH AND SCREENING

A literature search was performed to collect pertinent emissions data for operations associated with almond processing. This search produced source test reports and background documents found in Emission Inventory Branch (EIB) files, reports located in the U.S. Department of Agriculture Library, documents listed in "Dialog Information Services," and data base searches on Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF), VOC/PM Speciation Data Base Management System (SPECIATE), and the Air CHIEF CD-ROM.

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 or traceable to facility-specific test data:
   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. Generally, the referenced study must contain test results based on multiple test runs. However, in the absence of other data, single-run tests are used if all other aspects of the test are deemed acceptable.
3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions.

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 DATA QUALITY RATING SYSTEM[1]

Based on OAQPS guidelines, the following data are always excluded from consideration in developing AP-42 emission factors:

1. Test series averages reported in units that cannot be converted to the selected reporting units;

2. Test series representing incompatible test methods; and

3. Test series in which the production and control processes are not clearly identified and described.

If there is no reason to exclude a particular data set, data are assigned a quality rating based on an A to D scale specified by OAQPS as follows:

A—This rating requires that multiple tests be performed on the same source using sound methodology and reported in enough detail for adequate validation. Tests do not necessarily have to conform to the methodology specified by EPA reference test methods, although such methods are used as guides.

B—This rating is given to tests performed by a generally sound methodology but lacking enough detail for adequate validation.

C—This rating is given to tests that are based on an untested or new methodology or that lack a significant amount of background data.

D—This rating is given to tests that are based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

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

1. <u>Source operation.</u> The manner in which the source was operated should be well documented in the report, and the source should be operating within typical parameters during the test.

2. <u>Sampling procedures.</u> The sampling procedures should conform to a generally accepted methodology. If actual procedures deviate from accepted methods, the deviations must be well documented. When this occurs, an evaluation should be made of how such alternative procedures could influence the test results.

3. <u>Sampling and process data.</u> Adequate sampling and process data should be documented in the report. Many variations can occur without warning during testing and sometimes without being noticed. Such variations can induce wide deviations in sampling results. 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 should contain original raw data sheets. The nomenclature and equations used are compared to those specified by EPA (if any) to establish equivalency. The depth of review of the calculations is dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn is based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM[1]

EPA guidelines specify that the quality of the emission factors developed from analysis of the test data be rated utilizing the following general criteria:

A—Excellent: The emission factor was developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category was specific enough to minimize variability within the source category population.

B—Above average: The emission factor was developed only from A-rated test data from a reasonable number of facilities. Although no specific bias was evident, it was not clear if the facilities tested represented a random sample of the industries. As in the A-rating, the source category was specific enough to minimize variability within the source category population.

C—Average: The emission factor was developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias was evident, it was not clear if the facilities tested represented a random sample of the industry. As in the A-rating, the source category was specific enough to minimize variability within the source category population.

D—Below average: The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there was reason to suspect that these facilities did 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 footnoted in the emission factor table.

E—Poor: The emission factor was developed from C- and D-rated test data, and there was reason to suspect that the facilities tested did 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 footnoted.

The use of the above criteria is somewhat subjective depending to a large extent on the individual reviewer. Details of how each candidate emission factor was rated are provided in Section 4.

REFERENCE FOR SECTION 3

1. *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*, Draft, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 6, 1992.

SECTION 4

POLLUTANT EMISSION FACTOR DEVELOPMENT

This section describes the test data and methodology used to develop pollutant emission factors for almond processing operations.

4.1 REVIEW OF SPECIFIC DATA SETS

Eleven reports of air emissions testing at almond processing facilities were obtained and reviewed.[1-11] Of these, only five (References 1, 3, and 9-11, summarized below) contained sufficient process information to be helpful in developing particulate matter (PM) emission factors for various process sources. (Many reported only the pounds/hour [lb/h] and particle size distribution.) In addition, we have learned that extensive tests of six California facilities have been planned[12] and conducted,[13] but the report on these tests has not been completed.

These reports and communications reveal that the air stream handling practices differ substantially among facilities and have become much more complex, in many cases, since the first tests in 1974. For example, some facilities appeared to have had only one to three cyclones to clean air streams from precleaning and hulling/separating operations.[1] A 1981 test report[6] noted that the facility has 12 cyclones while others[2-5] involved tests of from one to four baghouses per facility. Some facilities today have several cyclones each in precleaning operations and in hulling/shelling/separating operations, or use combinations of cyclones and baghouses. Two large baghouses (or perhaps just one) may handle all air cleaning, but it is difficult to assign one to precleaning only and one to hulling only, because air streams may be mixed, depending on the layout of the facility. According to one source within the almond processing industry, out of approximately 350 almond hullers and huller/shellers, no two are alike. Because of this wide variation in control practices, detailed information on exhaust stream distribution must be included in the test report for the data to be usable for emission factor development.

A second important point is the variation in reporting the processing rate. The 1974 emission factors are based on pounds particulate per field weight ton (FWT). Field weight includes nuts plus orchard debris, including leaves, twigs, soil and stones, which varies among facilities. On average, field weight typically yields 13 percent debris, 50 percent hulls, 14 percent shells, and 23 percent clean almond meats and pieces, but these ratios can vary substantially from farm to farm. The actual process rate through an operation declines substantially as one moves down the processing flow diagram (Figure 2-3). Because of this variation, the best activity factor appears to be tons of finished almonds.

Reference 1

A copy of the report for this 1974 test was obtained from the California Air Resources Board (CARB). Tests were conducted of the particulate emissions from nine almond hullers operating in the San Joaquin Valley. Tests were conducted on 14 cyclones (8 facilities), 2 baghouses (one facility), and 1 air leg. Samples were collected at the inlet and outlet of the 14 cyclones and at the outlets of the 2 baghouses for particle size distribution determination. Only outlet particle size distributions are presented in the report. The inlet data were rejected because the concentrations of PM were so high that the sampler stages overflowed and therefore the data were invalid. The air leg tested was identified only as the "north" one rather than by process location. EPA Method 5 was used to determine filterable particulate matter concentrations. The test data are summarized in Table 4-1, based on the original data in the Appendix. Applicable hand calculations are provided in the Appendix.

A description of the process and raw test data were included in the report and a sound methodology was used. However, no individual site characterizations were provided so the relationship between the exhaust streams tested and total process exhausts could not be readily determined. Therefore, a rating of D was assigned to the test data contained in Reference 1 used to develop filterable PM emission factors. Although the descriptions of the process were insufficient to calculate mass emission rates, the particle size data presented in the report appear to have been collected with sound methodology and to show consistent relative size fractions. Consequently, the particle size fraction data are rated C.

Reference 3

This 1981 test involved three baghouses at the Superior Farming Almond Huller Facility, Bakersfield, California. Filterable PM sampling was performed using EPA Method 5, with two test runs per baghouse, while the system was operating normally. The baghouse had multiple fan outlets, but only one was tested; the result was multiplied by the number of outlets to get the overall emission. The data are summarized in Table 4-2. Emission factors are calculated for one baghouse treating precleaner air only and one treating huller air only. The other baghouse treated combined air streams. Emission factors were not calculated for this baghouse because it controlled air streams from three different process sources, each with a different process throughput.

This reference was not very detailed and tested baghouses at only one facility. Furthermore, not all baghouse exhaust ducts were sampled. Therefore, the data in Reference 3 are assigned a rating of C.

References 9 and 13

This 1991 test focused on determination of PM-10 emissions and volumetric flow rates for two baghouses at a central California almond growers association, Kerman, California. The devices were designated as the precleaner baghouse (24-in and 60-in outlets) and the huller baghouse (22-in, 36-in, and 70-in outlets). A process flow diagram was subsequently provided by Eckley Engineering. PM-10 sampling was performed using EPA Method 201A. Volumetric flow rates were determined in accordance with CARB Methods 1-4.

The report provided the following testing data.

	Precleaner baghouse		Huller baghouse		
	24-in duct	60-in duct	22-in duct	36-in duct	70-in duct
Airflow, dscfm	16,300	57,900	7,900	16,000	101,200
Total PM, gr/dscf	0.031		0.001		

Process rate information was not provided in the report, but a private communication from Eckley Engineering[13] revealed that field weights (uncleaned, unhulled) and 24-h almond meat production were recorded. Huller/sheller input weight of precleaned almonds was not available. This

TABLE 4-1. SUMMARY OF CARB PARTICULATE EMISSIONS TESTS AT ALMOND PROCESSING FACILITIES

Company	Air emission factors (kg/Mg [lb/FWT])[a] by emission source						
	Precleaner cyclone	Leaf aspirator[b]	Huller cyclone	Classifier screen decks cyclone[c]	Air leg[d]	Precleaner baghouse	Huller baghouse
Bogetti	0.99 (1.98)						
Boersma[e]	0.12 (0.23)	—0.70— —(1.39)—					
Degroot[e]	0.37 (0.74)	—0.89— —(1.78)—					
Winchester[e]	0.44 (0.88)	—0.38— —(0.75)—			0.26 (0.51)		
Scott	0.72 (1.44)						
Dunlap-Borman[f]	—0.89— —(1.78)—		0.65 (1.30)				
NMHA	0.18 (0.35)			0.20 (0.40)			
Atwater Fruit	0.11 (0.21)		0.22 (0.44)				
Cortez Growers						0.00070 (0.0014)	0.0080 (0.0155)

Source: Reference 1.

[a]Kilograms particulate per field weight megagram (pounds particulate per field weight ton). One FWT yields about 0.2 ton almonds for market.
[b]Some operators combine leaf aspirator airflow with the precleaner air, others with huller air.
[c]Some operators probably combine this airflow with huller air for treatment.
[d]Multiple air legs may exist. Specific air leg tested not identified within process. Some operators probably combined air leg gas with huller or other airflow.
[e]Combines leaf aspirator airflow with huller cyclone airflow.
[f]Combines precleaner cyclone airflow with leaf aspirator airflow.

TABLE 4-2. BAGHOUSE PARTICULATE MATTER EMISSIONS TEST
AT SUPERIOR FARMING COMPANY

Baghouse	Process air	Processing rate (FWT/h)	Emissions (avg., lb/h)	Emission factor, kg/Mg (lb/ton)[a]
1	Precleaner No. 1	16.30	5.36	Not calculated
	Huller No. 1	7.84		
	Huller No. 2	9.08		
2	Precleaner No. 2	18.67	0.60	0.016 (0.032)
3	Huller No. 3	10.63	0.16	0.0075 (0.015)

Source: Reference 3.

[a]Kilograms per field weight megagram (pounds per field weight ton).

communication also indicated the precleaner baghouse test results were declared invalid because of a split in one bag. For the huller/sheller, from the sum of mean airflows, an average particulate loading of 0.0012 gr/dscf, and an almond meat production rate of 6.18 tons/h, Eckley estimated an emission factor of 0.21 lb TSP/meat ton. The factor on a field weight basis would be about one-fifth of this value, or 0.04 lb/FWT.

The PM and PM-10 data reported in this reference were not suitable for emission factor development for several reasons, including the presence of cyclonic flow in the exhaust ducts which makes the measurements unreliable.

Reference 10

This 1991 compliance test includes measurements of filterable and condensible inorganic PM emissions from two baghouses at the Harris Woolf California Almonds facility in Coalinga, California. The devices were designated as the receiving/precleaning baghouse and the hulling/shelling baghouse. Filterable PM sampling was performed using EPA Method 5, and condensible inorganic PM emissions were quantified through analysis of the back-half catch from the Method 5 runs. Three test runs were conducted at the receiving/precleaning baghouse stack, and three test runs were conducted at each of two stacks (simultaneously), which vented emissions from the hulling/shelling baghouse. Volumetric flow rates were determined in accordance with EPA Methods 1-4. Process throughput rates that represent almond field weights are documented in the report. The data from this test are summarized in Table 4-3.

The data from this report are assigned an A rating. The report provided adequate detail, the testing methodology was sound, and no problems were reported during the test runs.

Reference 11

This 1992 compliance test includes measurements of filterable and condensible inorganic PM emissions from one baghouses at the Harris Woolf California Almonds facility in Coalinga, California. The device was designated as the receiving/precleaning baghouse. Filterable PM sampling was

TABLE 4-3. PARTICULATE MATTER EMISSION TESTS AT HARRIS WOOLF CALIFORNIA ALMONDS[a]

Process	Processing rate, (avg. FWT/h)	Filterable PM emissions, (avg. lb/h)	Condensible inorganic PM emissions, (avg. lb/h)	Filterable PM emission factor, kg/Mg (lb/ton)[b]	Condensible inorganic PM emission factor, kg/Mg (lb/ton)[b]
Unloading/precleaning[c]	16.8	1.62	0.0653	0.0485 (0.0969)	0.00194 (0.00388)
Hulling/shelling[c]	18.2	0.910	0.255	0.0257 (0.0513)	0.00680 (0.0136)
Unloading/precleaning[d]	14.4	0.812	0.0597	0.0283 (0.0566)	0.00205 (0.00411)

[a]Emission factors represent fabric filter-controlled processes unless noted.
[b]Kilograms per field weight megagram (pounds per field weight ton). Emission factors are based on run-by-run data, and cannot be calculated using the average process rates and emission rates shown.
[c]Reference 10.
[d]Reference 11.

performed using EPA Method 5, and condensible inorganic PM emissions were quantified through analysis of the back-half catch from the Method 5 runs. Three test runs were conducted at the receiving/precleaning baghouse stack. Volumetric flow rates were determined in accordance with EPA Methods 1-4. Process throughput rates that represent almond field weights are documented in the report. The data from this test are summarized in Table 4-3.

The data from this report are assigned an A rating. The report provided adequate detail, the testing methodology was sound, and no problems were reported during the test runs.

4.2 EMISSION FACTOR DEVELOPMENT

Emission factors for filterable PM, condensible inorganic PM, and PM-10 emissions were developed for almond unloading, precleaning, hulling, and shelling processes. Because of the substantial differences in process air stream handling between facilities, the uncertainties in much of the available data, and the expected availability in the near future of important new test data from multiple sources,[12,13] the present development has relied on data from References 1, 3, 10, and 11. Factors are given for six sources; "unloading," "precleaning," "hulling/shelling," "hulling/separating," "classifier screen decks," and "air legs." Emission factors for these processes are presented in Table 4-4. The following paragraphs describe the development of the filterable PM, condensible inorganic PM, and PM-10 emission factors found in Table 4-4.

Filterable PM

An arithmetic average of the source test results in Reference 1 was used to develop the cyclone-controlled filterable PM emission factors shown in Table 4-4. The precleaning cyclone emission factor is an average of data from eight tests, and the hulling cyclone emission factor is an average of data from five tests. The classifier screen deck cyclone emission factor represents data

TABLE 4-4. CANDIDATE EMISSION FACTORS FOR ALMOND PROCESSING[a]

		Average emission factor						
Process	Type of control	Filterable PM, kg/Mg (lb/ton)	Emission factor rating	Condensible inorganic PM kg/Mg (lb/ton)	Emission factor rating	PM-10[b], kg/Mg (lb/ton)	Emission factor rating	Ref(s).
Unloading	Baghouse	0.030 (0.060)	E	ND		ND		1,3,10, 11
Precleaning	Cyclone	0.48 (0.95)	E	ND		0.41 (0.82)	E	1
	Baghouse	0.0084 (0.017)	E	ND		0.0075 (0.015)	E	1,3
Hulling/ shelling	Baghouse	0.026 (0.051)	E	0.0068 (0.014)	E	ND		10,11
Hulling/ separating	Cyclone	0.57 (1.1)	E	ND		0.41 (0.81)	E	1
	Baghouse	0.0078 (0.016)	E	ND		0.0065 (0.013)	E	1,3
Classifier screen deck	Cyclone	0.20 (0.40)	E	ND		0.16 (0.31)	E	1
Air leg	None	0.26 (0.51)	E	ND		ND		1

ND = No data available at this time.

[a]All emission factors are per field weight megagram or per field weight ton.
[b]PM-10 emission factors are based on particle size fractions found in Reference 1 applied to the filterable PM emission factor for that source. See Section 4.2 of this report for a detailed discussion of how these emission factors were developed.

from only one test. Because it is not expected that these tests are representative of the industry, few tests were performed, and the limited process information in Reference 1 was insufficient to establish process conditions for the test, the emission factors for precleaning, hulling/separating operations, and the classifier screen deck are rated E.

The baghouse-controlled filterable PM emission factors for both precleaning and hulling were developed from two source tests (one from Reference 1 and one from Reference 3). These emission factors are rated E because they were developed using C- and D-rated data.

The baghouse-controlled filterable PM emission factor for hulling/shelling was developed from one source test. This emission factor is rated E because data from only one facility were used to develop the emission factor.

The baghouse-controlled filterable PM emission factor for unloading was calculated by subtracting the precleaning emission factor (described above) from the average unloading/precleaning emission factor of 0.038 kg/Mg (0.077 lb/ton) calculated from data presented in References 10 and 11 (shown in Table 4-3). This emission factor is rated E.

The uncontrolled filterable PM emission factor for air legs was developed from only one source test presented in Reference 1. This emission factor is rated E because it was developed using D-rated data.

Condensible Inorganic PM

The baghouse-controlled condensible inorganic PM emission factor for hulling/shelling was developed from one source test. This emission factor is rated E because data from only one facility were used to develop the emission factor.

PM-10

No reliable direct measured PM-10 data (Method 201 or 201A) were found for the almond processing industry. However, a limited amount of particle size distribution data from cascade impactors was provided in the CARB report (Reference 1). The PM-10 emission factors presented in Table 4-4 were calculated based on particle size distribution data found in Reference 1 and the average filterable PM emission factors as presented in Table 4-4.

Particle size distribution data were presented for eight precleaner cyclones and four huller cyclones. The cumulative percentages at each of the cut sizes were averaged to obtain an overall average cumulative percent at each cut size for precleaner cyclones and huller cyclones. Particle size distribution data were presented for only one screen deck cyclone, one precleaner baghouse, and one huller baghouse. The empirical distribution functions for particle cut sizes for each of the five sources were plotted using log probability paper. Such plots produce a straight line if the particle sizes distribution is lognormal. These graphs are included in Appendix A. After these points were plotted, a line or curve was drawn to fit each data set. From these plots, cumulative weight fraction less than 10µm was determined graphically for each of the five sources. These percentages are indicated in Table 4-5.

The PM-10 fraction determined from the particle size distribution data was then applied to the total PM emission factor already calculated for that source. The result is presented in Table 4-4 as the PM-10 emission factor for that source. Because these results were not obtained via reference methods for PM-10, they are rated E.

MRI recommends that the emission factors shown in Table 4-4 be adopted for Section 9.10.2 of AP-42—Salted and Roasted Nuts and Seeds.

TABLE 4-5. CUMULATIVE PM-10 PERCENTAGES

Emission source	% of PM ≤ 10μm
Precleaner cyclone	86
Huller cyclone	74
Screen deck classifier cyclone	77
Precleaner baghouse	86
Huller baghouse	82

REFERENCES FOR SECTION 4

1. *Report on Tests of Emissions From Almond Hullers in the San Joaquin Valley*, File No. C-4-029, California Air Resources Board, Division of Implementation and Enforcement, Sacramento, CA; undated report—the tests were performed in 1974.

2. *Almond Huller Baghouse Emissions, Minnehoma Land and Farming Company*, Truesdail Laboratories, Los Angeles, CA, November 14, 1979.

3. *Almond Huller Baghouse Emissions Tests, Superior Farms*, Truesdail Laboratories, Los Angeles, CA, November 5, 1980.

4. *Almond Huller Baghouse Exhaust, Kernpareil Co-op Inc.*, Truesdail Laboratories, Los Angeles, CA, November 26, 1980.

5. *Baghouses on Almond Hulling Process Emission Tests, Berrenda Mesa Almond Hulling*, Truesdail Laboratories, Los Angeles, CA, April 6, 1981.

6. *Field Data Source Test, Mid-State Manufacturing*, Report by Chemecology, Pittsburgh, CA, October 1981.

7. *Cyclone Dust Collector Emission Test Program, Cunha Farms*, Report by Pape & Steiner Environmental Services, Bakersfield, CA, September 1986.

8. *Compliance Source Test Report, Shafter-Wasco Ginning*, Report by Petro Chem Environmental Services, Bakersfield, CA, October 1991.

9. *Determination of PM-10 Emissions and Volumetric Flow Rates from the Precleaner Baghouse and the Huller Baghouse located in the Central California Almond Growers Association in Kerman, California*, Ecoserve Inc., prepared for Eckley Engineering, Fresno, CA, November 8, 1991.

10. *Emission Testing On Two Baghouses at Harris Woolf California Almonds*, Steiner Environmental, Inc., Bakersfield, CA, October 1991.

11. *Emission Testing On One Baghouse at Harris Woolf California Almonds*, Steiner Environmental, Inc., Bakersfield, CA, October 1992.

12. *Proposal to Almond Hullers and Processors Association for Pooled Source Test*, by Eckley Engineering, Fresno, CA, December 2, 1990.

13. Private communication, Wendy Eckley of Eckley Engineering, Fresno, CA, with Lance Henning, Midwest Research Institute, August-September 1992 and March 1993.