

**Emission Factor Documentation for AP-42
Section 9.11.1**

Vegetable Oil Processing

Final Report

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

**EPA Contract No. 68-D2-0159
Work Assignment No. 2-03 and 3-01**

**MRI Project No. 4602-03 and
4603-01-03**

November 1995

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Research Triangle Park, NC 27711

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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. 2-03 and 3-01. Mr. Dallas Safriet was the EPA work assignment manager for this project.

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EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 9.11.1
Vegetable Oil Processing

1. INTRODUCTION

The document *Compilation of Air Pollutant Emissions 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 is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors usually are expressed as the weight of pollutant divided by the unit weight, volume, distance, or duration of the activity that emits the pollutant. The emission factors presented in AP-42 may be appropriate to use in a number of situations, such as making source-specific emission estimates for areawide inventories for dispersion modeling, developing control strategies, screening sources for compliance purposes, establishing operating permit fees, and making permit applicability determinations. The purpose of this report is to provide background information from test reports and other information to support preparation of AP-42 Section 9.11.1, Vegetable Oil Processing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the vegetable oil processing industry. It includes a characterization of the industry, a description of the different process operations, a characterization of emission sources and pollutants emitted, and a description of the technology used to control emissions resulting from these sources. Section 3 is a review of emission data collection (and emission measurement) 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 how the new AP-42 section was developed. It includes the review of specific data sets and a description of how candidate emission factors were developed. Section 5 presents the AP-42 Section 9.11.1, Vegetable Oil Processing. References and supporting documentation are presented in the Appendix.

2. INDUSTRY DESCRIPTION

2.1 INDUSTRY CHARACTERIZATION¹⁻⁵

The industry group, fats and oils (SIC 2070), includes cottonseed oil mills (SIC 2074), soybean oil mills (SIC 2075), vegetable oil mills except corn, cottonseed, and soybean (SIC 2076), and other fats and oils, n.e.c. (2079). SIC 2076 consists of peanut, sunflower, rapeseed (canola), and other oil seeds produced in smaller quantities. Approximately 137 vegetable oil plants operate in the United States. Soybean processing dominates the industry, producing approximately 80 percent of the volume of vegetable oil. Over the last 2 to 3 years, approximately 1.1 billion to 1.3 billion bushels of soybeans were processed each year. Other major vegetable oils are cottonseed, peanut, and corn. In 1995 there were 86 soybean processing plants, 32 cottonseed oil mills, and 19 vegetable oil mills except corn, cottonseed, and soybean. Corn oil is processed primarily by wet corn mills (SIC 2046) which produce a variety of other corn by-products including starch, syrup, sugar, gluten, and corn meal. Not all wet corn mills are actively engaged in oil production. The Corn Refiners Association Inc. estimates that approximately 25 percent of the 27 wet corn mills engage in regular corn oil production. Table 2-1 lists the locations for soybean, cottonseed, and other vegetable oil mills by major vegetable oil producing states.

The largest use of vegetable oils is in foodstuffs. Cooking oils, salad dressings, prepared/processed foods, shortenings, and margarines utilize over 90 percent of vegetable oils. Vegetable oils also are used in industrial applications such as protective coatings. Recently, there has been interest in using vegetable oils as fuels for motor vehicles and other combustion engines, in paints and other oil-based coatings, and as an oil base in inks for newspapers and magazines. These alternative currently do not represent a significant share of the total soybean oil market; however, they have potential environmental and product quality benefits that may result in substantial new markets for vegetable oils.

2.2 PROCESS DESCRIPTION⁶⁻⁹

A description of the processing operation for soybean oil, cottonseed oil, corn oil, and peanut oil is presented in this section. More detail is given to soybean processing because of its greater relative importance to the vegetable oil industry.

2.2.1 Soybean Oil Processing

Soybean oil processing typically consists of oilseed handling/elevator operations (receiving, storing, and cleaning the raw soybeans); preparing the soybeans for solvent extraction; solvent extracting and oil desolventizing; oil refining; and desolventizing and processing the spent soybean flakes. These five processes are described below.

2.2.1.1 Oilseed Handling/Elevator Operations. Figure 2-1 is a schematic diagram of the typical soybean handling/elevator operations that precede the preparation of soybeans for the solvent extraction process. Soybeans received at a facility by truck or rail are sampled and analyzed for moisture content, foreign matter, and damaged seeds. All processing plants have maximum moisture specifications for the beans. After the sampling/analysis is completed, the beans are weighed and conveyed to large concrete silos or metal tanks for storage prior to processing. When the facility is ready to process the soybeans, the beans are removed from the silo or tank and cleaned of foreign

TABLE 2-1. NUMBER OF PLANTS IN MAJOR VEGETABLE OIL
PRODUCING STATES

State	Type of oil produced		
	Soybean oil	Cottonseed oil	Other vegetable oils ^a
Alabama	1	2	1
Arizona		2	
Arkansas	4	4	
California	2	2	5
Delaware	1		
Georgia	3		4
Hawaii	1		
Illinois	12		1
Indiana	5		1
Iowa	13		
Kansas	4		
Kentucky	1		
Louisiana	1	2	
Maryland	1		
Michigan	2		
Minnesota	6		3
Mississippi	4	4	
Missouri	5		
Nebraska	5		
New York	1		
North Carolina	3		
North Dakota			3
Ohio	6		
Oklahoma		2	1
South Carolina	3	1	
Tennessee		1	
Texas	1	12	
Virginia	1		
TOTAL	86 ^b	32	19

Source: Reference 5.

^aPlants in SIC 2076 and 2079; does not include corn oil production

^bThe 86 soybean processing plants include 69 solvent extraction plants and 17 press plants.

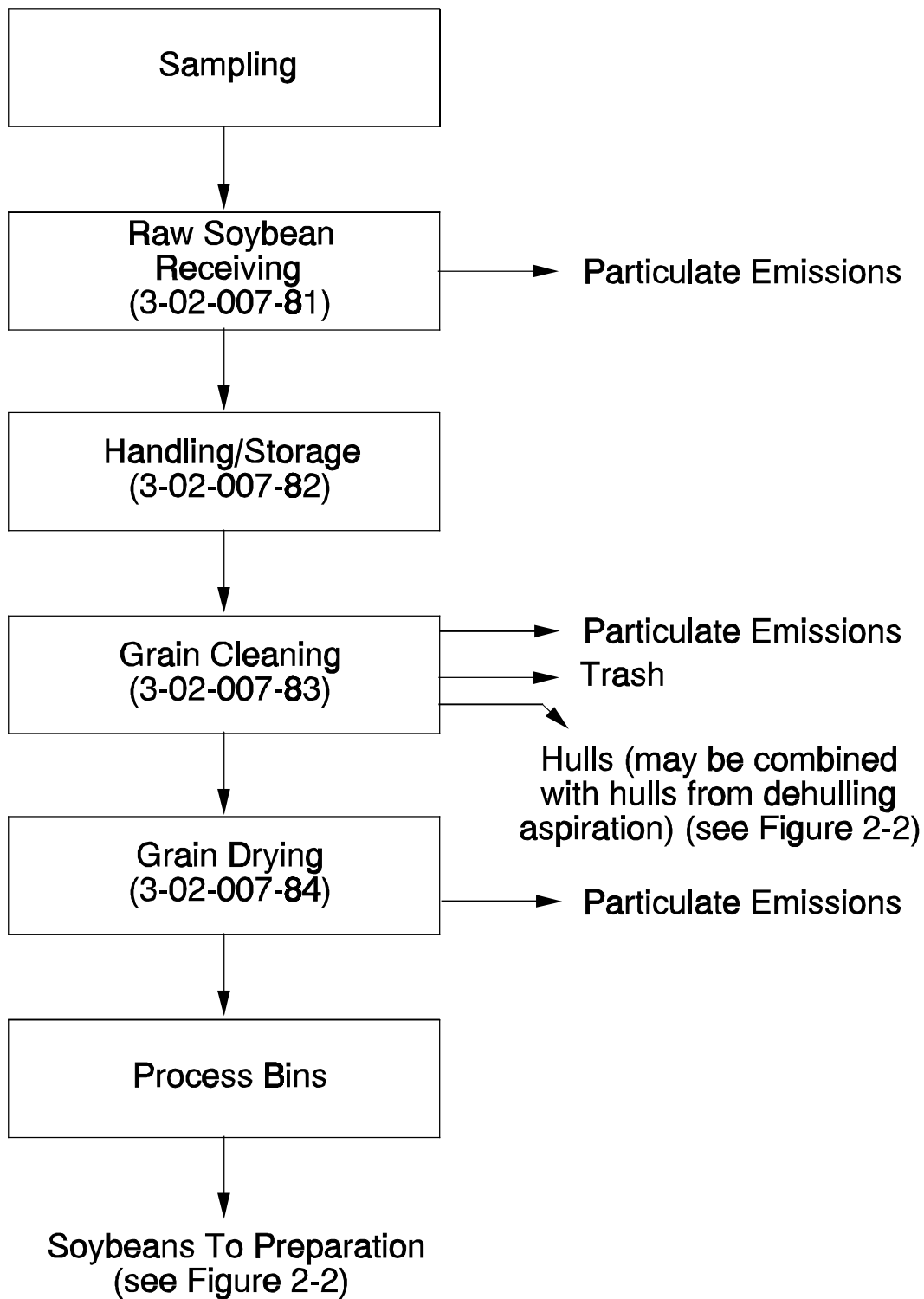


Figure 2-1. Flow diagram of typical soybean handling/elevator operations.

materials and loose hulls. Screens are typically used to remove the foreign materials such as sticks, stems, pods, tramp metal, sand, and dirt. An aspiration system is used to remove loose hulls from the soybeans. Later in the process, these hulls may be combined with the hulls produced during dehulling aspiration. The beans are passed through dryers to reduce their moisture content to approximately 10 percent to 11 percent moisture by weight and then conveyed to process bins for temporary storage and tempering in order to facilitate dehulling. The beans are tempered in the process bins for 1 to 5 days.

2.2.1.2 Preparation of Soybeans for Solvent Extraction. Figure 2-2 is a schematic diagram of the process of preparing soybeans for oil extraction. There are two principal methods for oil extraction. The first method is to press the soybeans, typically through a screw press. This method is not widely used since extraction efficiency is low. The widely-used second method is to extract the oil using a solvent, hexane, which dissolves the oil and strips it from the soybean flakes. The solvent extraction method requires stripping residual hexane from the oil and the soybean flakes. Since pressing is not believed to be a major source of volatile organic compound (VOC) emissions, only the solvent extraction method is described in detail.

The process, which is fairly well standardized, consists of four principal operations: cracking, dehulling/hull removal, conditioning, and flaking. Soybeans are conveyed from the process bins to the mill by means of belts or mass flow conveyors and bucket elevators. In the mill, the beans may be aspirated again, weighed, cleaned of tramp metal by magnets, and fed into corrugated cracking rolls. The cracking rolls "crack" each bean into four to six particles to facilitate separation of the hulls from the oil-rich bean. The cracked beans are passed through an aspirator to remove the hulls, which are processed separately. These hulls may be combined with the hulls from the grain cleaning step. The cracked beans and residual bean chips are then conveyed to the conditioning area, where they are either put into a rotary steam tube device or into a stacked cooker and heated to "condition" them (i.e., make them pliable and keep them hydrated). Conditioning is necessary to permit the flaking of the chips and to prevent their being broken into smaller particles. Finally, the heated, cracked beans are conveyed and fed to smooth, cylindrical rolls that press the particles into smooth "flakes," which vary in thickness from approximately 0.25 to 0.51 millimeters (0.010 to 0.020 inches). Flaking allows the soybean oil cells to be exposed and the oil to be more easily extracted.

2.2.1.3 Solvent Extraction and Oil Desolventizing. The extraction process consists of "washing" the oil from the soybean flakes with hexane solvent in a countercurrent extractor and then evaporating the solvent (i.e., desolventizing) separately from both the solvent/oil mixture (micella) and the solvent-laden, defatted flakes (see Figure 2-3). The oil is desolventized by exposing the solvent/oil mixture to steam (contact and noncontact). Then the solvent is condensed, separated from the steam condensate, and reused. The desolventized oil, called "crude" soybean oil, is stored for further processing or loadout. Specific steps in the solvent extraction and oil desolventizing processes are described below.

2.2.1.3.1 Extraction. Soybean flakes are conveyed into the extractor, where they are washed counter currently with various hexane/oil mixtures and, finally, with pure hexane. The initial oil content of the soybeans is approximately 18 percent to 20 percent by weight. After extraction, the defatted flakes contain approximately 0.5 percent to 2.0 percent oil by weight.

Either a "deep bed" extractor or a "shallow bed" extractor is typically used in the extraction process. The deep bed extractor consists of pie-shaped mesh baskets that rotate around a shaft. The bed depth in this extractor varies from approximately 6 to 10 ft. The shallow bed extractor, a more

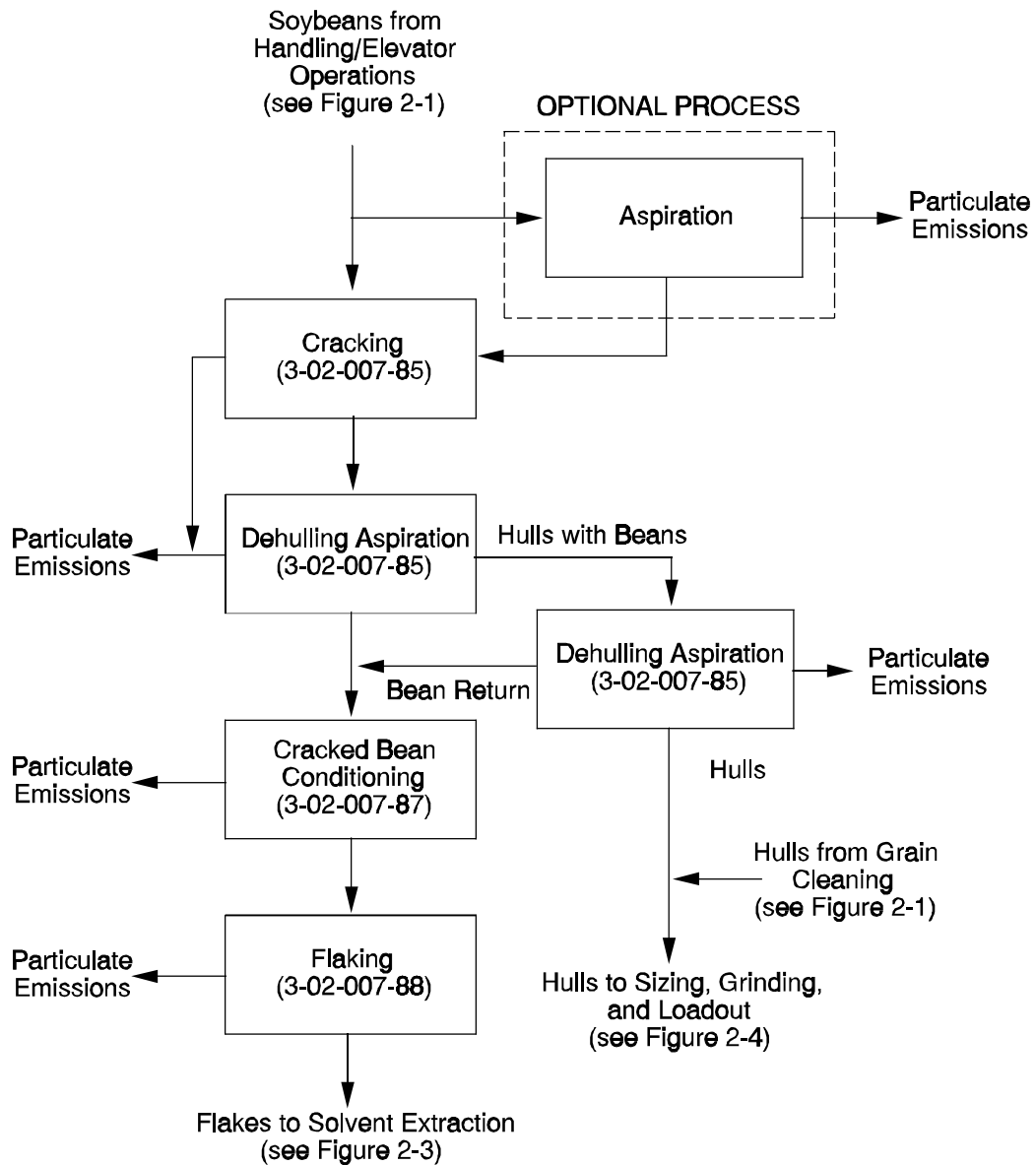
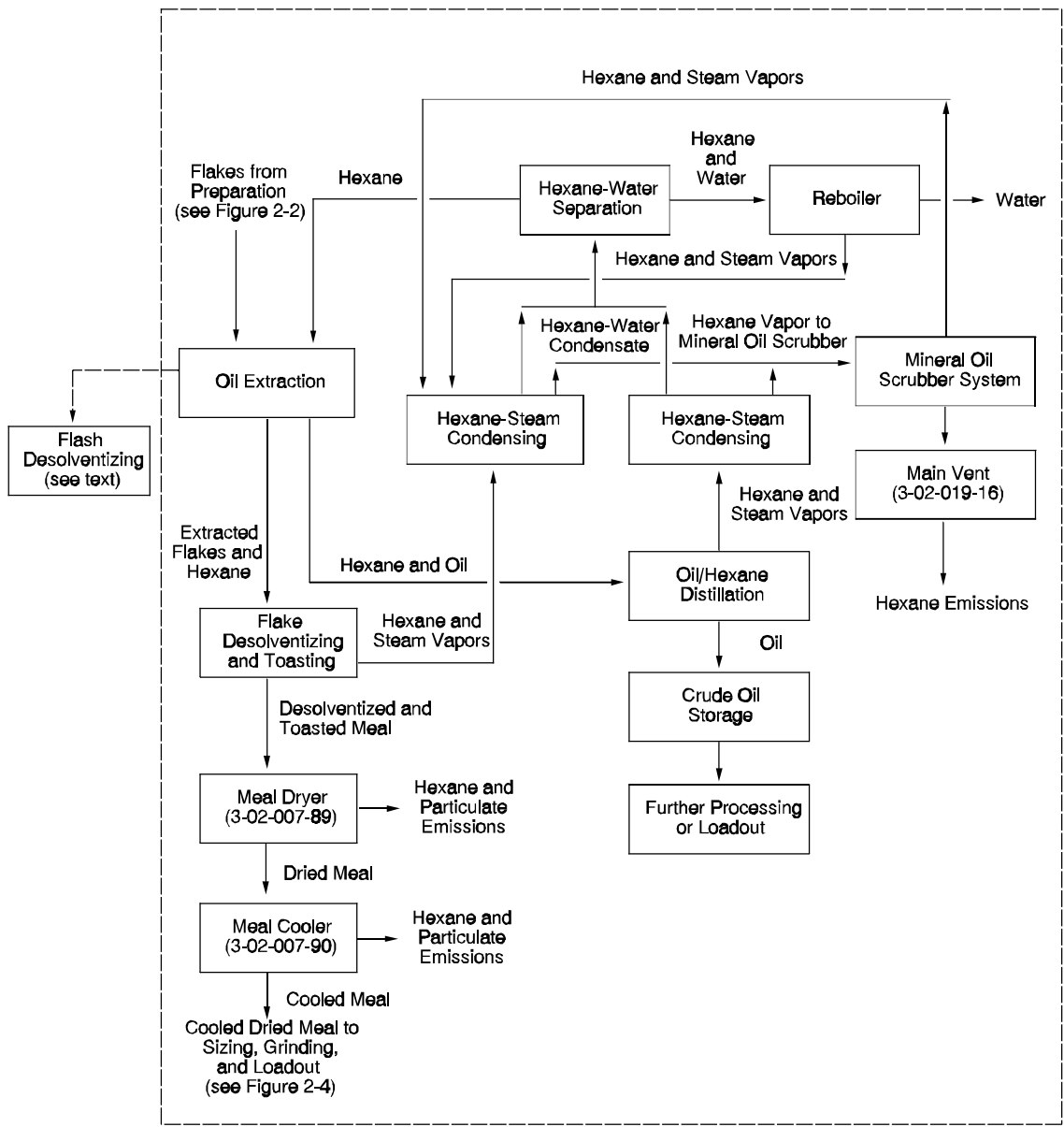


Figure 2-2. Flow diagram of the typical process for preparing soybeans for solvent extraction.



Soybean Extraction Facility--Total Hexane Losses
 (3-02-019-97)
 (3-02-019-98)

Figure 2-3. Flow diagram of the "conventional" solvent extraction process.

recent design than the deep bed extractor, conveys the soybean flakes horizontally over closely spaced "vee-bars" while washing them first with oil and hexane and then with pure hexane. Bed depth in the shallow bed extractor normally varies from approximately 2 to 3 ft.

2.2.1.3.2 Oil desolventizing. The oil/hexane mixture is removed from the extractor separately from the defatted flakes. The mixture is first pumped through heaters, then through film evaporators under vacuum and, finally, through a stripping column to remove the hexane. The hexane/water vapor mixture is removed from each oil desolventizing unit and condensed in a "separation" tank to separate the hexane from the water. Once separated from the water, the hexane is reused in the extraction process. Crude oil is cooled and stored in tanks for further processing or loadout.

2.2.1.4 Oil Refining. Crude vegetable oils contain small amounts of naturally occurring materials including proteinaceous material, free fatty acids, and phosphatides which must be removed to produce a "finished" or "refined" oil. Phosphatides are removed for lecithin recovery or to prepare the crude oil for export by preventing the formation of precipitated gums during transit. The most common method of refining oil is by reacting it with an alkali solution which neutralizes the free fatty acids and reacts with the phosphatides. These reacted products and the proteinaceous materials are then removed by centrifuge. Following alkali refining, the oil is washed with water to remove residual soap, which is the result of saponification of small amounts of the triglycerides (oil).

Color-producing substances within an oil (i.e., carotenoids, chlorophyll) are removed by a bleaching process which employs the use of adsorbents such as acid-activated clays. Volatile components which may cause undesirable odors or flavors are removed by deodorization. This process employs the use of steam injection under a high vacuum and temperature. The refined oil is then filtered and stored until used or transported. Nitrogen gas may be placed in the headspaces of tanks or transport vessels to reduce oxygen contact with the oil, thus preventing degradation of the oil by oxidation.

2.2.1.5 Desolventizing and Processing Spent Soybean Flakes. The flakes leaving the extractor contain up to 35 percent to 40 percent solvent and must be desolventized before use. Flakes are desolventized either through a "conventional" desolventizing process or a specialty ("flash") desolventizing process, depending on the end use of the material.

Conventional desolventizing takes place in a desolventizer-toaster where both contact and noncontact steam are used to evaporate the hexane. The hexane is condensed, separated from the steam condensate, and reused. In addition, the contact steam "toasts" the flakes, making them more usable for animal feeds. The desolventized and toasted flakes then pass to a dryer, where excess moisture is removed by heat, and then finally to a cooler, where ambient air is used to reduce the temperature of the dried flakes. The desolventized, defatted flakes are then ground for use as soybean meal—a protein source in animal feeds (see Figure 2-4). In the specialty or "flash" process, solvent is removed from the defatted flakes either with superheated solvent (hexane) or in a vacuum with a small quantity of noncontact steam. Flakes desolventized in this manner are typically used for human foods. Conventional and flash desolventizing are described in further detail below.

2.2.1.5.1 Conventional desolventizing. The solvent-laden, defatted soybean flakes are conveyed from the extractor to a desolventizer-toaster (DT) where the solvent is removed. The DT contains stacked pans with a vertical center shaft equipped with "sweeps" that mix and stir the flakes while they are being heated to about 100°C (212°F) with both contact and noncontact steam to evaporate the solvent. The resulting steam/solvent vapor mixture is exhausted from the top of the DT,

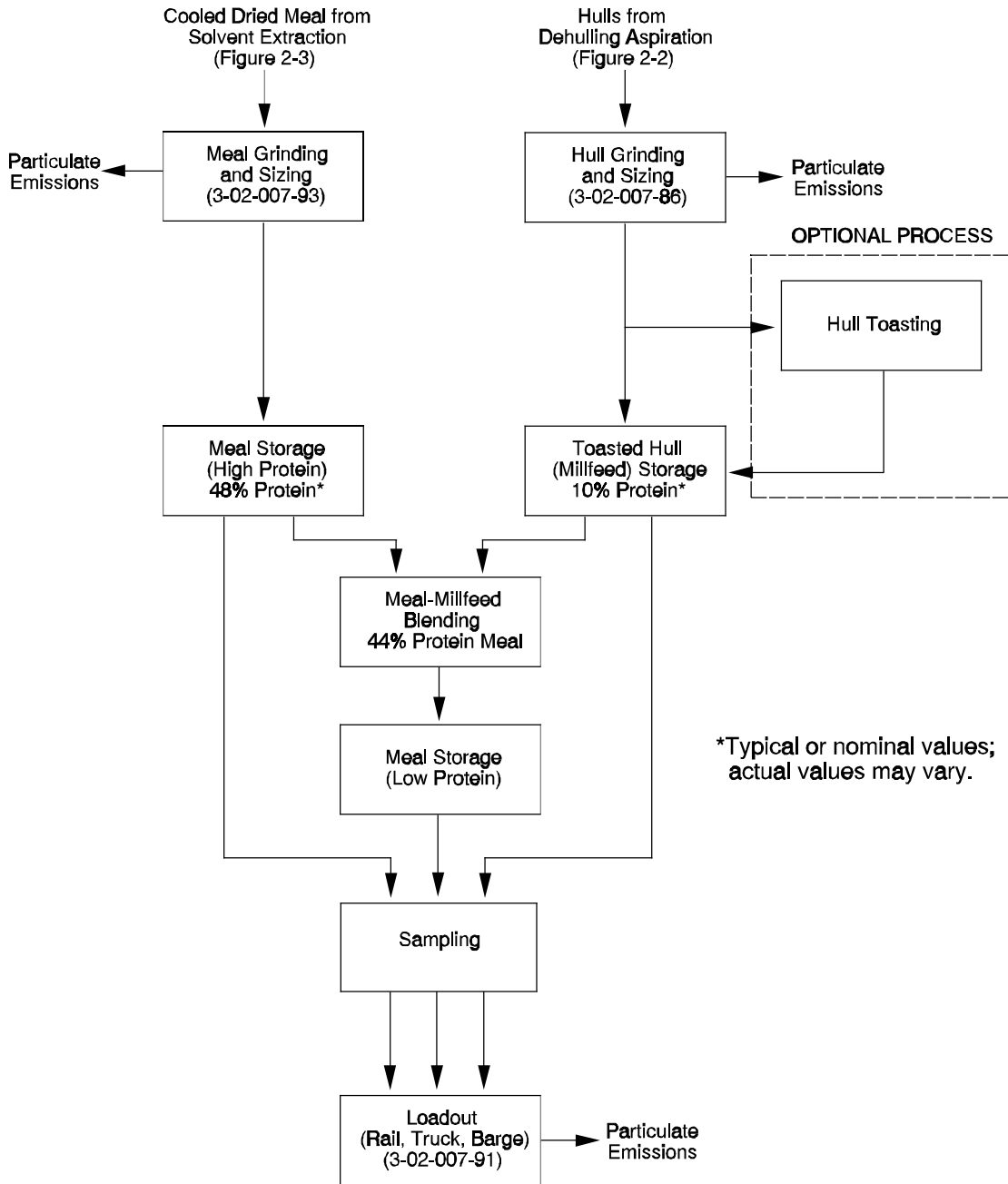
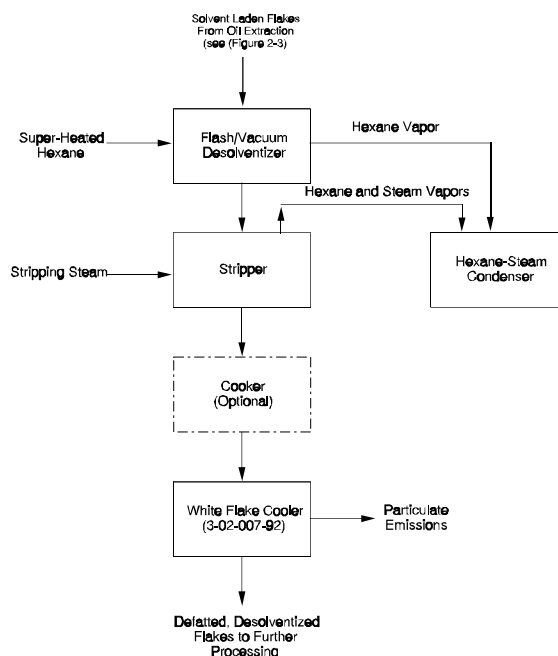


Figure 2-4. Flow diagram for "conventional" process of dry material sizing, grinding, and loadout.

and both are subsequently condensed and put into the same separation tank as that used in the oil desolventizing process. The desolventized flakes, whose moisture content has increased from approximately 10 percent to 11 percent by weight to approximately 18 percent to 22 percent by weight, are conveyed to a "dryer-cooler" to reduce their moisture back to approximately 12 percent.

2.2.1.5.2 Specialty or "flash" desolventizing. Flash or specialty desolventizing is used when the flakes are intended for human consumption and the objective is to minimize the denaturation of the protein in the flakes that occurs with toasting. This is a specialty process that accounts for less than 5 percent by volume of the annual nationwide soybean crush. In this process, flakes are "flash" desolventized in a vacuum with a small quantity of noncontact steam or in a pneumatic loop using superheated hexane. This step is followed by a final solvent stripping step using very small quantities of steam in a rotary or agitated vessel. The hexane vapor from the flash/vacuum desolventizer and the hexane and steam vapors from the stripper are directed to a condenser. From the condenser, the hexane vapor passes to the mineral oil scrubber system and the hexane-water condensate goes to the hexane-water separator. These latter steps from the condenser are the same steps as shown in Figure 2-3 for hexane and steam vapors from the "conventional" flake desolventizing and toasting step. The flakes produced by this desolventizing process are termed "white flakes". A process flow diagram for the "flash" desolventizing portion of the soybean processing is shown below.



Specialty or "flash" desolventizing utilizes different equipment and is far less efficient than conventional desolventizing in both energy consumption and solvent removal. Given these factors, solvent emission factors are considerably higher for a specialty desolventizing process than for a similar-sized conventional desolventizing process.

2.2.1.5.3 Dryer-coolers. Two types of dryer-coolers are used by the industry. One type is a horizontal, cylindrical dryer paired with a horizontal cylindrical cooler. The dryer is approximately 6 to 10 ft in diameter, approximately 30 to 50 ft long, contains longitudinal steam tubes, and rotates on a

horizontal axis. The cooler is a horizontal cylinder of approximately the same dimensions through which ambient air is circulated to cool the dried flakes.

The second type of dryer-cooler is a stacked pan unit similar in design to the DT discussed above. Each pan in the unit is perforated, and drying/cooling of the flakes is achieved by passing high volumes of air through the perforations and the defatted flakes. Heated air is circulated through the first few pans, and ambient air is circulated through the last few pans.

2.2.2 Cottonseed Oil Processing^{8,10,11}

Cottonseed oil processing is similar to soybean oil processing. Figure 2-5 serves as a general process diagram. The process includes cleaning of the cottonseeds, preparation for oil extraction, oil extraction and refining, and processing spent cottonseed meal. As with the soybean process, extraction of cottonseed oil is accomplished by both pressing and solvent extraction methods. In some processing plants, however, cottonseed meals are prepressed to extract some oil before solvent extraction. Since pressing is a mechanical process, only the solvent extraction method is described in detail in this section.

Cottonseeds are supplied by cotton gins, where the seeds are separated from the cotton fiber (see Section 9.7 of AP-42, Cotton Ginning, for process information). The cleaning process begins with screening and aspiration to remove the cotton lint (cotton fibers) and hull fragments remaining on the seeds after ginning. After cleaning, the cottonseed passes through a series of cylindrical saws, which remove the remaining fiber (fuzzy fiber/lint).

Next, the cleaned and delinted seeds are prepared for oil extraction by hulling, flaking, and conditioning (cooking). The hulls are removed by bar-type hullers that split the hulls, and screens and/or aspirators separate the hulls from the seed meat. Further hull/meat separation is achieved with vibrating beaters. Cottonseed hulls are used as a source of protein and roughage in animal feeds.

Prior to solvent extraction, the seeds are steam conditioned at approximately 82°C (180°F). The flaking step follows, which breaks down the cell structure and increases the surface area for contact with the solvent. Some facilities use an expander option in which flaked cottonseed is pelleted using an extrusion device. Expander processes are used to improve solvent extraction and reduce the amount of time for solvent to drain from the flakes. Flaking of the cottonseed meats is the same as for the soybeans.

Prepressing, which is used in some plants for initial oil extraction, is performed by mechanical screw presses exerting up to 2,000 pounds per square inch (psi) pressure. The remaining oil is extracted using the solvent extraction equipment. Likewise, the spent cottonseed meal is desolventized using the same desolventizer-toaster, dryer, and cooling processes as for soybeans. Oil refining and screened oil from prepressing produces fine solid material called foots or soapstock that is returned to the meal desolventizer.

There are two primary differences between cottonseed and soybean crushing. First, when considering overall solvent loss, scale of size favors the larger plants. In almost all cases, soybean crushers are much larger than cottonseed crushers. Second, the cottonseed crushing industry utilizes the additional step of delinting in processing cottonseed, which increases PM-10 emissions per ton of raw product processed.

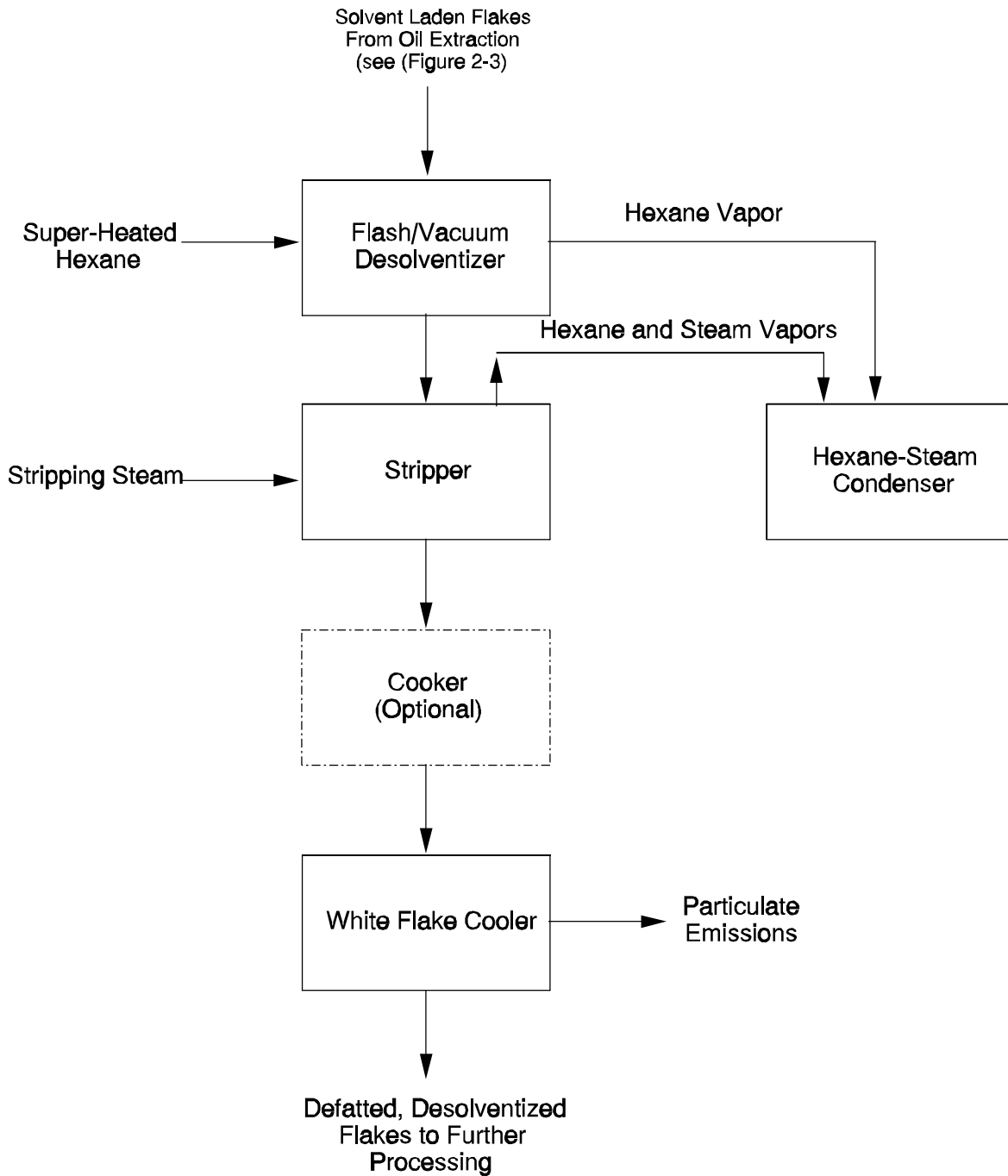


Figure 2-5. Flow diagram of a typical cottonseed extraction process.

2.2.3 Corn Oil Processing^{8,12}

Extraction of corn oil differs from soybean and cottonseed oil processing because most of the oil in corn is present only in the seed germ. Therefore, the major difference in corn oil processing is the preparation of corn kernels for oil extraction.

Corn is either wet milled or dry milled. Wet milling consists of steeping corn in water/sulfur dioxide (SO₂) baths to loosen the hulls from the kernels. Dry milling involves only mechanical separation techniques.

In wet milling, clean corn is steeped (soaked) in tanks of warm water and dissolved SO₂ (approximately 0.1 percent reduces bacterial growth) to loosen the hulls from the corn kernels. The steeped corn is passed through a series of mills (of various types) to break down the kernel and loosen the germ. The ground corn, in a water slurry, flows to germ separators. The germ is separated from the slurry with cyclones, washed to remove starch, and dried. For dry milling, once germ separation has been achieved by mechanical milling, the germ is ground and passed through a solvent extraction device.

Corn germ is typically prepressed through continuous screw presses or expellers before solvent extraction. Because pressing extracts about 80 percent of the germ's oil content, solvent extraction is typically used to remove the residual oil. After the expellers, the germ may be flaked and the remaining oil extracted using a solvent. Large wet milling operations use both prepress and solvent extraction. Again, solvent extraction processes are believed to be the only significant sources of VOCs.

Oil extraction for both dry and wet milled germ is performed with the hexane solvent and uses equipment similar to that described in Section 2.2.1 for soybean oil processing. Solvent is driven off the spent germ meal by the desolventizer-toasters, dryers, and coolers also described in Section 2.2.1.

2.2.4 Peanut Oil Processing¹³

Peanut oil is extracted from peanuts via a process similar to that used for other high oil content oilseeds. Peanut kernels are typically cracked into small pieces, conditioned (cooked), and prepressed through continuous screw presses or expellers where approximately 50 percent of the oil is removed. The prepressed peanut cake is then conveyed to extraction where the balance of the oil is removed by hexane extraction.

The hexane is removed from the oil by an evaporation and condensing system. The crude oil is stored for further processing or shipment. The extracted peanut cake is desolventized and the evaporated hexane is condensed for reuse. The extracted, desolventized peanut cake (now peanut meal) is dried, cooled, ground, sized, and stored for shipment. Figure 2-6 illustrates a typical peanut oil extraction process.

2.3 EMISSIONS^{8,14-15}

There are two principal pollutants from vegetable oil processing: hexane, a reactive VOC commonly used to extract oil from the grains, and particulates, which are released as the raw grain is handled, cleaned and milled. Particulate emissions from grain handling are discussed in the background document and AP-42 Section 9.9.1, Grain Elevators and Processing.

Solvent emissions arise from several sources within vegetable oil processing plants. There are potential solvent emissions from the transfer and storage of hexane onsite, as well as potential leaks of solvent from piping and tanks. Small quantities of solvent (up to 0.2 percent by volume of oil) are present in the crude vegetable oil, even after solvent recovery by film evaporators and the distillation stripper (see Section 2.2.1.3). This hexane may volatilize during the oil-refining process, although no emission data are available. Trace quantities of solvent also are present in the waste water collected from direct contact steam in the distillation stripper and desolventizer-toaster. Adequate emission data from waste water also are not available.

Vents are another source of emissions. Solvent emissions are discharged from three vents: the main vent from the solvent recovery section, the vent from the meal dryer, and the vent from the meal cooler. The main vent receives gases from the oil extractor, the film evaporator and distillation stripper, and the desolventizer-toaster. The meal dryer and cooler typically vents to the atmosphere.

Solvent retained in the meal after the desolventizer-toaster is a fugitive emission source. The hexane retained in the meal is believed to volatilize over time and may occur at the oil processing plant or offsite at a meal processing facility. Hexane concentrations reported from nine of the reviewed source tests showed that the average decrease in hexane concentration from the meal leaving the dryer and the meal leaving the cooler was 21 percent. Samples were taken from the conveyor immediately after the meal left the cooler. Hexane concentrations in meal leaving the cooler and leaving the flour mill (applies only to meal processed into soy flour) decreased by 52 percent. These results suggest that volatilization of hexane may occur from the soybean meal as it is processed into feedstuffs. Hexane in white flakes that is processed into flour for cooking or cooked food for human consumption will probably be volatilized during cooking.

Hexane is listed as a hazardous air pollutant by the U. S. Environmental Protection Agency, and therefore vegetable oil plants represent a potential major source of hazardous air pollution. In addition, trace heavy metal particulate emissions have been identified at cottonseed oil mills at the seed cleaners and linter cyclones. Heavy metals detected were cadmium, chromium, copper, lead, manganese, nickel, zinc, and mercury; all of these metals are hazardous air pollutants. These emissions may be the result of the metals naturally present in soil and may occur in particulate emissions from other vegetable oil mills.

2.4 EMISSION CONTROL TECHNOLOGY⁸

Hexane is recovered and reused in the oil extraction process due to its cost. Condensers and mineral oil scrubbers are used together to recover hexane from exhaust streams. The most efficient recovery or control device is a mineral oil scrubber (MOS). Mineral oil scrubbers used to recover hexane from the main vent gases are approximately 95 percent efficient. However, over half of hexane loss may occur as a result of fugitive emissions from tanks, piping, and equipment shutdowns and breakdowns requiring extraction equipment to be opened. Process controls to reduce breakdowns and leaks can be used to effectively reduce emissions.

REFERENCES FOR SECTION 2

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3. *1987 Census of Manufactures: Fats and Oils*, U.S. Department of Commerce, Bureau of Census, 1988.
4. *Corn Annual 1992*, Corn Refiners Association Inc., Washington, DC, 1992.
5. *95-96 Soya Bluebook Plus-Annual Directory of the World Oilseed Industry*, Soyatech, Inc., Bar Harbor, ME; Data supplied by the National Oilseed Processors Association, September 1995.
6. *Handbook of Soy Oil Processing and Utilization*, D. R. Erickson et al., editors, American Soybean Association and the American Oil Chemists' Society, St. Louis, MO, 1980.
7. *Vegetable Oil Manufacturing*, Contract No. 68-02-2583, Pacific Environmental Services, Santa Monica, CA, September 1979.
8. *Control of Volatile Organic Emissions from Manufacture of Vegetable Oils*, EPA-450/2-78-035, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1978.
9. Written communication from D. C. Ailor, Director of Regulatory Affairs, National Oilseed Processors Association, Washington, DC, to D. Reisdorph, Midwest Research Institute, September 20, 1992.
10. *NFPA 36-Solvent Extraction Plants*, 1993 Edition, National Fire Protection Association, Quincy, MA, February 1993.
11. J. P. Cherry, "Cottonseed Oil," *Journal of the American Oil Chemists' Society*, 60(2):360-367, February 1983.
12. *Corn Refining: The Processes, The Products*, Corn Refiners Association Inc., Washington, DC, 1992.
13. Written communication from D. C. Ailor, Director of Regulatory Affairs, National Oilseed Processors Association, Washington, D.C., to T. Lapp, Midwest Research Institute, September 21, 1995.
14. R. L. Chessin, *Investigating Sources of Hexane Emissions*, Oil Mill Gazetteer, 86(2):35-36,38-39, August 1981.
15. Particulate and Metals Pooled Source Tests, Western Cotton Services Corporation, BTC Environmental Inc., Ventura, CA, April 30-May 1, 1990.

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 vegetable oil processing. Review of emissions data began with a literature and source test search. Literature and data from EPA were reviewed first, including a review of the AP-42 background files located in the Emission Factor and Inventory Group (EFIG), and data base searches on the Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF), VOC/PM Speciation Data Base Management System (SPECIATE), and Air Chief CD-ROM. Source tests from the Emissions, Monitoring, and Analysis Division (EMAD) also were reviewed.

During the review of each document, the following criteria were used to determine the acceptability of reference documents for emission factor development:

1. The report must be 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.
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.

3.2 DATA QUALITY RATING SYSTEM¹

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. Source operation. 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. Sampling procedures. 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. Sampling and process data. 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 SYSTEM¹

The 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.

* Source category: A category in the emission factor table for which an emission factor has been calculated.

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 1992.

4. AP-42 SECTION DEVELOPMENT

The new AP-42 Section 9.11.1, Vegetable Oil Processing, was developed using information provided by the American Soybean Association, National Oilseed Processors Association (NOPA), National Cotton Council (NCC), National Cottonseed Products Association (NCPA), reference documents, and source tests. Emission factor development is only for soybean vegetable oil because of lack of emissions data for other vegetable oil sources.

4.1 REVIEW OF SPECIFIC DATA SETS

For vegetable oil processing, 18 emission test reports and an engineering analysis of vegetable oil processing emissions were reviewed. Ten of the references (Nos. 4 to 9 and 11 to 14) documented a series of tests conducted during 1979 for the Office of Air Quality Planning and Standards (OAQPS) to quantify hexane emissions. These emission tests followed a methodology developed for the EPA to measure vegetable oil emissions. Other references included a draft AP-42 section prepared for EPA in 1979 and a particulates and heavy metals source test performed at a cottonseed oil gin. A brief review of 18 documents selected during the literature search is given below. Full citations of these references are given at the end of this section.

4.1.1 Reference 1

This reference is an engineering analysis of hexane emissions from soybean oil processing. Since a detailed analysis was not provided, it cannot be determined how the emission factors were developed. No data rating was given because no original source test data were presented.

4.1.2 Reference 2

This report is an EPA-prepared document that analyzes emission control technology for the vegetable oil industry. The report provides process descriptions and a discussion of the sources of hexane emissions. Data from reference 1, an engineering analysis of air emissions, were used to create emission factors for vegetable oil manufacturing plants. The development of the emission factors is not completely described, and original data are not provided. Various potential control technologies are investigated for control efficiency, cost effectiveness, and adverse impacts. No data rating was applied to this report because it does not provide source test results.

4.1.3 Reference 3

This reference presents a test method using carbon disulfide to evaluate hexane emissions from vegetable oil processing for the Emission Measurement Center (EMC) of OAQPS. This method was used to analyze vent gases from vegetable oil manufacturers. No rating was assigned to this report because it does not provide source test results.

4.1.4 Reference 4

The Cargill Inc. (East Plant), Cedar Rapids, Iowa, vegetable oil manufacturing plant participated in a 1979 source test sponsored by EPA. Soybean meal samples were taken from the desolventizer-toaster exit, the cooler exit, and the final milling exit. Samples were drawn in triplicate

every hour for a 7-hr period. A volatilization headspace extraction technique and GC/FID analysis were used to measure hexane concentrations in meal.

A rating of A was assigned to the test data. The report includes adequate detail, the methodologies appear to be sound, and no significant problems were reported during valid test runs. Data tables from this report are given in the Appendix (pp. A-3 to A-6).

4.1.5 Reference 5

The Cargill Inc. (West Plant), Cedar Rapids, Iowa, vegetable oil manufacturing plant participated in the 1979 source test sponsored by EPA. Soybean meal samples were taken from the desolventizer-toaster exit, the cooler exit, the flash-desolventizer-toaster exit, the meal grinding exit, the flash tank after the Schneckens cooker, and the flour milling exit. Samples were drawn in triplicate every hour for a 7-hr period. A volatilization headspace extraction technique and GC/FID analysis were used to measure hexane concentrations in soy meal samples. Hexane concentrations in the soymeal from the flash-desolventizer-toaster were higher than concentrations from conventional desolventizer-toasters at other facilities tested.

A rating of A was assigned to the test data. The report includes adequate detail, the methodologies appear to be sound, and no significant problems were reported during valid test runs. Data tables from this report are given in the Appendix (pp. A-7 to A-9).

4.1.6 Reference 6

AGRI Industries, Mason City, Iowa, participated in the 1979 source test of soybean oil emissions sponsored by EPA. Soybean meal samples were taken from the desolventizer-toaster exit, the cooler exit, and the final milling exit. Samples were drawn in triplicate every hour for a 7-hr period. A volatilization headspace extraction technique and GC/FID analysis were used to measure hexane concentration in grab samples of the soybean meal.

A rating of A was assigned to the test data. The report includes adequate detail, the methodologies appear to be sound, and no significant problems were reported during valid test runs. Data tables from this report are given in the Appendix (pp. A-11 to A-13).

4.1.7 Reference 7

The Cargill Inc., Fayetteville, North Carolina, vegetable oil extraction plant participated in the 1979 source test sponsored by EPA. Soybean meal samples were taken from the desolventizer-toaster exit, the dryer exit, the cooler exit, and the meal grinder exit. Samples were drawn in triplicate every hour for a 5-hr period on July 12 and each hour for 2 hr on July 13. A volatilization headspace extraction technique and GC/FID analysis were used to measure hexane concentrations in soy meal samples.

A rating of A was assigned to the test data. The report includes adequate detail, the methodologies appear to be sound, and no significant problems were reported during valid test runs. Data tables from this report are given in the Appendix (pp. A-15 to A-17).

4.1.8 Reference 8

Central Soya Inc., Delphos, Ohio, participated in the EPA-sponsored test for vegetable oil emissions. Hexane vapor emissions were collected at the mineral oil scrubber (MOS) inlet, the mineral oil scrubber outlet, and the cooler vent. The dryer vent was omitted because of unsteady exhaust flow. Samples were drawn using a carbon disulfide (CS₂) impinger train. A series of four runs were performed on the mineral oil scrubber and two runs were performed on the cooler using the EPA Method 25 to obtain samples. Soybean meal samples from the desolventizer-toaster, dryer, and cooler exits were analyzed using a volatilization headspace extraction technique and subsequent analysis with a GC/FID. Six meal sample runs were conducted at the desolventizer-toaster and three at the cooler. Fugitive emissions were measured on-site with an FID.

A rating of A was assigned to the test data. The report includes adequate detail, the methodologies appear to be sound, and no significant problems were reported during valid test runs. Data tables from this report are given in the Appendix (pp. A-19 to A-23).

4.1.9 Reference 9

A. E. Staley Manufacturing Company, Des Moines, Iowa, was another site of the 1979 EPA-sponsored test for soybean vegetable oil emissions. Hexane vapor emissions were collected to determine the extent of solvent loss at vegetable oil plants. Emissions samples were collected from the mineral oil scrubber inlet and outlet, the cooler vent, and the dryer vent. A series of three test runs were conducted. Gas flow estimates were made using EPA Methods 1 and 2; however, the mineral oil scrubber ducts were too small to accommodate an S-type pitot tube so gas velocity was measured with a vane anemeter. Emissions were sampled using an impinger train, a dry-ice freeze trap, and an evacuated cylinder. Soybean meal samples were drawn from the desolventizer-toaster exit, the dryer exit, the cooler exit, and the milling exit. Volatilization headspace extraction and GC/FID analysis were used to measure hexane concentrations.

A rating of B was assigned to the test data. The report included adequate detail and the methodologies appeared to be sound; however, in later reports (see reference 16), it was suggested that the plant was not operating normally. Also, the gas flow measurement problem noted above downgrades the results. Data tables from this report are given in the Appendix (pp. A-25 to A-30).

4.1.10 Reference 10

A draft AP-42 section was prepared in this 1979 report for vegetable oil manufacturing. The emission factors developed relied exclusively on engineering analysis data reported in references 1 and 2. No data rating was assigned to this reference because it provides no source test data.

4.1.11 Reference 11

MFA Soybeans, Mexico, Missouri, participated in the 1979 source test sponsored by EPA. Soybean meal samples were taken in a series of seven test runs from the desolventizer-toaster exit, the cooler exit, and the milling exit. A volatilization headspace extraction technique and GC/FID analysis were used to measure hexane concentrations in the soy meal samples.

A rating of A was assigned to the test data. The report included adequate detail, the methodology appeared to be sound, and no significant problems were reported during valid test runs. Data tables from this report are given in the Appendix (pp. A-31 to A-33).

4.1.12 Reference 12

The Cargill Inc. vegetable oil extraction plant in Sidney, Ohio, participated in a series of vegetable oil processing tests sponsored by EMB in 1979. Hexane vapor emissions were collected at the mineral oil scrubber inlet, the mineral oil scrubber outlet, and the cooler vent using a CS₂ impinger train. The dryer vent was omitted because of unsteady exhaust flow. A series of four runs were conducted on the mineral oil scrubber and two runs on the cooler. EPA Method 25 was used to collect gas samples that were analyzed for hexane by GC/FID. Soybean meal samples were drawn from the desolventizer-toaster, dryer, cooler, and final milling exits and quantified for hexane using a volatilization headspace extraction technique and GC/FID analysis. Six meal sample runs were conducted at the desolventizer-toaster and three at the cooler.

Fugitive emissions of VOCs were measured on-site with an organic vapor analyzer at the following points: outside of extraction building, and at flanges, valves, seams and doors, sightglasses, open-ended pipes, pumps, drains, and ventilation vents. Pumps at the two oil extractor units and at one desolventizer-toaster showed high levels of hexane concentration. The extractor pump hexane readings ranged from 220 ppm to 500 ppm. The desolventizer-toaster pump had readings of 2,000 to 6,000 ppm hexane.

A rating of A was assigned to the test data. The report includes adequate detail, the methodologies appear to be sound, and no significant problems were reported during valid test runs. Data tables from this report are given in the Appendix (pp. A-35 to A-45).

4.1.13 Reference 13

The Ralston Purina, Memphis, Tennessee, vegetable oil extraction plant participated in the 1979 source test sponsored by EPA. Soybean meal samples were taken from the desolventizer-toaster exit, the cooler exit, and the final milling exit. Samples were drawn in triplicate every hour for a 7-hr period. A volatilization headspace extraction technique and GC/FID analysis were used to measure hexane concentrations in the grab samples of soy meal.

A rating of A was assigned to the test data. The report includes adequate detail, the methodologies appear to be sound, and no significant problems were reported during valid test runs. Data tables from this report are given in the Appendix (pp. A-47 to A-49).

4.1.14 Reference 14

The Ralston Purina vegetable oil extraction plant in Bloomington, Illinois, also participated in the 1979 source test sponsored by EPA. Soybean meal samples were taken from the desolventizer-toaster exit, the dryer exit, the cooler exit, edible product meal stripper exit, edible product meal cooler exit, and the final meal product. Samples were drawn in triplicate every hour for a 7-hr period. A volatilization headspace extraction technique and GC/FID analysis were used to measure hexane concentrations in soybean meal samples.

A rating of A was assigned to the test data. The report includes adequate detail, the methodologies appear to be sound, and no significant problems were reported during valid test runs. Data tables from this report are given in the Appendix (pp. A-51 to A-53).

4.1.15 Reference 15

This report provides a national vegetable oil processing plant inventory and estimated emissions based on reference 1 emission factors. The report provides process descriptions and size and location data on most vegetable oil plants operating in the United States. This report provided throughput data for the source test plants. No data rating was given because no source test data were available.

4.1.16 Reference 16

Reference 16 is a technical article that analyzes the 1979 EMC vegetable oil source test results, which present the major hexane emission points at vegetable oil processing plants. Emission factors were developed using the combined source test data. Emissions from hexane remaining in meal are considered a significant source, even though the total measured emissions accounted for only approximately 25 percent to 50 percent of the total hexane usage reported by the plants. Emissions from vegetable oil and wastewater are considered very minimal, because laboratory analysis detected only trace quantities of hexane. Fugitive emissions other than from the meal are suspected to be a major source of hexane loss. Breakdowns, downtime, and leaks were estimated to account for 20 percent to 25 percent of hexane loss. No data rating was given because original source test data were not presented. This article is provided in the Appendix (pp. A-55 to A-58).

4.1.17 Reference 17

This reference provides source emissions tests for particulate matter, metals, and crystalline silica for a cotton gin in Madera County, California. The tests were run on the No. 1 seed cleaner cyclone and the No. 2 linter cyclone. The test used EPA methods for the stack gas velocity and for the particulate emissions. The metals and crystalline silica analysis descriptions sufficiently explain the methods for their analysis.

The ginning process emits small amounts of toxic metals listed as hazardous air pollutants in the Clean Air Act Amendments of 1990. The metals identified in emissions from cotton gins were arsenic, beryllium, cadmium, chromium, lead, manganese, mercury, nickel, and selenium. Since these are trace constituents in soil, the source of these metals is believed to be soil picked up during growing and harvesting operations. As with total particulate matter, the type and amount of metal emissions vary depending on the type of gin, geographic region, type of cotton, harvest method, trash content, climate, production rate, and type and number of controls used.

No process description or process rates are contained in the report, but a Facility Emissions Diagram is included. However, it lacked detailed information on the facility. Therefore, the report could not be used for emission factor development due to the lack of process data. The emission summary data for this source test are included in the Appendix (pp. A-59 to A-61).

4.1.18 Reference 18

Reference 18 presents the results of an engineering and cost study of the grain and feed industry. The report contains survey information from a variety of public and private sources on the emissions from grain elevators and grain processing operations, including soybean processing plants. Normally, data from such a report would not be considered for AP-42 emission factor development because no original test data are reported, and the references in the report are not sufficiently detailed to obtain the original references. However, because Reference 18 formed the basis for most of the particulate matter emission factors from handling operations at soybean plants, the data from this document were considered for those operations.

For a survey report, the emission data reported in Reference 18 are reasonably well documented with explanations provided in the text concerning the general source of the data and the test methods or estimation techniques used to develop the emission estimates. However, original references could not be checked so all data from Reference 18 were rated D. The report contained four data tables with sufficient information for emission factor development, three based on Method 5 type PM tests and one based on engineering estimates. The tables are included in the Appendix (pp. A-63 to A-66) and the emission factors that could be developed from the information in the tables are included in Table 4-1. Emission factors based on emission tests and on engineering estimates are presented separately in the table.

4.1.19 Review of XATEF and SPECIATE Data Base Emission Factors

Emission factors provided on XATEF were based on references 1 and 2, which are engineering analyses. Particulate matter emission factors also are provided, which come from Interim AP-42 Section 9.9.1, Grain Elevators and Processes, November 1995.

4.1.20 Review of Test Data in AP-42 Background File

A draft AP-42 section (reference 10) was prepared in 1979 for vegetable oil processing, but it was not accepted into AP-42. Emission factor data for the section were developed from an engineering analysis (reference 1) of hexane losses from vegetable oil processing plants. No emission tests were conducted for the analysis. The analysis was refined in reference 1 to estimate controlled and uncontrolled hexane emissions.

The 1979 draft AP-42 section included emission factors for soybean, cottonseed, corn, and peanut oil production. The cottonseed, corn, and peanut oil emission factors were estimated from the soybean estimates, which were based upon oil content of the respective products and oil extraction efficiency. Although the analysis of reference 1 was thorough, the proposed emission factors for grains other than soybeans were not based on source test data. Moreover, because reference 16 did not provide a detailed discussion of how emission factors were estimated, no verification of the analysis could be made.

The background file also includes the 10 primary references from the plants that participated in the 1979 source tests cited here to develop vegetable oil emission factors.

TABLE 4-1. SUMMARY OF SOYBEAN PROCESSING PARTICULATE EMISSION FACTORS FROM REFERENCE 18^a

Operation	Control device	Data source ^b	No. of data points	Emission factor	
				kg/Mg	lb/ton
Truck dump pit	Fabric filter	T	1	0.0092	0.018
Forsberg screen	Cyclone	T	1	0.010	0.021
White flakes cooling system	Cyclone	T	1	0.48	0.95
Hull toaster	Cyclone	T	1	0.041	0.082
Flake roll aspiration	Cyclone	T	1	0.064	0.13
Primary dehulling	Cyclone	T	1	0.16	0.31
Hull screens and conveyor	Cyclone	T	1	0.010	0.020
Meal cooler	Cyclone (2)	T	1	0.093	0.19
Meal dryer	Cyclone	T	1	0.0052	0.010
Cracking rolls	Cyclone	Q	1	0.020	0.039
Primary dehulling aspirator	Cyclone	Q	2	0.17	0.33
Secondary dehulling aspirator	Cyclone	Q	2	0.016	0.032
Bean conditioner	Cyclone	Q	1	0.0055	0.011
Hull grinder	Cyclone	Q	3	0.099	0.20
Flaking rolls	Cyclone	Q	3	0.018	0.037
Meal dryer	Cyclone	Q	5	0.076	0.15
Meal grinder	Cyclone	Q	2	0.17	0.34

^aAll data are secondary data from unpublished sources.

^bT = source test, Q = questionnaire

4.1.21 Summary

Table 4-2 summarizes the review of 18 references for purposes of developing emission factors for AP-42 Section 9.11.1, Vegetable Oil Processing.

With respect to hexane emissions, the data presented in this section show that hexane emissions are variable over time and may occur from a number of point and fugitive sources throughout the process. However, there are insufficient data to document plant-to-plant and temporal variability from the various emission points and no data are available for several sources that may account for significant portions of total hexane emissions.

4.2 DEVELOPMENT OF CANDIDATE EMISSION FACTORS

The development of emission factors for vegetable oil processing is limited to soybean oil processing. Development of factors for cottonseed, corn, and peanuts was not possible because no emission measurements were available. Hexane emission factors have been developed for the main vent (controlled emissions only), the dryer vent, the cooler vent, and for fugitive emissions from volatilizing hexane in soybean meal (hexane concentrations in meal exiting the desolventizer-toaster

TABLE 4-2. DOCUMENTS REVIEWED FOR EMISSION FACTOR DEVELOPMENT

Reference No.	Comments
1	Rejected—No source emission tests
2	Rejected—No source emission tests
3	Rejected—No source emission tests
4	Used in emission factor development
5	Used in emission factor development
6	Used in emission factor development
7	Used in emission factor development
8	Used in emission factor development
9	Used in emission factor development
10	Rejected—No source emission tests
11	Used in emission factor development
12	Used in emission factor development
13	Used in emission factor development
14	Used in emission factor development
15	Rejected—No source emission tests
16	Rejected—No source emission tests
17	Rejected-Insufficient process data
18	Used in emission factor development

less dryer vent and cooler vent losses). Particulate matter emission factors for soybean handling were obtained from secondary data provided in Reference 18.

Hexane emissions from vegetable oil manufacture may occur throughout the process. Emissions are generated by:

1. The hexane storage (working) tanks. Hexane volatilizes (breathes) from storage tanks under normal environmental conditions.
2. Leaking or faulty equipment (extractor, oil/solvent strippers, desolventizer-toasters, etc.), seals, piping, vents, and so forth. Shutdowns and breakdowns are suspected to be a major source of hexane emissions because sealed equipment must be opened for repairs and adjustments, thereby releasing solvent.
3. The main vent. Gases from the oil extractor, the oil/solvent stripping system, and the desolventizer-toaster are exhausted through the main vent in most plants. The main vent emissions are controlled by mineral oil scrubbers, which recover up to 95 percent of hexane in the vent gases.
4. The meal dryer and cooler vents. These vents are typically exhausted to the atmosphere with only cyclone control to reduce particulate matter. Meal exiting the desolventizer-toaster contains residual hexane, which under normal ambient conditions may volatilize from the meal. During the

meal drying and cooling processes, hexane volatilizes from the meal and is vented to the atmosphere through the dryer and cooler vents.

5. Soybean meal. As noted above, soybean meal, which contains hexane, normally volatilizes as it leaves the desolventizer-toaster. The meal is typically carried on open (nonsealed) conveyors when it exits the desolventizer-toaster, allowing hexane to volatilize to the atmosphere. All of the hexane in the meal is believed to volatilize (although not at the processing plant), except for possible trace amounts that may remain bound to any residual oil in the meal. Some of this hexane will be emitted through the dryer and cooler vents; however, the rest will be emitted to the atmosphere as fugitive emissions.

6. Wastewater. The desolventizer-toaster and the oil/solvent distillation stripper contact steam is collected as wastewater. Trace quantities of hexane have been detected in the wastewater. Under normal conditions the hexane will volatilize from the wastewater.

Following is a discussion of the summary results of the source tests, as well as a discussion of the reported data on total hexane loss from the 10 plants participating in the source tests. The discussion is divided into total emissions, emissions from vents, and fugitive emissions from soybean meal. Data are not available to adequately discuss emissions from equipment breakdown, storage tanks, oil refining and wastewater.

4.2.1 Total Emissions

The vegetable oil industry reports hexane disappearance or loss and, consequently, hexane makeup quantity (the amount of hexane replaced to make up losses), to estimate hexane emissions for air permitting purposes. Hexane is very volatile; therefore, it is assumed that all hexane lost becomes an air emission. Under Section 112 of the 1990 Clean Air Act Amendments, hexane is classified as a hazardous air pollutant (HAP). Data from state environmental agencies were unobtainable; however, reference 16 provides the reported hexane losses from the 10 plants that participated in the 1979 source tests. The data on hexane loss were self-reported by the plant operators and are shown in Table 4-3.

The mean reported loss by the 10 plants is 3.3 liters per metric ton (L/MT) of raw soybeans processed (0.89 gal/ton). This mean loss is based on the quantity of hexane purchased to replenish solvent losses and the total quantity of soybeans processed. This loss rate is an estimate of a total emission factor for soybean oil processing. Hexane is used only during the oil extraction step so that the quantity of hexane purchased represents solvent losses during the extraction step and subsequent processing steps.

4.2.2 Vent Emissions

To develop hexane emission factors from the soybean processing source test reports, the vent gas hexane concentrations (in ppm) were converted into equivalent volume of liquid hexane released per weight of soybeans processed. This conversion was accomplished by taking hexane weight gas flow rates from the respective vents and dividing by the estimated weight of raw soybeans being processed in the test period. Calculations for the respective tests are shown in the Appendix,

TABLE 4-3. REPORTED HEXANE LOSS^a

Ref. No.	Plant	Reported hexane loss (gal/ton raw soybeans)	Reported hexane loss (L/MT raw soybeans)
6	A	0.3	1.12
14	B	1.75	6.52
4	C	0.4	1.49
9	D	0.85	3.17
13	E	2.2	8.20
5	F	0.9	3.35
11	G	0.9	3.35
12	H	0.3	1.12
7	I	0.5	1.86
8	J	0.75	2.79
Average		0.89	3.3

^aReference 16.

Calculations and Source Test Data. Only the outlet data for the main vent were analyzed since all plants use condensers and mineral oil scrubbers to control hexane emissions.

Table 4-4 provides the summary test data for the source tests. The average (mean) vent gas concentrations shown in Table 4-4 provide the emission factors for these sources. Data from reference 9 are not included in Table 4-4 because it was believed the plant was not operating normally at the time of the source test. Likewise, reference 9 data are not used to develop the final emission factors.

Main vent emissions are largest, followed by the dryer vent and cooler vent emissions. The emissions drop considerably from the dryer vent to the cooler vent. This result was expected because the hexane concentration in soybean meal should be high when the meal exits the desolventizer toaster and should decline while the meal is dried.

4.2.3 Fugitive Emissions from Soybean Meal

Emission factors were estimated for fugitive emissions from soybean meal based upon the hexane concentration data, in parts per million (ppm), provided in the source test reports. To utilize the data, a conversion from ppm of hexane in the meal to gallons of hexane per weight of raw soybeans processed was used.¹⁶

$$H = HC \cdot R \quad (\text{Eq. 4-1})$$

where:

- H = gallons of hexane per ton of raw soybeans
- HC = hexane concentration in soybean meal, ppm ($\mu\text{g/g}$)
- R = 0.0003; gallons of hexane per ton of raw soybean equivalent to 1 ppm of hexane in the soybean meal.

TABLE 4-4. HEXANE CONCENTRATIONS IN SOYBEAN MEAL AND VENT GASES DURING PROCESSING IN L/MT (GAL/TON)

Ref No.	Plant	Average meal concentrations			Average vent gas concentrations		
		Desolventizer toaster	Dryer	Cooler	Main vent	Dryer vent	Cooler vent
4	C	0.253 (0.068)	—	0.122 (0.033)	—	—	—
5	F	1.54 (0.414)	—	0.492 (0.132)	—	—	—
6	A	0.25 (0.067)	—	0.126 (0.034)	—	—	—
7	I	0.82 (0.220)	0.668 (0.179)	0.731 (0.196)	—	—	—
8	J	0.829 (0.223)	0.742 (0.199)	0.656 (0.176)	0.121 (0.032)	0.089 (0.024)	0.023 (0.006)
11	G	0.298 (0.08)	—	0.235 (0.063)	—	—	—
12	H	0.195 (0.052)	0.117 (0.031)	0.119 (0.032)	0.184 (0.05)	—	0.018 (0.005)
13	E	0.463 (0.124)	0.277 (0.074)	—	—	—	—
14	B	0.433 (0.116)	0.406 (0.109)	0.396 (0.106)	—	—	—
Average		0.565 (0.152)	0.442 (0.119)	0.360 (0.097)	0.153 (0.041)	0.089 (0.024)	0.021 (0.005)

The processed weight of soybeans is less than the raw weight due to removal of debris and soybean hulls. The approximate weight reduction during processing for oil extraction is approximately 400 lb; therefore, 1 ton of raw soybeans yields 1,600 lb of processed bean.

Table 4-4 shows the summary test data for hexane concentrations in meal exiting the desolventizer-toaster, the meal dryer, and the meal cooler. As expected, the data show on average that the hexane concentration decreases as the meal moves from the desolventizer-toaster to the dryer and cooler. The desolventizer-toaster hexane in meal concentration from the reference 5 plant was substantially higher than the average concentration from the nine plants. The high concentrations at the reference 5 plant may be because of the use of a specialty flash desolventizer that is believed to be less efficient than the standard desolventizer-toasters used at the other plants.

The emission factor for fugitive emissions from soybean meal was estimated starting from the point where the meal exits the desolventizer-toaster. Fugitive emissions from the soybean meal equals the amount of hexane present in the meal exiting the desolventizer-toaster less the amount of hexane that is emitted through the dryer and cooler vents (References 1, 15, and 16).

This approach compares the amount of hexane exiting the dryer and cooler vents and the amount of hexane present in meal exiting the desolventizer-toaster.

$$\text{FEF} = \text{DTC} - (\text{DVE} + \text{CVE}) \quad (\text{Eq. 4-2})$$

where:

- FEF = fugitive emission factor for hexane volatilizing from soybean meal
- DTC = average hexane concentration in soybean immediately exiting the desolventizer-toaster
- DVE = average hexane concentration for dryer vent gas emissions
- CVE = average hexane concentration for cooler vent gas emissions

Applying Eq. 4-2 gives an emission factor for fugitive emissions from meal of 0.455 L/MT of soybeans processed (0.123 gal/ton). This factor is based on average concentration data reported in Table 4-4.

4.2.4 Comprehensiveness of the Source Test Data

Because the source test data do not cover all sources of hexane loss, the total hexane loss cannot be estimated from the source test data. Fugitive emissions from storage tanks, leaking or faulty equipment, and wastewater were not measured; appropriate throughput data were unavailable to develop total loss estimates. An estimate of the total amount of hexane loss was determined because each plant reported average hexane loss in gallons per ton (gal/ton) of raw soybeans processed. If an estimate of hexane loss attributable to fugitive losses from storage tanks, equipment, and from wastewater is necessary, subtraction of measured hexane losses from the total hexane loss can provide this estimate.

Reference 8 is the only source test that provides measurements for losses from the main vent, cooler and dryer vents, and soybean meal (fugitive emission from soybean meal). Average (arithmetic

mean) values of hexane loss (L/MT of raw soybeans processed) for each source from reference 8 (see Table 4-4) are:

Main vent—0.121 L/MT
Dryer vent—0.089 L/MT
Cooler vent—0.023 L/MT
Soybean meal—0.717 L/MT (see Eq. 4-2)

The reported total loss of hexane from the plant was 2.79 L/MT (0.75 gal/ton) of raw soybeans processed. Subtracting the emissions from the main vent, dryer vent, cooler vent, and soybean meal from the reported total hexane loss gives a difference of 1.84 L/MT (0.49 gal/ton) in emissions that were unaccounted for by this source test.

4.2.5 Summary of Emission Factors

The emission factors for the main vent, cooler vent, and dryer vent are rated D. Fugitive emissions are rated E because they are estimates derived from D-rated data. Although the source tests used were all A-rated, there were a relatively small number of source tests compared to the total number of soybean processing plants. Because of the small number of source tests, it is unlikely that the tested facilities represented a random sample of the industry.

In addition, the source tests are conducted over a relatively short time period and are representative of the hexane usage and emissions at the time of the test. The quantity of hexane used for extraction is dependent, among other factors, on the type of soybean being processed and the moisture level of the beans. Depending on the particular soybean being processed, the conditions during the tests may not be representative of annual operations at that facility or representative of operations at facilities in other geographical regions.

Only two source test results could be used to estimate cooler and main vent emissions. Although the data for the two source tests for cooler and main vent emissions appear to be consistent, the variability in vent emissions over short time periods may be large. The source tests did provide usable hexane concentrations in soybean meal from which fugitive emissions from soybean meal could be estimated. Only one source test result could be used to estimate dryer vent emissions.

The recommended method for estimating annual hexane emissions from soybean solvent extraction facilities is to obtain the annual hexane usage from the specific plant's records, and assume that all hexane make-up is due to losses to the air (SCC 3-02-019-97). (Some hexane leaves the facilities as a small fraction of the oil or meal products, but this amount has not been quantified.) If the hexane usage amount is determined from purchase records and accounts for any change in amount stored on-site, then storage tank losses would already be accounted for in the loss estimate. If the usage is determined from the amount metered out of the storage tanks, then the storage tank losses should be calculated separately and in addition to the usage losses, using the equations in Chapter 7 or the TANKS software. Careful application of such a material balance approach should produce emission estimates comparable in quality to those derived from a B-rated emission factor.

The mean total hexane loss reported by the plants in References 11 through 19 was 3.3 L/Mg (0.89 gal/ton) of raw soybeans processed (SCC 3-02-019-98). This represents an overall total loss factor for soybean oil processing, encompassing all sources of vented and fugitive emissions (and storage tanks), as well as any hexane leaving the facility as part of the oil or meal products. If a

facility is new or plant-specific usage data are unavailable, this factor can be used as a default value until the relevant data become available for the facility. The default value should be used only until the facility can compile the data needed to develop a plant-specific hexane loss for the period of interest. This emission factor is rated D.

Limited data on PM emissions from soybean processing plants were presented in Reference 18. These data were obtained from unpublished emission test data and from industry questionnaires. Because all data were secondary data, the test data and questionnaire data were weighted equally in calculating emission factors, and the factors were calculated as arithmetic means of the data presented in Table 4-1. Table 4-5 presents the recommended total particulate emission factors for vegetable oil processing. Because the data are secondary, all emission factors are rated E.

Table 4-6 presents the hexane emission factors for three specific processes and for fugitive emissions from the soybean meal. Main vent emissions are identified as oil extraction-main vent process, and the dryer and cooler vent emissions are identified as meal dryer and meal cooler processes. The emission factor for fugitive emissions from soybean meal is based on the assumption that all of the solvent remaining in the meal at the exit point from the desolventizer-toaster is released either through the dryer vent, meal cooler vent, or as fugitive emissions from the soybean meal. Residual hexane contained in the meal may be emitted when the meal is processed into feedstuffs. The emission factor in Table 4-6 represents total emissions from the meal. It does not represent hexane emissions from the meal at the oil processing facility; there are no data to quantify those emissions.

These emission factors should be used only in the event that factors are required for specific processes. The sum of these factors do not represent total hexane emissions from the facility because there are other potential emission sources for which no emission data are available. Because these factors were developed using data from a small number of facilities, the factors should be used as default values until facility specific data are available.

TABLE 4-5. TOTAL PARTICULATE EMISSION FACTORS FOR SOYBEAN MILLING^a
EMISSION FACTOR RATING: E

Operation	Control device	Emission factor ^b	
		kg/Mg	lb/ton
Receiving ^c (SCC 3-02-007-81)	None	0.075	0.15
Handling (SCC 3-02-007-82)	ND	ND	ND
Cleaning (SCC 3-02-007-83)	ND	ND	ND
Drying (SCC 3-02-007-84)	ND	ND	ND
Cracking/dehulling (SCC 3-02-007-85)	Cyclone	0.18	0.36
Hull grinding (SCC 3-02-007-86)	Cyclone	0.099	0.20
Bean conditioning (SCC 3-02-007-87)	Cyclone	0.005	0.010
Flaking rolls (SCC 3-02-007-88)	Cyclone	0.018	0.037
White flake cooler (SCC 3-02-007-92)	Cyclone	0.48	0.95
Meal cooler (SCC 3-02-007-90)	Cyclone	0.093	0.19
Meal dryer (SCC 3-02-007-89)	Cyclone	0.09	0.18
Meal grinder/sizing (SCC 3-02-007-93)	Cyclone	0.17	0.34
Meal loadout ^d (SCC 3-02-007-91)	None	0.14	0.27

^a Emission factors are based on quantity of soybeans processed by the unit. Factors represent controlled emissions unless noted otherwise. SCC = Source Classification Code.

^b Reference 18. These data were obtained from unpublished emission test data and from industry questionnaires. Because these are secondary data, the test data and questionnaire results were weighed equally and the emission factors were calculated as arithmetic means of the data. The emission factor rating is a reflection of the source of the data.

^c See Interim AP-42 Section 9.9.1, Grain Elevators and Processes, dated November 1995.

^d Reference 19.

TABLE 4-6. HEXANE EMISSION FACTORS FOR SOYBEAN OIL MANUFACTURING^a

Process	Emission factor		Emission factor rating
	L/MT	gal/ton	
Oil extraction-main vent ^b (SCC-3-02-019-16)	0.153	0.041	D
Meal dryer ^c (SCC-3-02-007-89)	0.089	0.024	D
Meal cooler ^c (SCC-3-02-007-90)	0.021	0.006	D
Fugitive emissions from meal ^d (SCC-3-02-019-22)	0.455	0.122	E

^a Factors represent controlled emissions. SCC = Source Classification Code.

^b References 8 and 12.

^c Reference 8.

^d References 4-8, 11-14. This factor represents total emissions from the meal. A portion of the emissions may occur at the oil processing facility and the remainder may occur off site during subsequent processing of the meal.

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