

9.11.1 Vegetable Oil Processing

9.11.1.1 General¹⁻⁵

The industry group producing fats and oils includes cottonseed oil mills, soybean oil mills, vegetable oil mills (other than corn, cottonseed, and soybean), and other mills. Wet corn mills are the primary producers of corn oil. Approximately 137 vegetable oil plants operate in the United States. Soybean processing, which dominates the industry, produces approximately 80 percent of the volume of vegetable oil and is concentrated in the states of Iowa, Illinois, Missouri, Kansas, Indiana, and Minnesota, but also found across the nation. Likewise, wet corn mills are concentrated in Corn Belt states. Cottonseed oil mills are found in southern states and California.

9.11.1.2 Process Description⁶⁻⁹

The following process description discusses only soybean oil manufacture, because emission factors are available only for that activity. Corn, cottonseed, and peanut oil processing are similar to soybean processing, except for differences in the soybean preparation for oil extraction. The process for soybeans typically consists of five steps: oilseed handling/elevator operations, preparation of soybeans for solvent extraction, solvent extraction and oil desolventizing, flake desolventizing, and oil refining.

Oilseed Handling/Elevator Operations -

Figure 9.11.1-1 is a schematic diagram of a typical soybean handling/elevator operation that precedes the preparation of soybeans for the solvent extraction process.

Soybeans received at the facility by truck or rail are sampled and analyzed for moisture content, foreign matter, and damaged seeds. Then 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 materials and loose hulls. Screens typically are used to remove foreign materials such as sticks, stems, pods, tramp metal, sand, and dirt. An aspiration system is used to remove loose hulls from the soybeans; these hulls may be combined later with hulls from the dehulling aspiration step. The beans are passed through dryers to reduce their moisture content to approximately 10 to 11 percent by weight and then are conveyed to process bins for temporary storage and tempering for 1 to 5 days in order to facilitate dehulling.

Preparation Of Soybeans For Solvent Extraction -

Figure 9.11.1-2 is a schematic diagram of the process used to prepare soybeans for the solvent extraction process. 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, which are passed through aspirators to remove the hulls (processed separately after the removal of residual bean chips). These hulls may be combined with the hulls from the grain cleaning step.

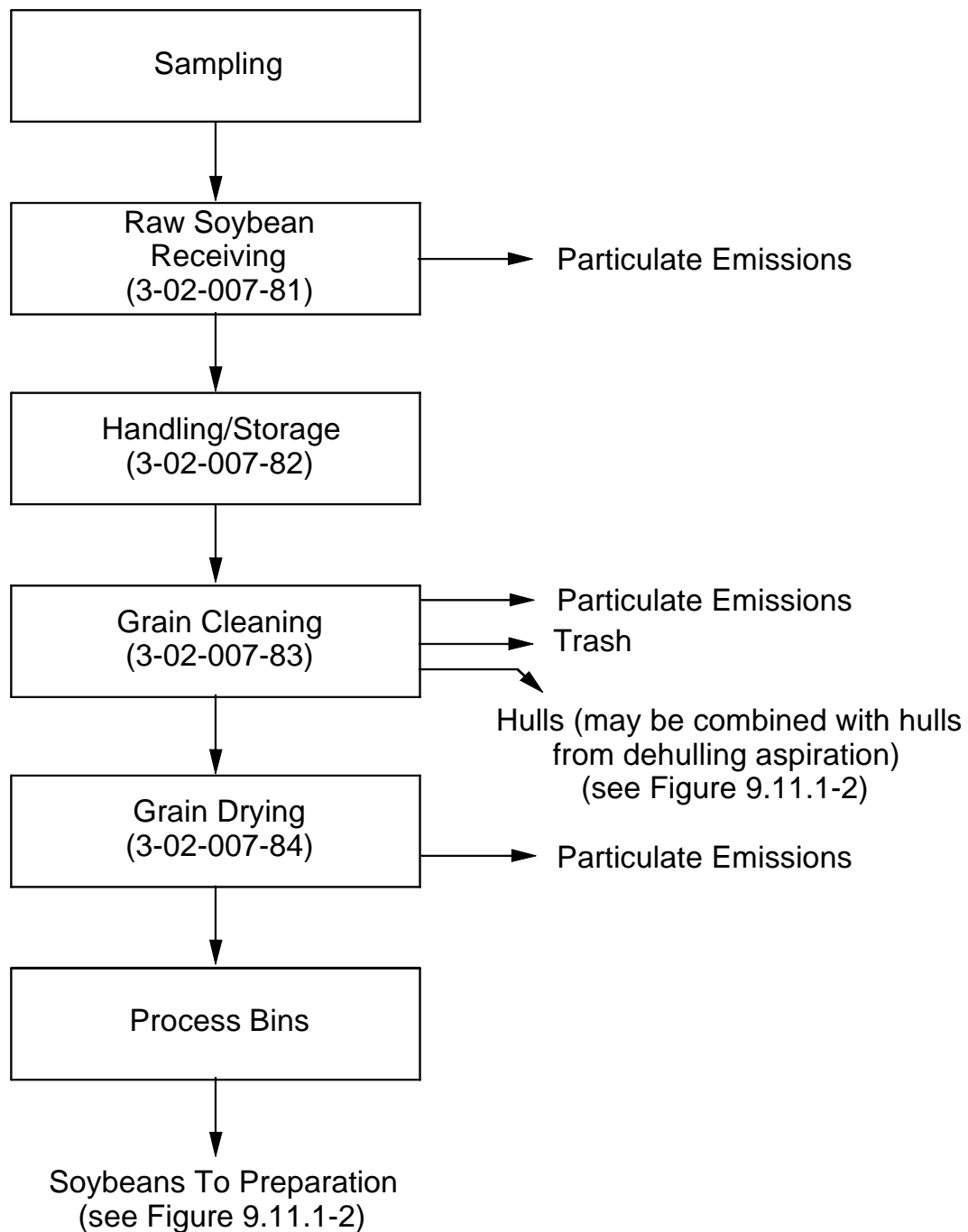


Figure 9.11.1-1. Flow diagram of typical soybean handling/elevator operations.
(Source Classification Codes in parentheses.)

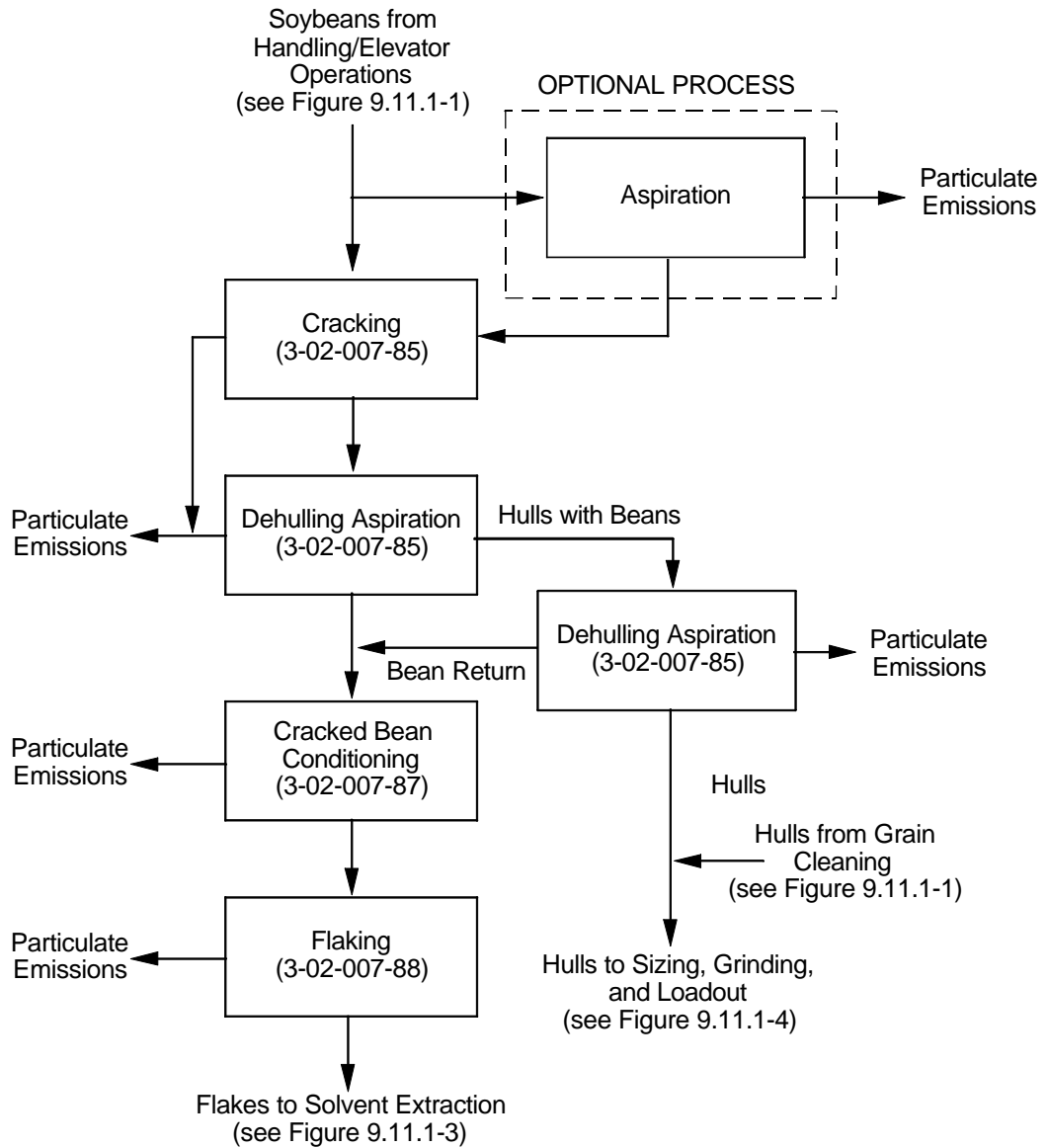


Figure 9.11.1-2. Flow diagram of the typical process for preparing soybeans for solvent extraction. (Source Classification Codes in parentheses.)

Next, the cracked beans and bean chips are conveyed to the conditioning area, where they are put either into a rotary steam tubed device or into a stacked cooker and are 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.

Solvent Extraction and Oil Desolventizing -

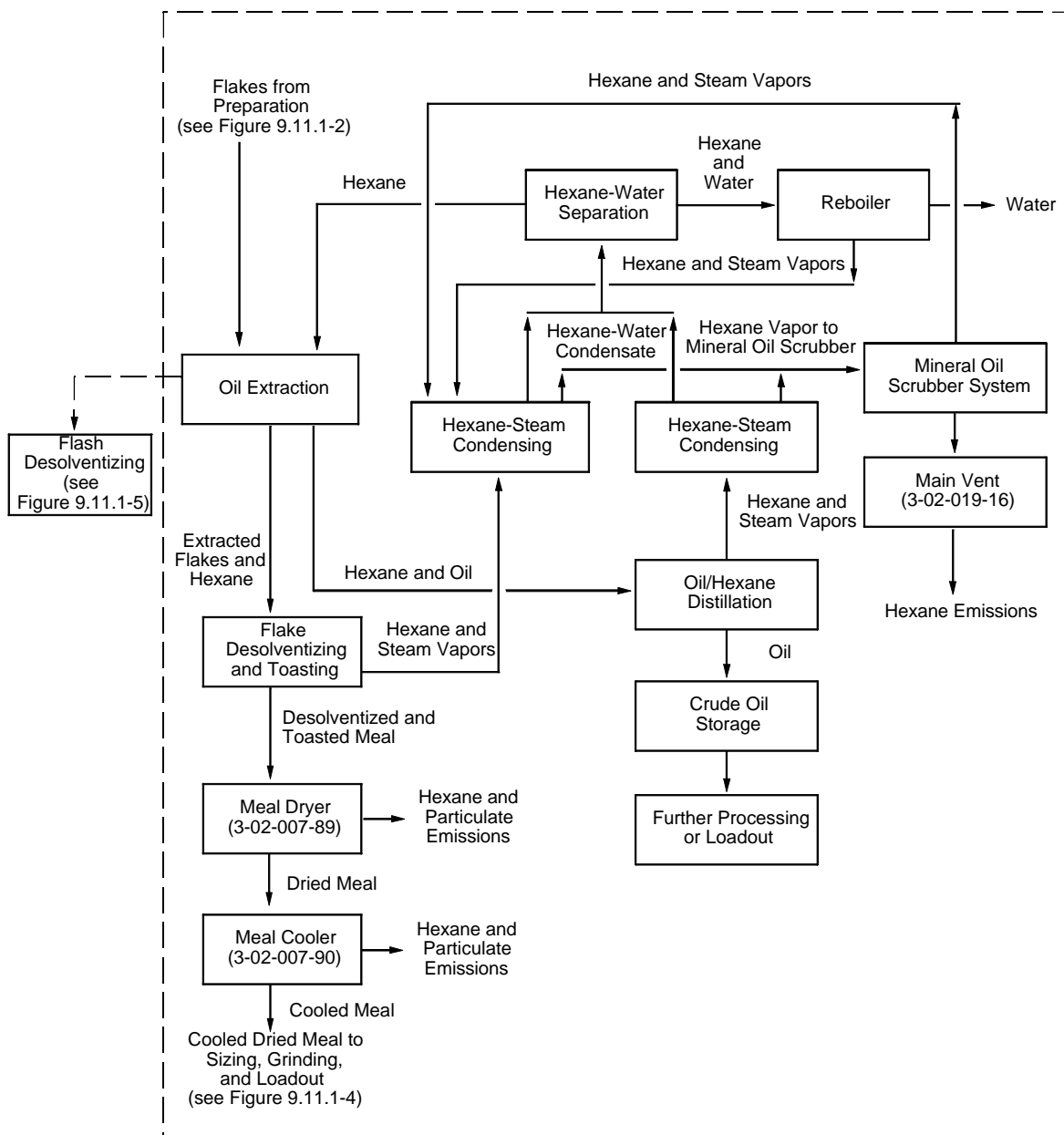
The extraction process consists of "washing" the oil from the soybean flakes with hexane solvent in a countercurrent extractor. Then the solvent is evaporated (i. e., desolventized) from both the solvent/oil mixture (micella) and the solvent-laden, defatted flakes (see Figure 9.11.1-3). The oil is desolventized by exposing the solvent/oil mixture to steam (contact and noncontact). Then the solvent is condensed, separated from the steam condensate, and reused. Residual hexane not condensed is removed with mineral oil scrubbers. The desolventized oil, called "crude" soybean oil, is stored for further processing or loadout.

Desolventizing Flakes -

The flakes leaving the extractor contain up to 35 to 40 percent solvent and must be desolventized before use. Flakes are desolventized in one of two ways: either "conventional" desolventizing or specialty or "flash" desolventizing. The method used depends upon the end use of the flakes. Flakes that are flash desolventized are typically used for human foods, while conventionally desolventized flakes are used primarily in animal feeds.

Conventional desolventizing takes place in a desolventizer-toaster (DT), where both contact and noncontact steam are used to evaporate the hexane. 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 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 (see Figure 9.11.1-4).

Flash desolventizing is a special process that accounts for less than 5 percent by volume of the annual nationwide soybean crush. The production of flakes for human consumption generally follows the flow diagram in Figure 9.11.1-3 for the "conventional" process, except for the desolventizing step. In this step, the flakes from the oil extraction step are "flash" desolventized in a vacuum with noncontact steam or superheated hexane. This step is followed by a final solvent stripping step using steam. Both 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, hexane vapors pass to the mineral oil scrubber and the hexane-water condensate goes to the separator, as shown in Figure 9.11.1-3. The flakes produced by the flash process are termed "white flakes". A process flow diagram for the flash desolventizing portion of the soybean process is shown in Figure 9.11.1-5. From the stripper, the white flakes pass through a cooker (an optional step) and a cooler prior to further processing steps similar to the "conventional" process. A plant that uses specialty or "flash" desolventizing requires different equipment and is far less efficient in energy consumption and solvent recovery than a plant that uses conventional desolventizing. Given these facts, solvent emissions are considerably higher for a specialty desolventizing process than for a similar-sized conventional desolventizing process.



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

Figure 9.11.1-3. Flow diagram of the "conventional" solvent extraction process.
 (Source Classification Codes in parentheses.)

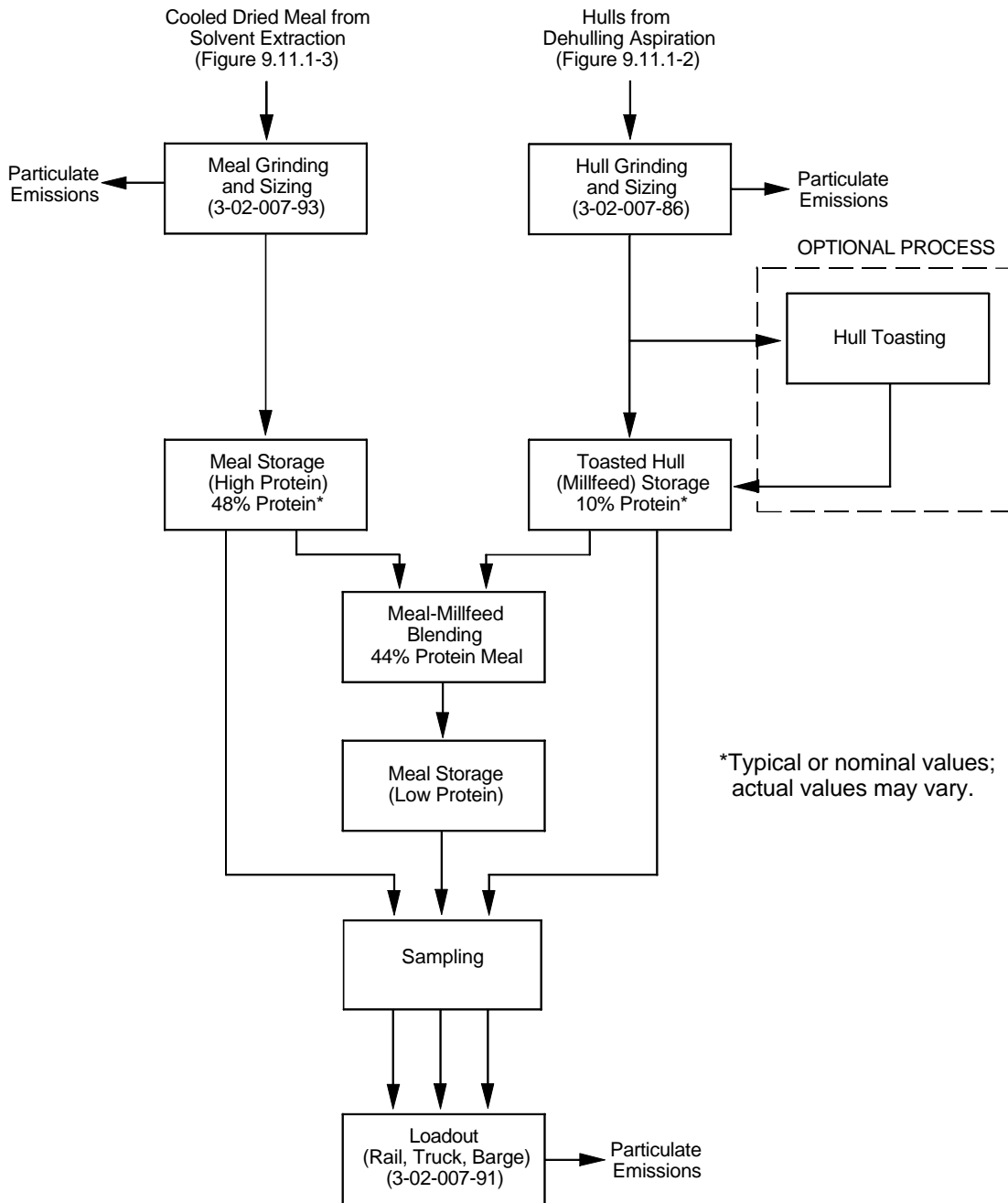


Figure 9.11.1-4. Flow diagram for "conventional" process of dry material sizing, grinding, and loadout.
(Source Classification Codes in parentheses.)

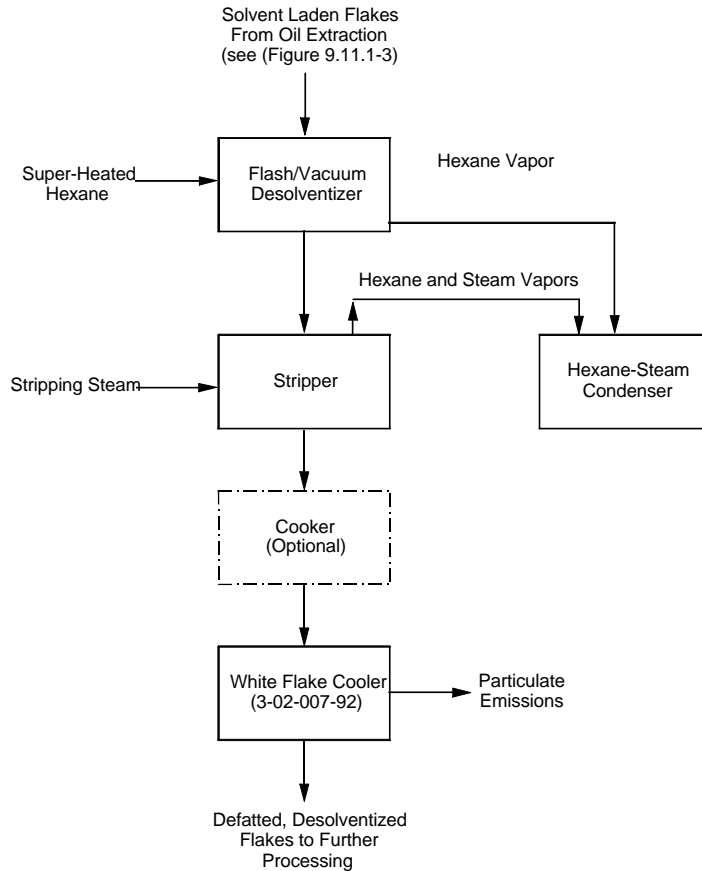


Figure 9.11.1-5. Flow diagram of the flash desolventizing process.
(Source Classification Code in parentheses.)

Vegetable Oil Refining -

Crude oil is typically shipped for refining to establishments engaged in the production of edible vegetable oils, shortening, and margarine. Crude vegetable oils contain small amounts of naturally occurring materials such as proteinaceous material, free fatty acids, and phosphatides. Phosphatides are removed for lecithin recovery or to prepare the crude oil for export. 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, caused by 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 are removed by deodorization, which uses steam injection under a high vacuum and temperature. The refined oil is then filtered and stored until used or transported.

9.11.1.3 Emissions And Controls^{6,10-20}

Emissions -

Particulate matter and volatile organic compounds are the principal emissions from vegetable oil processing. Particulate matter (PM) results from the transfer, handling, and processing of raw seed. VOC emissions are the oil extraction solvent, hexane, which is classified as a hazardous air pollutant. Particulate emissions from grain handling are discussed in the Interim AP-42 Section 9.9.1, "Grain Elevators And Processes".

Solvent emissions arise from several sources within vegetable oil processing plants. There are potential solvent emissions from the transfer and storage of hexane on site as well as potential leaks from piping and vents. Small quantities of solvent (up to 0.2 percent by volume of oil) are present in the crude vegetable oil after the solvent is recovered by film evaporators and the distillation stripper. This hexane may volatilize during the oil-refining process; however, no emission data are available. Trace quantities of solvent are present and available for volatilization in waste water collected from the condensation of steam used in the distillation stripper and desolventizer-toaster. Emission data from waste water also are not available.

Vents are another source of emissions. Solvent is 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. Vents for the meal dryer and meal cooler typically vent to atmosphere.

Hexane 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 to 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 is determined from purchase records and the purchased amount accounts for any change in quantities 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 AP-42 Chapter 7 or in 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 [4.9 lb/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. For a new facility or if plant-specific usage data are unavailable, this factor, rated D, can be used as a default value until the relevant data for the facility become available. 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.

Particulate Emissions -

Table 9.11.1-1 presents emission factors for total PM emissions resulting from handling and processing soybeans in vegetable oil manufacturing. Emission factors are provided for PM-generating processes for the meal production process, including meal drying and cooling.

Table 9.11.1-1. TOTAL PARTICULATE EMISSION FACTORS FOR SOYBEAN MILLING^a

EMISSION FACTOR RATING: E

Process	Control Device	Emission Factor (lb/ton) ^b
Receiving ^c (SCC 3-02-007-81)	None	0.15
Handling (SCC 3-02-007-82)	ND	ND
Cleaning (SCC 3-02-007-83)	ND	ND
Drying (SCC 3-02-007-84)	ND	ND
Cracking/dehulling (SCC 3-02-007-85)	Cyclone	0.36
Hull grinding (SCC 3-02-007-86)	Cyclone	0.20
Bean conditioning (SCC 3-02-007-87)	Cyclone	0.010
Flaking rolls (SCC 3-02-007-88)	Cyclone	0.037
White flake cooler (SCC 3-02-007-92)	Cyclone	0.95
Meal cooler (SCC 3-02-007-90)	Cyclone	0.19
Meal dryer (SCC 3-02-007-89)	Cyclone	0.18
Meal grinder/sizing (SCC 3-02-007-93)	Cyclone	0.34
Meal loadout ^d (SCC 3-02-007-91)	None	0.27

^a Emission factors are based on pounds per ton of soybeans processed by the unit. Factors represent controlled emissions, except as noted. Divide the lb/ton factor by two to obtain kg/Mg. SCC = Source Classification Code, ND = No Data.

^b Reference 21. These data were obtained from unpublished emission test data and from industry questionnaires. Because these are secondary data, the test data and the 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".

^d Reference 22.

Controls -

Hexane is recovered and reused in the oil-extraction process because of its cost. The steam and hexane exhausts from the solvent extractor, desolventizer-toaster, and oil/hexane stripping are passed through condensers to recover hexane. Residual hexane from the condensers is captured by mineral oil scrubbers. The most efficient recovery or control device is a mineral oil scrubber (MOS), which is approximately 95 percent efficient. The meal dryer and cooler vents are typically exhausted to the atmosphere with only cyclone control to reduce particulate matter. Process controls to reduce breakdowns and leaks can be used effectively to reduce emissions. Quantities of hexane may be lost through storage tanks, leaks, shutdowns, or breakdowns. These losses are included in the material balance.

References for Section 9.11.1

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