Emission Factor Documentation for AP-42
Section 9.13.3

Snack Chip Deep Fat Frying

Final Report

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

EPA Contract No. 68-D2-0159
Work Assignment No. I-08

MRI Project No. 4601-08

August, 1994

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

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NOTICE

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Contract No. 68-D2-0159 to Midwest Research Institute. It has been subjected to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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 EPA Contract No. 68-D2-0159, Work Assignment No. 005 and I-08. Mr. Dallas W. Safriet was the EPA Work Assignment Manager.

Approved for:

MIDWEST RESEARCH INSTITUTE

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August, 1994

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SECTION 1
INTRODUCTION

The document *Compilation of Air Pollutant Emission Factors* (AP-42) has been published by the U.S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been issued to add new emission source categories and to update existing emission factors. The EPA also routinely updates AP-42 in response to the needs of federal, state, and local air pollution control programs and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. Emission factors reported in AP-42 are used to:

1. Estimate areawide emissions;
2. Estimate emissions for a specific facility; and
3. Evaluate emissions relative to ambient air quality.

The purpose of this background report is to provide information to support preparation of a new AP-42 Section 9.13.3—Snack Chip Deep Fat Frying.

This report consists of five sections. Following this introduction, Section 2 gives a description of the potato chip and snack chip industry, including a brief characterization of the industry, an overview of the deep fat frying process, and identification of the emission sources and emission control techniques. Section 3 describes the literature search, screening of emission source data, and the EPA quality rating system for both emission data and emission factors. Section 4 describes the documents that were evaluated to develop candidate emission factors for deep fat frying operations in the snack chip industry, and Section 5 presents the proposed AP-42 Section 9.13.3—Snack Chip Deep Fat Frying.

SECTION 2
INDUSTRY DESCRIPTION

2.1 INDUSTRY CHARACTERIZATION[1-4]

The production of potato chips, corn chips, and other related snack chips is a growing, competitive industry. Sales of snack chips in the United States are projected to grow 5.7 percent between 1991 and 1995. Between 1987 and 1991, potato chip sales increased from 649 x 10^6 kg to 712 x 10^6 kg (1,430 x 10^6 lb to 1,570 x 10^6 lb) an increase of 63 x 10^6 kg (140 x 10^6 lb) (10 percent). In 1991, the average annual per capita consumption of potato chips in the United States was 2.9 kg (6.3 lb).

New products and processes are being developed to create a more health-conscious image for snack chips. Examples include the recent introduction of multigrain chips and the use of vegetable oils (noncholesterol) in frying. Health concerns are also encouraging the promotion and introduction of nonfried snack products like pretzels, popcorn, and crackers.

While many companies distribute on a nationwide basis, several new local and regional manufacturers have been introduced into the market in recent years. Competition from new national manufacturers is growing as well. Snack chip plants are widely dispersed across the country with the highest concentrations in high population states like California and Texas. Table 2-1 shows the geographical distribution of snack chip plants by EPA region.

The standard industrial classification code (SIC) for snack chips is 2096. The industry source classification code (SCC) for snack chips is 3-02-036.

TABLE 2-1. NUMBER OF SNACK CHIP PLANTS IN THE UNITED STATES BY EPA REGION

Region	Number of plants[a]
I	10
II	8
III	38
IV	35
V	76
VI	45
VII	30
VIII	13
IX	53
X	6
Total	343

Source: Reference 1.
[a]Difference between sum for regions and nationwide total is a result of nonreporting for some states to maintain confidentiality of data for specific plants.

2.2 PROCESS DESCRIPTION[5,6,7]

Vegetables and other raw foods are cooked by industrial deep fat frying and packaged for later use by consumers. When the raw food is immersed in hot cooking oil, the oil replaces the food's naturally occurring moisture during the cooking process. Either batch or continuous processes may be used for deep fat frying; continuous fryers, however, produce the majority of snack chips. The batch frying process consists of immersing the food in the cooking oil until it is fried and then removing it using a basket or dipper. In the continuous frying process, the food is continuously moved through the cooking oil on a conveyor.

Figure 2-1 provides an overview of the deep fat snack chip frying process. The differences between the potato chip process and other snack chip processing operations are also shown in Figure 2-1. Some snack chip processes (e.g., tortilla chips) include a toasting step. Because the potato chip processes represent the largest industry segment, they are discussed as a representative example.

2.2.1 Continuous Frying

Figure 2-2 is a process flow diagram for continuous fryer operation. Potato chip production begins with preparation of the raw material. Dirt, decayed potatoes, and other debris are first removed in cleaning hoppers. The potatoes go next to washers and then to either abrasion, steam, or lye peelers. The abrasion method, which is the most popular procedure, is performed as either a batch or continuous process, depending on the number of potatoes to be peeled.

Slicing, which is the next step, is performed by a rotary slicer. Potato slice widths vary according to the condition of the potatoes and the type of chips being made. The potato slices next move through rotating wheels where high pressure water separates the slices and removes starch from the cut surfaces. Slices are then conveyed to a tank for final rinsing. In the next step, surface moisture is removed by one or more of the following methods: perforated revolving drum, sponge rubber-covered squeeze roller, compressed air, vibrating mesh belt, heated air, or centrifugal extraction.

After preparation of the feedstock, the partially dried chips are fried in hot oil. Most producers use a continuous process in which the slices are automatically moved through a fryer or cooker using rotating paddles. Continuous processing systems can provide chip production rates of 90 to more than 2,300 kilograms (200 to more than 5,000 pounds) per hour.[6] A variety of popular oils are used for frying chips, including cottonseed, corn, soy, canola, and peanut oils. Animal fats are rarely used in this industry.

Following cooking, the product is typically seasoned with salt or other seasonings and then packaged for distribution and sale.

2.2.2 Batch Kettle Frying

The material preparation steps for the kettle frying operation are similar to those used for continuous frying. Typically, each batch kettle fryer requires a potato slicer, peeler, oil filter, oil makeup tank, and an accumulating conveyor. However, some facilities do not use a peeler, preferring to cook the potato slices with the skin on. Each batch kettle fryer is equipped with an exhaust hood and associated exhaust stack components. Figure 2-3 is a process flow diagram of a batch kettle fryer.

Potatoes are prepared for batch frying in much the same manner as for continuous frying. The major differences are that kettle fryer potato slices are thicker than those used for continuous fryers and they are typically not washed after slicing.

Batch kettle fryers use lower oil temperatures and a slower cooking process (longer dwell time) than continuous fryers. The same oils are used as in continuous fryers. In batch kettle frying, the potato slices must be constantly stirred and dunked in the hot oil during cooking. Typically, a long-handled rake or paddle is used by the operator to move the chips in the fryer. Either a basket immersed in the fryer or a long-handled dipper is used to remove the cooked chips. Most batch kettle fryers can produce between 57 and 91 kilograms (125 and 200 pounds) of chips per hour.

Following cooking, the product is seasoned with salt or other seasonings and then packed for distribution and sale.

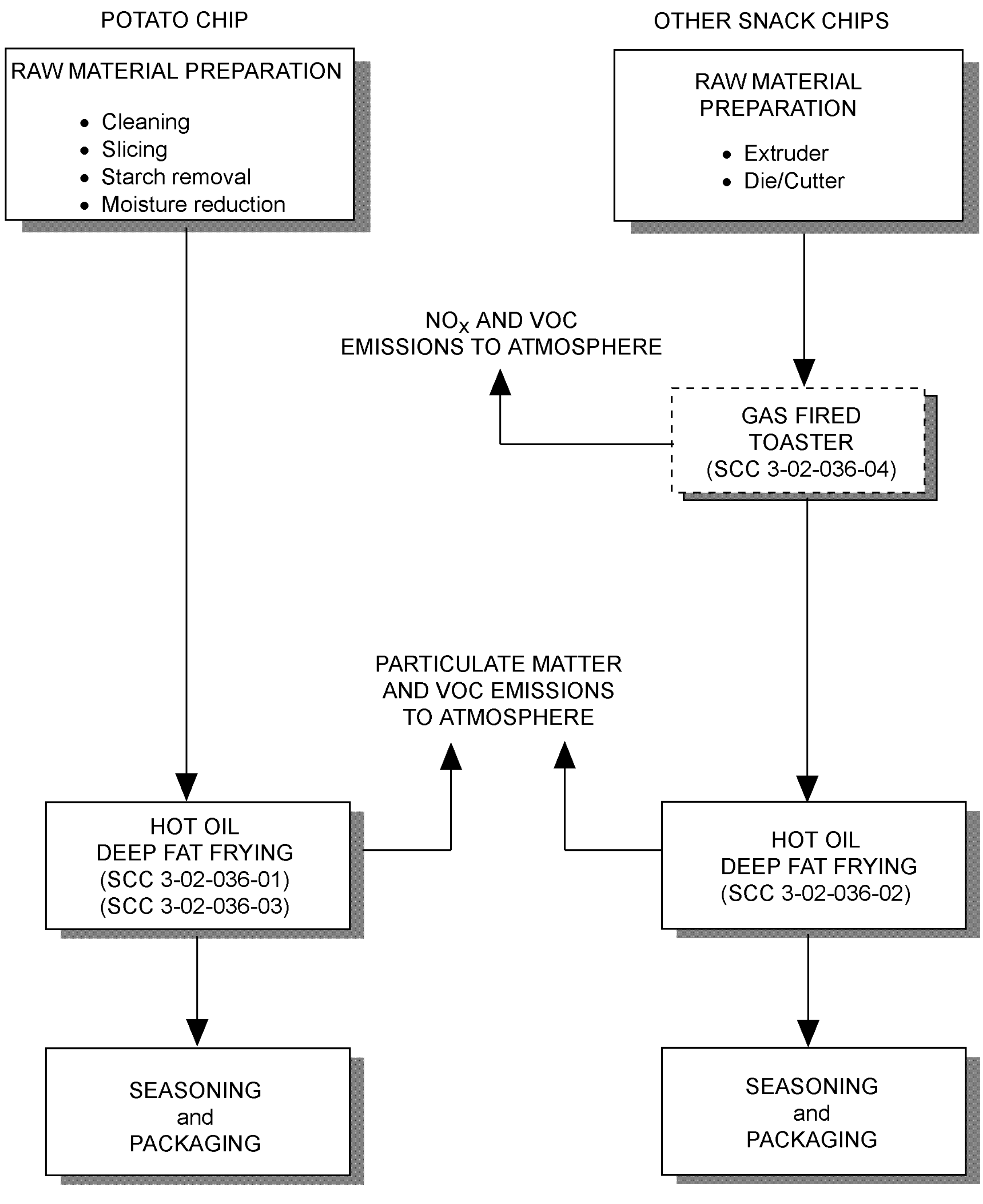

Figure 2-1 Generalized deep fat frying process for snack chips

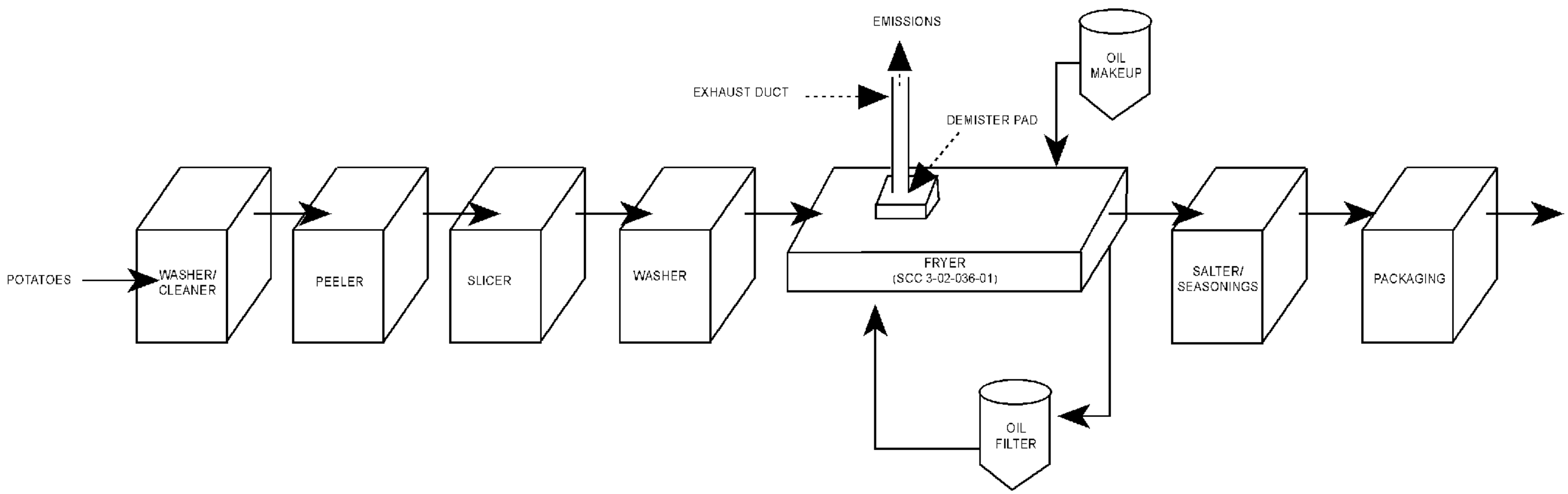

Figure 2-2. Continuous potato snack chip fryer

2.3 EMISSIONS[7]

Particulate matter (PM) is the major air pollutant emitted during the deep fat frying process. Emissions are released when moist foodstuff, such as potatoes, are introduced into hot oil. The rapid vaporization of the moisture in the food stuff results in violent bubbling and cooking oil droplets become entrained in the water vapor stream. The emissions are exhausted from the cooking vat into the ventilation system where the condensed water and oil droplets in the exhaust stream are vented to the atmosphere. In some cases, emission controls may be applied to the exhaust stream prior to venting to atmosphere. The amount of PM emitted depends on process throughput, oil temperature, moisture content of the feed material, equipment design, and emission controls.

Volatile organic compounds (VOCs) are also produced from deep fat frying. The quantity of VOC emissions is expected to be relatively low because of the low vapor pressure of the vegetable oils used. However, entrained droplets may react with the water vapor at the relatively high temperatures found at the cooking oil surface to form volatile products. The toasting operation also may emit small quantities of VOC and natural gas combustion products.

2.4 EMISSION CONTROL TECHNOLOGY[8]

According to information from two of the major producers, emission control equipment for particulate matter is typically installed on potato chip fryer exhaust streams because of the high particulate loadings caused by the high volume of water contained in potatoes. Examples of control devices are oil mist eliminators, impingement devices, and wet scrubbers. Although the pollutants are primarily organic material, catalytic and thermal incinerators are reported to be impractical because of the high moisture content of the fryer exhaust. Little information is available on the capture efficiency of the exhaust stream from the fryer or on the removal efficiency of the add-on air pollution control measures.

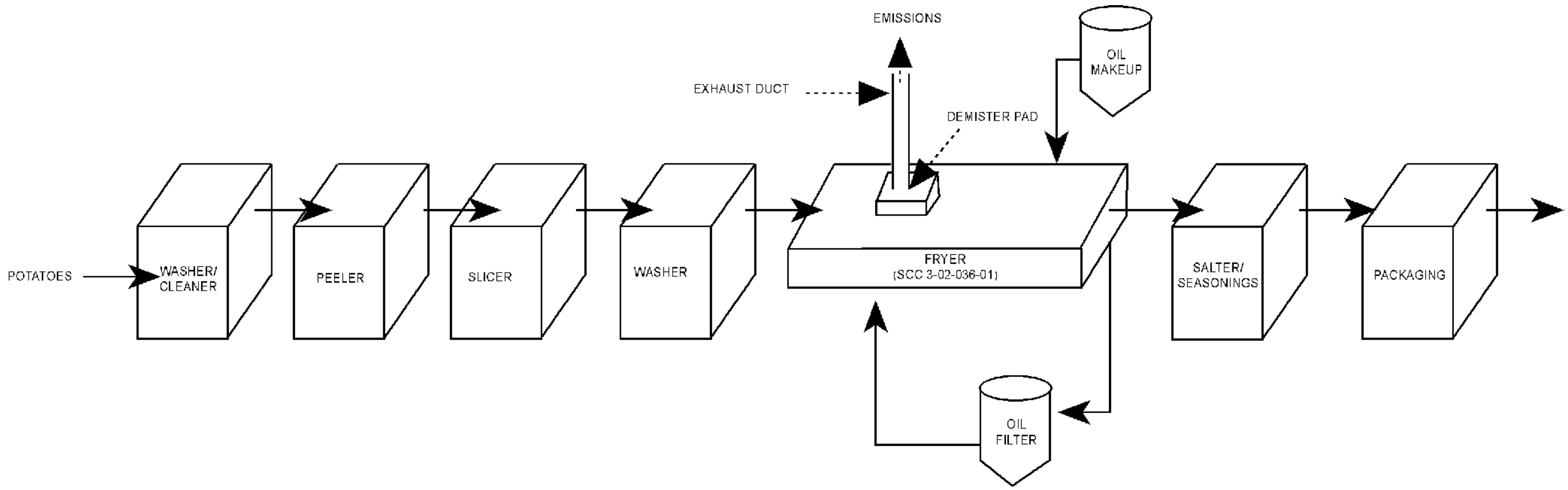

Figure 2-3. Batch kettle potato snack chip fryer

REFERENCES FOR SECTION 2

1. *1987 Census of Manufactures Miscellaneous Food and Kindred Products*, Report No. MC87-I-201, U.S. Department of Commerce, Bureau of the Census, April 1990.

2. *Predicast's Forecasts*, Predicasts Inc., Cleveland, OH, August 1991.

3. *Standard & Poor's Industry Surveys: Food, Beverages & Tobacco, Current Analysis*, Standard & Poor's Corp., New York, March 19, 1992.

4. *1992 Snack Food Association State-of-the-Industry Report*, Snack Food Association, Alexandria, VA. 1993.

5. Brown, Bill, "The Art of Kettle-Style Potato Chip Cooking", SnackWorld, p. 41. March 1989.

6. O. Smith, *Potatoes: Production, Storing, Processing*, Avi Publishing, Westport, CT, 1977.

7. Memorandum. D. March, Midwest Research Institute, to D. Safriet, EPA/EIB. Trip report, Frito-Lay, Inc., Charlotte, NC. September 14, 1993.

8. *Characterization of Industrial Deep Fat Fryer Air Emissions*, Frito-Lay Inc., Plano, TX, 1991.

SECTION 3
GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

A literature search was performed to collect the available data on emissions from operations associated with potato chip and related snack chip production. This search included data contained in the open literature (e.g., National Technical Information Service), source test reports and background documents from EPA's Office of Air Quality Planning and Standards (OAQPS), and MRI internal files (Kansas City and North Carolina offices). Also, major chip manufacturers were contacted to request process information and emission test data.

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 SYSTEM[1]

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

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

2. Test series representing incompatible test methods; and

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

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

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

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

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

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

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

1. 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 SYSTEM[1]

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

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

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

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

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

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

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

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

3.4 EMISSION TESTING METHODS FOR DEEP FAT FRYING[2,3]

Only limited emission testing has been conducted for snack chip deep fat frying operations. This section describes the procedures for particulate matter and volatile organic compound emissions that were used in these limited tests.

3.4.1 Particulate Matter

Particulate matter (PM) emissions in deep fat frying exhaust streams were sampled with an EPA Method 5 train. In this application of Method 5, PM was withdrawn from the source isokinetically; filterable PM was collected in the probe and on a glass fiber filter, and condensible PM was collected in the back-half impingers. The filterable mass, which includes any material that condenses at or above the filtration temperature, was determined gravimetrically after removal of uncombined water.

In the source tests reviewed, the material collected in the impingers positioned after the filter of the Method 5 train was analyzed to determine condensible PM emission levels. These samples contained either organic compounds that had passed through the particulate filter as a vapor during the test run and condensed in the impingers, or were very fine particulate not retained by the filter. The condensed material was analyzed using thermogravimetric analysis (TGA). Using this method, condensate samples collected in the impingers were subjected to increasing temperature, and the weight loss was measured.

3.4.2 Volatile Organic Compounds

Volatile organic compound (VOC) emissions were collected from deep fat frying exhaust streams using several different methods including EPA Method 25 (Determination of Total Gaseous Nonmethane Organic Emissions as Carbon), EPA Method 25A (Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer [FIA]), and EPA Method 18 (Measurement of Gaseous Organic Compound Emissions by Gas Chromatography [GC]). An alternative VOC measurement was obtained from the Method 5 train by withdrawing a slip stream from the Method 5 train downstream from the impingers. The VOC content of this stream was determined by a gas chromatograph/flame ionization detector (GC/FID).

REFERENCES FOR SECTION 3

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections, EPA-454/-B-93-050 U.S. Environmental Protection Agency, Research Triangle Park, NC, October, 1992.

2. Code of Federal Regulations, Title 40--"Protection of Environment," Part 60--Appendix A, Method 5, Revised July 1, 1988.

3. Characterization of Industrial Deep Fat Fryer Air Emissions, Frito-Lay Inc., Plano, TX, 1991.

SECTION 4
AP-42 SECTION DEVELOPMENT

This section describes the test data and methodology used to develop pollutant emission factors for deep fat frying. Section 9.13.3, Snack Chip Deep Fat Frying, will be new to Chapter 9 of AP-42.

4.1 REVIEW OF SPECIFIC DATA SETS[1-10]

Only one reference containing test data for an uncontrolled source was located during the literature search. It presented the results from source testing conducted by the Frito-Lay Company at several facilities for different fried chip products and different cooking oils.[1,2] Eagle Snacks, Inc., provided test data for controlled sources at one facility.[3-10] The facility has several process lines and some lines have had multiple source tests performed. The data from each of the nine references used in the analyses are discussed in the subsections below.

4.1.1 Reference 1

This paper is a secondary reference that summarized the results of PM and VOC tests performed by one snack manufacturing company at different facilities. The snack chip products from which emission data were generated included potato chips, corn chips, tortilla corn chips, and multigrain chips, and tests were conducted using different frying oils. Most of the tests were conducted on uncontrolled emission sources, but limited data are presented for sources controlled by one of three control devices, an ESP, a wet scrubber, and a condenser. One corn chip line was tested at the stack after an "oil mist eliminator" for which no details on the design were presented.

The paper presents only limited information on the sampling and analysis methods. The PM tests were conducted using EPA Method 5, and both front half and back half results are reported. No information is presented on either sampling location, number of sampling runs, or sampling duration for the different tests. Only average results for a specific site are presented, and no field data are included in the paper. The VOC tests were conducted using one of three methods, Method 25 (using an on-site Byron analyzer), Method 25A (using on-site FID analysis with either a Beckman or OVA FID), and Method 18 (using a GC/FID). No information was provided on either the sampling location, the number of sampling runs associated with each test, or sampling duration. The paper did report that because the exhaust streams had a high moisture content and contained entrained droplets, the stack samples were drawn through condensate traps and filters prior to injection into the analyzers, and the temperature of these filters is contained in the paper. In addition to the standard sampling methods, some additional information was collected on VOC emissions downstream from the filter in the Method 5 trains. Data were also collected on the volatility of material collected in the front and back halves of the Method 5 trains using thermogravimetric analyses.

The paper provides very limited information on the processes associated with the test data. No process descriptions are provided, and no information is provided on the design and operating characteristics of the air pollution control devices that were tested. Furthermore, the data that are presented are limited to overall test averages at each site.

A summary report without original run-specific test data normally would not be used for developing AP-42 emission factors. However, because these are the only available data on uncontrolled emissions from deep fat fryers, they were used in this instance. Because of the deficiencies described above (i.e., lack of significant background data) and the fact that these are secondary data, the results were given a D rating. The emission factors from Reference 1 are summarized in Table 4-1 , and the full paper is included in Appendix A. The following paragraphs provide additional information about the factors presented in Table 4-1.

Table 4-1 presents PM emission factors for the production of four types of fried chips. Reference 1 reported mass emission rates for filterable PM emissions based on material collected from the probe and filter of the Method 5 train (front-half particulate matter), and condensible PM emission rates from the back-half results. The emission factor was obtained by dividing the appropriate PM emission rate (lb/hr) by the process operating rate (ton/hr) measured as product.

Table 4-1 also presents calculated VOC emission factors. The VOC emissions were measured using a variety of analytical methods. The VOC emissions are reported as total hydrocarbon (HC) or nonmethane hydrocarbon (NMHC), both expressed as mass methane. The emission factors were obtained by dividing the HC or NMHC VOC emission rates (lb/hr) by the operating rate in terms of ton of product/hr (ton/hr).

The interpretation of VOC emission data presented in Table 4-1 must account for differences in test methods and for the lack of specific information on the procedures. First, some of the VOC samples were collected downstream from the impingers in the Method 5 PM train. (These samples are denoted as "M-5 Outlet" in Table 4-1.) Because the impingers will remove from the gas stream any organic compounds that condense at temperatures above 20°C (68°F), this procedure generally produces lower estimates of VOC emissions than those produced by Methods 18, 25, and 25A. Second, because little information is available on either the composition of the organic constituents in the deep fat fryer exhaust or the procedures used with the FID systems to account for moisture interferences and different response factors, the basis for the conversion of the raw concentration data, which were not included in the test summary, to the mass emission rates in Table 4-1 is unclear. Consequently, the emission factors presented in Table 4-1 are considered highly uncertain, and the data are rated D.

4.1.2 Reference 3

This test report summarizes the results of PM emission tests for two operations, Kettle Fryer No. 7 and Continuous Fryer No. 1 at the Eagle Snacks, Visalia, California, plant. Both of these operations produce potato chips. The tests were conducted in November 1991 to provide compliance data for the local air pollution control district. Triplicate tests were conducted on each operation using EPA Method 5, and both front half and back half results were reported. The test report included field data sheets and detailed computer printouts that provided process information.

The major limitation of the test report was that it did not contain any process description. However, information subsequently supplied by the facility identified the control devices in operation at the time of the test. Kettle No. 7 was controlled by a hood scrubber, while Continuous Fryer No. 1 was controlled by a "large demister," which was described as a demister designed for higher efficiency than the standard demister. The high efficiency demister includes a coarse-weave 4-inch pad and a 6-inch fine weave pad and operates with a 2.5 to 3 inches water column pressure drop (when clean). Another problem reported in the test was that Run 1 on the continuous fryer was superisokinetic and was considered void.

The test appears to have been conducted appropriately, and the data in the test report are fully documented. However, because the report did not contain a process description or process data, the kettle fryer data are rated B. The continuous fryer data are rated C because only two valid test runs were performed. The test data from Reference 3 are summarized in Table 4-2, and pertinent test data and process data and emission factor calculations are provided in Appendix B.

TABLE 4-1. SUMMARY OF EMISSION FACTORS FROM REFERENCE 1

Product and oil	Control	Emission factor, kg/Mg (lb/ton) chips produced[a]			VOC method (trap temp., °F)
		Filterable PM[b]	Condensible PM[c]	VOC	
Corn chips/ sunflower oil	Uncontrolled[d]	0.28 (0.56)	0.14 (0.28)	0.22 (0.44)	M25 (80)
	ESP[e]	0.17 (0.35)	0.12 (0.23)	0.29 (0.59)	M25 (80)
	Condenser	0.12 (0.23)	0.05 (0.11)	0.15 (0.31)	M25 (80)
Potato chips/ cottonseed oil	Uncontrolled[a]	0.83 (1.65)	0.19 (0.39)	0.0074 (0.015) 0.064 (0.13) 0.0099 (0.020)[h]	M25A (60) M25A (120) M18 (60)
Corn chips/ sunflower oil	Oil mist eliminator[g]	0.25 (0.51)	0.17 (0.35)	0.25 (0.51) 0.19 (0.38) 0.01 (0.020)[h]	M25A (60) M25A (120) M18 (60)
Tortilla chips/ soybean oil	Uncontrolled	0.17 (0.34)	0.07 (0.13)	0.048 (0.096) 0.057 (0.11) 0.086 (0.17) 0.048 (0.096)[h]	M25A (60) M25A (60) M25A (60) M25A (60)
Multigrain chips/ canola oil	Uncontrolled	0.40 (0.81)	0.11 (0.21)	0.12 (0.25) 0.07 (0.14)[h]	M25A (60) M25A (60)

[a]Expressed as the weight of pollutant per unit weight of finished product, 1 lb/ton = 0.5 kg/Mg; 1 ton = 2,000 lb.
[b]Filterable PM--Particulate collected from the front half of the Method 5 train.
[c]Condensible PM--Particulate collected from the back half of the Method 5 train.
[d]Inlet--Samples taken before the condenser and electrostatic precipitator (ESP).
[e]ESP outlet, cond. off--Samples taken at the ESP outlet (ESP on, condenser off).
[f]ESP outlet, ESP off--Samples taken at the ESP outlet (ESP off, condenser on).
[g]Uncontrolled process.
[h]Sample taken downstream of impingers in Method 5 train.

4. 1.3 Reference 4

This test report summarizes the results of PM emission tests for Continuous Potato Chip Fryer No.1 at the Eagle Snacks, Visalia, California, plant. The tests were conducted in January 1993 to provide compliance data for in-house engineering analyses. Triplicate tests were conducted on this operation using EPA Method 5, and both front half and back half results were reported. For the back half, results were reported separately for the organic and inorganic fractions. The test report included field data sheets and detailed computer printouts that provided process information.

The report had three major limitations. First, it did not contain any process description. However, information subsequently supplied by the facility identified the control device in operation at the time of the test. This information indicated that Continuous Fryer No.1 was controlled by a "large demister," which was described as a demister designed for higher efficiency than the standard demister. The high efficiency demister includes a coarse-weave 4-inch pad and a 6-inch fine weave pad and operates with a 2.5 to 3 inches water column pressure drop (when clean). The second major limitation was that the sampling train was operated at greater than 110 percent isokinetic on test runs 1 and 2. Review of the test data showed the emissions measured during run 2 to be greater than those measured during run 3. Because superisokinetic sampling produces results that are potentially negatively biased, the average for runs 2 and 3 is a better estimate of the emissions from this source than the emission estimate developed from run 3 only. Therefore, the data from run 2 were retained for the emission factor development, but the emission factors were downrated accordingly. The third major limitation was that run 1 started about 15 minutes after a cold fire start up, and the results are questionable because equilibrium was not reached. Therefore, run 1 was not used to develop emission factors.

The test appears to have been conducted appropriately, and the data in the test report are fully documented. However, the report did not contain a process description or process data, only two valid test runs were performed, and test conditions during run 2 were superisokinetic. Therefore, the data are rated C. The test data from Reference 4 are summarized in Table 4-2, and pertinent test data and process data and emission factor calculations are provided in Appendix C.

TABLE 4-2. SUMMARY OF EMISSION FACTORS FROM REFERENCES 3-10

Ref.	Product	Fryer type	Control	Emission factors kg/Mg (lb/ton) chips produced[a]			
				Filterable PM[b]	Condensible inorganic PM[c]	Condensible organic PM[d]	Filterable PM-10
3	Potato chip	Kettle	Hood scrubber	2.61 (5.21)	0.565 (1.13)	0 (0)	
3	Potato chip	Continuous	Large demister	0.110 (0.219)	0.106 (0.213)	0.0233 (0.0466)	
4	Potato chip	Continuous	Large demister	0.121 (0.242)	0.142 (0.284)	0.104 (0.208)	
5	Potato chip	Continuous	Standard demister	0.194 (0.388)	0.000595 (0.00119)	0.185 (0.369)	0.168 (0.337)
5	Tortilla	Continuous	Standard demister	0.094 (0.187)	0 (0)	0.0365 (0.0729)	0.061 (0.121)
6	Tortilla	Continuous	Standard demister	0.126 (0.251)	0.0338 (0.0676)	0.0077 (0.0154)	
7	Potato chip	Kettle	Hood scrubber	1.26 (2.52)	0.373 (0.746)	0.0385 (0.0761)	
8	Potato chip	Kettle	Hood scrubber	0.515 (1.03)	0.95 (1.90)	0.291 (0.581)	
9	Potato chip	Continuous	Standard demister	0.370 (0.740)	0.00361 (0.00722)	0.201 (0.403)	
10	Potato chip	Continuous	Standard demister	0.485 (0.971)	0.00770 (0.0154)	0.171 (0.341)	

[a]Expressed as weight of PM per unit weight of finished product.

1 lb/ton = 0.5 kg/Mg
1 ton = 2,000 lb

[b]Filterable—Particulate collected from the front half of the Method 5 train.
[c]Condensible inorganic PM--Inorganic fraction of particulate collected from the back half of the Method 5 train.
[d]Condensible organic PM--Organic (extractable) fraction of particulate collected from the back half of the Method 5 train.

4.1.4 Reference 5

This test report summarizes the results of PM and particle size emission tests for two operations, a continuous potato chip fryer line and Continuous Tortilla Fryer Line No. 1 at the Eagle Snacks, Visalia, California, plant. The tests were conducted in November 1990 to provide compliance data for the local air pollution control district. Triplicate PM tests were conducted on each operation using EPA Method 5, and both front half and back half results were reported. For the back half, results were reported separately for the organic and inorganic fractions. For each operation, triplicate particle size samples were collected at a single traverse point isokinetically using an Anderson eight-stage impactor with an appropriately sized nozzle. For the potato chip line, the impactor was heated to 121°C (250°F) to avoid condensation problems in the high moisture stack. The test report included field data sheets and detailed handwritten tables that provided process information.

The major limitation of the test report was that it did not contain any process description. However, information subsequently supplied by the facility identified the control devices in operation at the time of the test. Both operations were equipped with a standard demister. The standard demister includes a single, 6-inch, two-layer mist pad that operates with a pressure drop of about 0.5 inch water column (when clean).

The test appears to have been conducted appropriately, and the data in the test report are fully documented. However, because the report did not contain a process description or process data, the PM data are rated B. The particle size data appear to have been collected by appropriate methods. However, because the tortilla chips data had large inconsistencies, they are downrated to C. The potato chip particle size data are rated B.

The PM test data from Reference 5 are summarized in Table 4-2, and the particle size results are summarized in Table 4-3. Pertinent test data and process data and emission factor calculations are provided in Appendix D.

TABLE 4-3. FRYER LINE PARTICLE SIZE DISTRIBUTION DATA

Product	Control measure	Run	Cumulative percent less than size			
			1 µm	3 µm	5 µm	10 µm
Potato chip-continuous	Demister	1	26	48	60	75
		2	29	56	69	83
		3	2	29	72	99
		Avg.	19	44	67	86
Tortilla chip-continuous	Demister	1	100	100	100	100
		2	6	37	60	85
		3	2	8	23	55
		Avg.	36	48	61	80

4.1.5 Reference 6

This test report summarizes the results of PM emission tests for Continuous Tortilla Fryer Line No. 1 at the Eagle Snacks, Visalia, California, plant. The tests were conducted in October 1992 to provide compliance data for the local air pollution control district. Triplicate tests were conducted on this operation using EPA Method 5, and both front half and back half results were reported. For the back half, results were reported separately for the organic and inorganic fractions. The test report included field data sheets and detailed computer printouts that provided process information.

The major limitation of the test report was that it did not contain any process description. However, information subsequently supplied by the facility identified the control device in operation at the time of the test to be a standard demister. The test appears to have been conducted appropriately, and the data in the test report are fully documented. However, because the report did not contain a process description or process data, the data are rated B. The PM test data from Reference 6 are summarized in Table 4-2, and pertinent test data and process data and emission factor calculations are provided in Appendix E.

4.1.6 Reference 7

This test report summarizes the results of PM emission tests for Kettle Fryer No. 5 at the Eagle Snacks, Visalia, California, plant. This line produces potato chips. The tests were conducted in February 1992 to provide compliance data for the local air pollution control district. Triplicate tests were conducted on this operation using EPA Method 5, and both front half and back half results were reported. For the back half, results were reported separately for the organic and inorganic fractions. The test report included field data sheets and detailed computer printouts that provided process information.

The major limitation of the test report was that it did not contain any process description. However, information subsequently supplied by the facility identified the control device in operation at the time of the test to be a hood scrubber. The test appears to have been conducted appropriately, and the data in the test report are fully documented. However, because the report did not contain a process description or process data, the data are rated B. The PM test data from Reference 7 are summarized in Table 4-2, and pertinent test data and process data and emission factor calculations are provided in Appendix F.

4.1.7 Reference 8

This test report summarizes the results of PM emission tests for Kettle Fryer No. 8 at the Eagle Snacks, Visalia, California, plant. This line produces potato chips. The tests were conducted in February 1992 to provide compliance data for the local air pollution control district. Triplicate tests were conducted on this operation using EPA Method 5, and both front half and back half results were reported. For the back half, results were reported separately for the organic and inorganic fractions. The test report included field data sheets and detailed computer printouts that provided process information.

The major limitation of the test report was that it did not contain any process description. However, information subsequently supplied by the facility identified the control device in operation at the time of the test to be a hood scrubber. The test appears to have been conducted appropriately, and the data in the test report are fully documented. However, because the report did not contain a process description or process data, the data are rated B. The PM test data from Reference 8 are summarized in Table 4-2, and pertinent test data and process data and emission factor calculations are provided in Appendix G.

4.1.8 Reference 9

This test report summarizes the results of PM tests for a continuous potato chip fryer line at the Eagle Snacks, Visalia, California, plant. The tests were conducted in October 1989 to provide compliance data for the local air pollution control district. Triplicate PM tests were conducted on the continuous fryer using EPA Method 5, and both front and back half results were reported. For the back half, results were reported separately for the organic and inorganic fractions. The test report included field data sheets and detailed handwritten tables that provided process information.

The major limitation of the test report was that it did not contain any process description. However, information subsequently supplied by the facility identified the control device in operation at the time of the test as a standard mesh pad mist eliminator. The standard demister includes a single, 6-inch, two-layer mist pad that operates with a pressure drop of about 0.5-inch water column (when clean).

The test appears to have been conducted appropriately, and the data in the test report are fully documented. However, because the report did not contain a process description or production data, the PM data are rated B.

The PM test data from Reference 9 are summarized in Table 4-2. Pertinent test data, process data, and emission factor calculations are provided in Appendix H.

4.1.9 Reference 10

This test report summarizes the results of PM tests for a continuous potato chip fryer line at the Eagle Snacks, Visalia, California, plant. The tests were conducted in May 1989 to provide compliance data for the local air pollution control district. Triplicate PM tests were conducted on the continuous fryer using EPA Method 5, and both front and back half results were reported. For the back half, results were reported separately for the organic and inorganic fractions. The test report included field data sheets and detailed handwritten tables that provided process information.

The major limitation of the test report was that it did not contain any process description. However, information subsequently supplied by the facility identified the control device in operation at the time of the test as a standard mesh pad mist eliminator. The standard demister includes a single, 6-inch, two-layer mist pad that operates with a pressure drop of about 0.5-inch water column (when clean).

The test appears to have been conducted appropriately, and the data in the test report are fully documented. However, because the report did not contain a process description or production data, the PM data are rated B.

The PM test data from Reference 10 are summarized in Table 4-2. Pertinent test data, process data, and emission factor calculations are provided in Appendix I.

4.2 CANDIDATE EMISSION FACTORS

Candidate emission factors are presented in Tables 4-4 and 4-5 for PM and VOC, respectively. Emission factors are calculated as the weight of PM or VOC per ton of finished product including added salt and other seasonings, not per ton of raw potatoes used. Because the emission factors for potato chip manufacture differ substantially from the factors generated for other products and because operators suggest that the higher moisture content in potatoes yield higher emissions, separate emission factors were developed for potato chips and other snack chips. The basis for these factors is discussed below.

4.2.1 Particulate Matter Emission Factors

Separate emission factors were developed for filterable PM (material collected in the front half of the Method 5 train), and condensible PM (material collected in the back-half of the Method 5 train); where data were available, separate emission factors for organic and inorganic condensibles were calculated. The data that form the basis for the uncontrolled PM emissions factors are from Reference 1. The uncontrolled emission factors for potato chip deep fat frying are based on the single data point in Table 4-1. The uncontrolled emission factors for other snack chip deep fat frying were obtained by averaging the other four data points for uncontrolled emissions (two for corn chips and one each for tortilla chips and multigrain chips) contained in Table 4-1. Although the emissions in one of the two corn chip tests were measured after an oil mist eliminator, the emission factor for this test was equivalent to the other uncontrolled corn chip test. Consequently, no PM control was attributed to the oil mist eliminator and these data were included in the calculation of the average uncontrolled emission factors. Because the data that form the basis of these emission factors are D-rated data, the emission factors are rated E.

Reference 1 provided little information on the design and operation of the control systems for which controlled emission data were generated. Furthermore, information on the control system tested suggests that it was not operated in a typical manner during the test. Consequently these data from Reference 1 and presented in Table 4-1 were not used to calculate controlled emission factors.

References 3-10 report filterable PM, condensible inorganic PM and condensible inorganic PM data for controlled emissions. These data were used to calculate separate emission factors as follows.

4.2.1.1 Potato Chips--

The emission factors for continuous potato chip fryer emissions controlled by a standard demister are based upon the three data points from Reference 5, 9, and 10 presented in Table 4-2. The emission factors for filterable PM, condensible inorganic PM, and condensible organic PM were developed from three B-rated tests conducted at the same facility (same fryer) and are rated D. The emission factor for filterable PM-10 was developed from particle size data from Reference 5 and extrapolated to References 9 and 10. This emission factor is E-rated.

The emission factors for continuous potato chip fryer emissions controlled by a high efficiency demister are based upon the data from References 3 and 4 presented in Table 4-2. These emission factors were developed from two C-rated tests conducted at the same facility (same fryer) and are rated E.

TABLE 4-4. CANDIDATE PARTICULATE MATTER EMISSION FACTORS FOR SNACK CHIP DEEP FAT FRYING

Source	Type of control	Pollutant	No. of tests	Emission factor		Standard deviation		Rating	Ref.
				kg/Mg	lb/ton[a]	kg/Mg	lb/ton		
Potato chip (continuous)	None	Filterable PM	1	0.83	1.65			E	1
		Condensible	1	0.19	0.39			E	1
Potato chip (continuous)	Standard mesh pad mist eliminator[b]	Filterable PM	3	0.350	0.700			D	5,9,10
		Condensible inorganic PM	3	0.00396	0.00792			D	5,9,10
		Condensible organic PM	3	0.186	0.371			D	5,9,10
		Filterable PM-10	1	0.301	0.602			E	5
Potato chip (continuous)	High efficiency mesh pad mist eliminator[c]	Filterable PM	2	0.116	0.231			E	3,4
		Condensible inorganic PM	2	0.124	0.248			E	3,4
		Condensible organic PM	2	0.0635	0.127			E	3,4
Potato chip (kettle)	Hood scrubber	Filterable PM	3	0.89	1.78			D	3,7,8
		Condensible inorganic PM	3	0.66	1.32			D	3,7,8
		Condensible organic PM	3	0.165	0.329			E	3,7,8
Other snack chips	None	Filterable	4	0.28	0.56	0.10	(0.20)	E	1
		Condensible PM	4	0.12	0.24	0.043	(0.087)	E	1
Other snack chips	Standard mesh pad mist eliminator	Filterable PM	2	0.11	0.219			D	5,6
		Condensible inorganic PM	2	0.0169	0.0338			E	5,6
		Condensible organic PM	2	0.0220	0.0441			E	5,6
		Filterable PM-10	1	0.088	0.18			E	5

[a]Expressed as weight of particulate matter per unit weight of product.
1 lb/ton = 0.5 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6g
[b]The standard demister includes a single, 6-inch, two-layer mist pad that operates with a pressure drop of about 0.5-inch water column (when clean).
[c]The high efficiency demister includes a coarse-weave 4-inch mist pad and a 6-inch fine weave pad and operates with a 2.5 to 3 inches water column pressure (when clean).

TABLE 4-5. CANDIDATE UNCONTROLLED VOC EMISSION FACTORS FOR SNACK CHIP DEEP FAT FRYING
Emission Factor Rating: E

Process	Emission factor, kg/Mg (lb/ton)[a]	No. of tests	Rating	Ref.
Potato chips	0.0099 (0.020)	1	E	1
Other snack chips	0.043 (0.085)	3	E	1

[a]Expressed as equivalent weight of methane (CH_4) per unit weight of product.
1 lb/ton = 0.5 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.

The emission factors for kettle potato fryer emissions controlled by a hood scrubber are based upon the three data points from References 3, 7, and 8, presented in Table 4-2. The tests from References 3, 7, and 8 were all B-rated. The filterable PM and condensible inorganic PM emission factors are D-rated. Because of the variability among the three data points, the condensible organic PM emission factor is E-rated.

A filterable PM-10 emission factor for continuous fryer emissions controlled by a standard demister is based upon the particle size distribution data from Reference 5 and the average filterable PM emission factor from References 5, 9, and 10. Reference 5 indicated that 86 percent of the filterable PM emission were less than 10 µm in diameter. Consequently, the estimated PM-10 factor was calculated as the product of 0.86 and 0.350 kg/Mg (0.700 lb/ton). The factor is rated E.

4.2.1.2 Other Snack Chips--

The emission factors for other snack chip fryer emissions controlled by a demister are based upon the two data points from References 5 and 6, presented in Table 4-2. These tests were B-rated; the emission factor for filterable PM is D-rated. Because of the variability of the data in the two tests, the emission factors for condensible inorganic PM and condensible organic PM are E-rated.

A filterable PM-10 emission factor for other snack chip fryer emissions controlled by a demister is based upon the particle size distribution from Reference 5 for tortilla chips and the average filterable PM emission factor from References 5 and 6. The PM-10 emission factor was obtained as the product of the average fraction less than 10 µm in diameter (0.80) and the filterable PM emission factor of 0.11 kg/Mg (0.22 lb/ton). The factor is E-rated.

4.2.2 VOC Emission Factors

Because no information was provided on the sampling and analysis protocols used to collect the VOC data, the VOC emission factors were calculated based on the results obtained from the Method 5 impinger exhaust. These results were selected because the procedure appears to be most consistent across processes and because all organic compounds that are volatile downstream from the impingers are certain to be volatile at the deep fat fryer exhaust stack. The emission factor for potato chips was obtained from the single value in Table 4-1, while the factor for other snack chips was obtained by averaging the values for corn chips, tortilla chips, and multigrain chips in Table 4-1.

The reader should note that the emission factors obtained here may be biased low. First, they do not account for any VOC that may condense at temperatures between the stack temperatures of 70° to 116°C (160° to 240°F) and the impinger temperature of 20°C (68°F). Also, these procedures do not account for the low response of the FID to oxygenated compounds. Although the report indicates that the most of the material collected was C2 to C6 hydrocarbons, it also raises the possibility that the moisture in the exhaust stream may oxidize the cooking oils. If oxygenated organic compounds are present in the exhaust, the procedures used for these tests will not fully account for them.

REFERENCES FOR SECTION 4

1. Characterization of Industrial Deep Fat Fryer Air Emissions, Frito-Lay Inc., Plano, TX, 1991.

2. Telephone communication between Jill Guthrie, Midwest Research Institute, Kansas City, MO, and Robert Ajax, Robert L. Ajax & Associates, Cary, NC, August 31, 1992.

3. Emission Performance Testing for Two Fryer Lines, prepared for Eagle Snacks, Inc., Visalia, CA, by Western Environmental Services, November 19, 20, and 21, 1991.

4. Emission Performance Testing on One Continuous Fryer, prepared for Eagle Snacks, Inc., Visalia, CA, by Western Environmental Services, January 26, 1993.

5. Emission Performance Testing of Two Fryer Lines, prepared for Eagle Snacks, Inc., Visalia, CA, by Western Environmental Services, November 1990.

6. Emission Performance Testing of One Tortilla Continuous Frying Line, prepared for Eagle Snacks, Inc., Visalia, CA, by Western Environmental Services, October 20-21, 1992.

7. Emission Performance Testing of Fryer No. 5, prepared for Eagle Snacks, Inc., Visalia, CA, by Western Environmental Services, February 4-5, 1992.

8. Emission Performance Testing of Fryer No. 8, prepared for Eagle Snacks, Inc., Visalia, CA, by Western Environmental Services, February 3-4, 1992.

9. Emission Performance Testing of Two Fryer Lines, prepared for Eagle Snacks, Inc., Visalia, CA, by Western Environmental Services, November 1989.

10. Emission Performance Testing of Two Fryer Lines, prepared for Eagle Snacks, Inc., Visalia, CA, by Western Environmental Services, June 1989.

11. Telephone communication between B. Shrager, Midwest Research Institute, Cary, NC, and L. Klein, Heat and Control, San Francisco, CA, August 8, 1994.

SECTION 5
PROPOSED AP-42 SECTION 9.13.3

A proposed new AP-42 section for snack chip deep fat frying is presented on the following pages as it would appear in the document.