Emission Factor Documentation for AP-42
Section 9.8.1

Canned Fruits and Vegetables

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. II-03

MRI Project No. 4602-03

August 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 EPA Contract No. 68-D2-0159. The EPA work assignment manager for this project is Mr. Dallas Safriet.

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August 1995

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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 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 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 background report is to provide information to support preparation of AP-42 Section 9.8.1, Canned Fruits and Vegetables.

This report contains five sections. Following this introduction, Section 2 gives a description of the canned fruits and vegetables industry including a brief characterization of the industry, an overview of the process, and the identification of emissions and emission control technology. Section 3 describes the literature search, screening of emission source data, and the EPA quality ranking system for emission data and emission factors. Section 4 describes the results of the literature search. Section 5 presents the proposed AP-42 Section 9.8.1, Canned Fruits and Vegetables.

2. INDUSTRY DESCRIPTION

This section provides an overview of the U.S. canning industry for fruits, vegetables, and juices. The section is divided into four subsections: industry characterization (2.1), process description (2.2), emissions (2.3), and emission control technology (2.4). The canned fruits and vegetables industry is classified in Standard Industrial Classification (SIC) Code 2033.

2.1 INDUSTRY CHARACTERIZATION[1,2]

The canning of fruits and vegetables is a growing, competitive industry, especially the international export portion. The industry comprises establishments primarily engaged in canning fruits, vegetables, fruit and vegetable juices; processing ketchup and other tomato sauces; and producing natural and imitation preserves, jams, and jellies.

Current-dollar value of shipments of the canned goods industry rose from $29.8 billion in 1991 to $32.3 billion in 1992 (8.5 percent). The value of exports of canned goods increased from $1.39 billion in 1991 to $1.53 billion in 1992 (10 percent). Although there is not much growth in the domestic market for canned goods, exports to Canada and Mexico continue to increase. During the next 5 years, the real value of export shipments is expected to increase at a compound annual rate of 2 percent.

In the mid-1980's, the U.S. canning industry was annually processing approximately 33 billion pounds (lb) of food, which were packed in approximately 35.6 billion containers. Additionally, more than 1 billion containers were processed using aseptic packaging. In the mid-1980's, the annual consumption of canned foods in the United States was estimated at 140 lb per capita. More than half of the fruit and vegetable crops grown on U.S. acreage are used for processing.

Consumer demand for more quality and variety in their meals has resulted in an increased demand for sauces, low-calorie dressings, tomato products, and ethnic foods. Demand for the higher value-added products, such as ethnic foods, entrees, and low-calorie salad dressings, is expected to grow at a much higher rate than commodity items, such as canned fruits and vegetables. Some growth potential for canned commodities is anticipated from the North American Free Trade Agreement (NAFTA), which would stimulate the free flow of goods among Canada, Mexico, and the United States.

The 1987 Census of Manufactures indicated that 65.6 thousand people were employed in the industry, a decrease of 7 percent from the 1982 Census. The leading States in employment in 1987 were California, Florida, New York, and Wisconsin. There are a large number of firms in the canning industry, with the larger firms processing 75 percent to 85 percent of the total product. The industry is composed of multiple-product plants, which process a diversified line of fruits, vegetables, and juices and single product plants. Some plants operate on a year-round basis whereas other plants are seasonally operated.

2.2 PROCESS DESCRIPTION[3-6]

The primary objective of food processing is preservation of perishable foods in a stable form that can be stored and shipped to distant markets during all months of the year. Processing also can change foods into new or more usable forms and make foods more convenient to prepare.

The goal of the canning process is to destroy any microorganisms in the food and prevent recontamination. Heat is the most common agent used to destroy microorganisms. Removal of oxygen can be used in conjunction with other methods to prevent the growth of oxygen-requiring microorganisms.

In the conventional canning of fruits and vegetables, there are certain basic process steps that are similar for both types of products. However, there is a great diversity among plants and even among plants processing the same commodity. The differences encompass the inclusion of certain operations for some fruits or vegetables, the sequence of the process steps used in the operations, and the cooking or blanching steps. Production of fruit or vegetable juices occurs by a different sequence of operations. As with the fruit and vegetable canning industry, there is a great diversity among juice canning plants. Typical canned products include beans (cut and whole), beets, carrots, corn, peas, spinach, tomatoes, apples, peaches, pineapple, pears, apricots, and cranberries. Typical juices are orange, pineapple, grapefruit, tomato, and cranberry. Generic process flow diagrams for the canning of fruits, vegetables, and fruit juices are shown in Figures 2-1, 2-2, and 2-3. The steps outlined in these figures are intended to present the basic stages in production. As stated earlier, there is a great diversity among plants and it is not possible to present figures that are representative of all steps employed by an industry segment. A typical commercial canning operation may employ the following general processes: washing, sorting/grading, preparation, container filling, exhausting, container sealing, heat sterilization, cooling, labeling/casing, and storage for shipment.In these diagrams, no attempt has been made to be product specific and include all process steps that would be used for all products. Figures 2-1 and 2-2 show optional operations, as dotted line steps, that are often used but are not used for all products. One of the major differences in the sequence of operations between fruit and vegetable canning is the blanching operation. Most of the fruits are not blanched prior to can filling whereas many of the vegetables undergo this step. Canned vegetables generally require more severe processing than do fruits because the vegetables have much lower acidity and contain more heat-resistant soil organisms. Many vegetables also require more cooking than fruits to develop their most desirable flavor and texture. There is a large difference among plants in the methods used in the blanching or cooking steps. With many fruits, preliminary treatment steps (e.g., peeling, coring, halving, pitting) occur prior to any heating or cooking step but with vegetables, these treatment steps often occur after the vegetable has been blanched. For both fruits and vegetables, peeling is done either by a mechanical peeler, steam peeling, or lye peeling. The choice depends upon the type of fruit or vegetable or the choice of the company. The lye process is used to peel beets, carrots, tomatoes, pears, and peaches. Steam peeling is also used for tomatoes.

Some citrus fruit processors produce dry citrus peel, citrus molasses and D-limonene from the peels and pulp residue collected from the canning and juice operations. However, other juice processing facilities prepare juices from concentrates and raw commodity processing does not occur at that facility. The peels and residue are collected and ground in a hammermill, lime is added to neutralize the acids, and the product pressed to remove excess moisture. The liquid from the press is screened to remove large particles, which are recycled back to the press, and the liquid is concentrated to molasses in an evaporator. The pressed peel is sent to a direct-fired hot-air drier.

After passing through a condenser to remove the D-limonene, the exhaust gases from the drier are used as the heat source for the molasses evaporator.

For conventional canning, facilities have been converting from batch to continuous units. In continuous retorts, the cans are fed through a lock, then rotated through the pressurized heating chamber, and subsequently cooled through a second section of the retort in a separate cold-water cooler. Commercial methods for sterilization of canned foods with a pH of 4.5 or lower include use of static retorts, which are similar to large pressure cookers. A newer unit is the agitating retort, which mechanically moves the can and the food, providing quicker heat penetration. In the aseptic packaging process, the problems with slow heat penetration in the in-container process are avoided by sterilizing and cooling the food separately from the container. Presterilized containers are then filled with the sterilized and cooled product and are sealed in a sterile atmosphere.

To provide a closer insight into the actual processes that occur during a canning operation, a description of the canning of whole tomatoes is presented in the following paragraphs. This description provides more detail for each of the operations than can be presented in the generic process flow diagrams in Figure 2-1.

2.2.1 Preparation

Mechanically harvested tomatoes are usually thoroughly washed by high-pressure sprays or by strong-flowing streams of water while being passed along a moving belt or on agitating or revolving screens. The raw produce may be sorted for size and maturity. Sorting for size is accomplished by passing the raw tomatoes through a series of moving screens with different mesh sizes or over differently spaced rollers. Separation into groups according to degree of ripeness or perfection of shape is done by hand; any trimming is also done by hand.

2.2.2 Peeling and Coring

Formerly, tomatoes were initially scalded followed by hand peeling, but steam peeling and lye peeling have also become widely used. In steam peeling, the tomatoes are treated with steam to loosen the skin, which is then removed by mechanical means. In lye peeling, the fruit is immersed in a hot lye bath or sprayed with a boiling solution of 10 to 20 percent lye. The excess lye is then drained and any lye that adheres to the tomatoes is removed with the peel by thorough washing.

Coring is done by a water-powered device with a small turbine wheel. A special blade mounted on the turbine wheel spins and removes the tomato cores.

2.2.3 Filling

After peeling and coring, the tomatoes are conveyed by automatic runways, through washers, to the point of filling. Before being filled, the can or glass containers are cleaned by hot water, steam, or air blast. Most filling is done by machine. The containers are filled with the solid product and then usually topped with a light puree of tomato juice. Acidification of canned whole tomatoes with 0.1 to 0.2 percent citric acid has been suggested as a means of increasing acidity to a safer and more desirable level. Because of the increased sourness of the acidified product, the addition of 2 to 3 percent sucrose is used to balance the taste. The addition of salt is important for palatability.

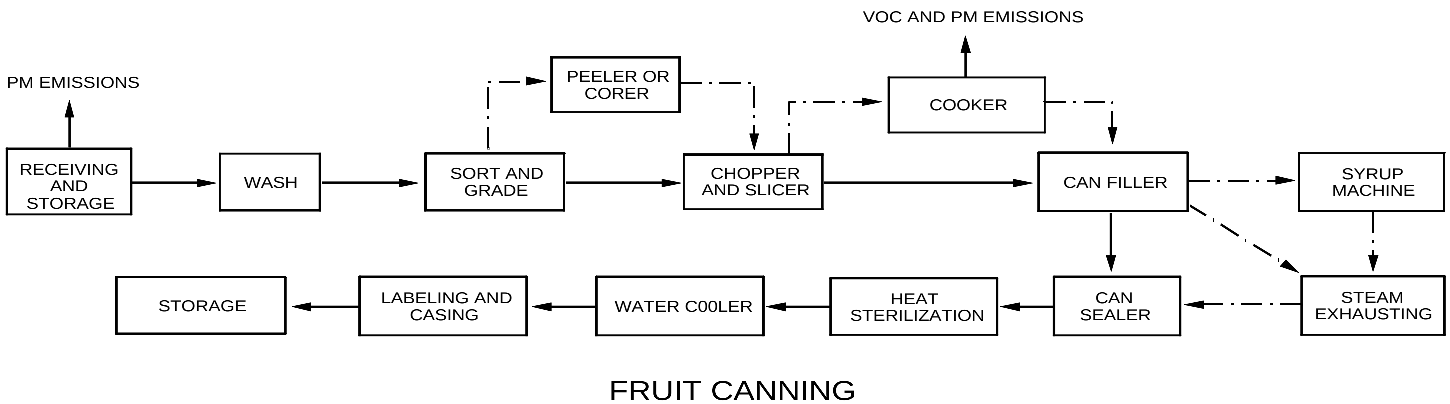

Figure 2-1: Generic process diagram for fruit canning

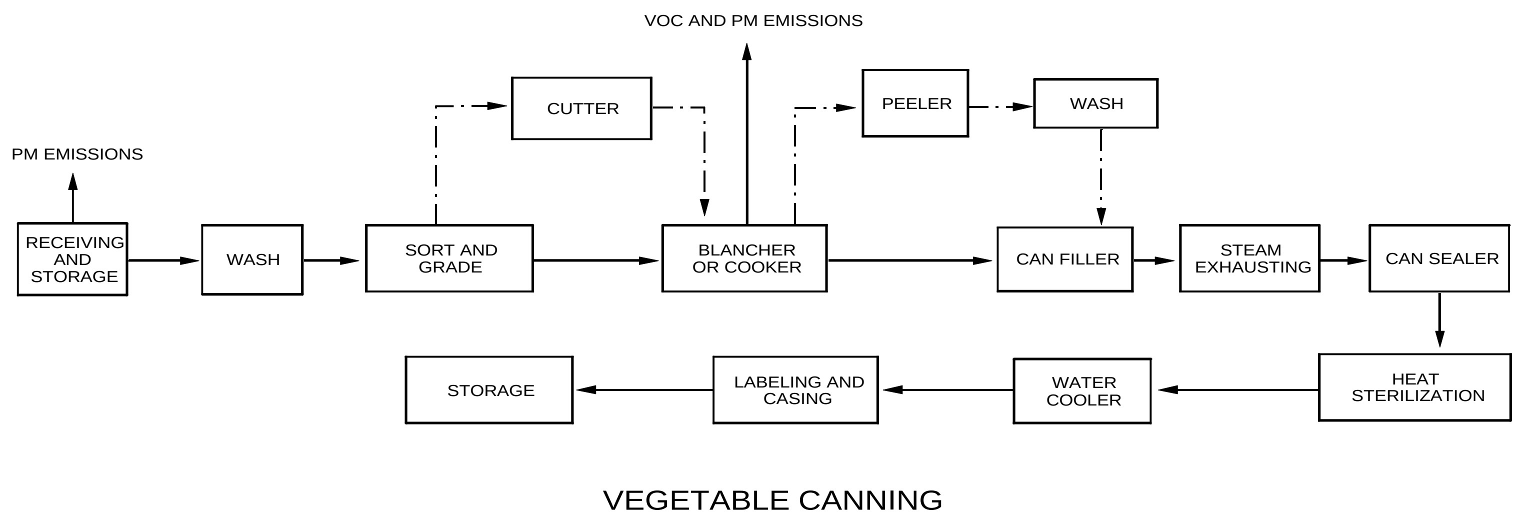

Figure 2-2: Generic process diagram for vegetable canning

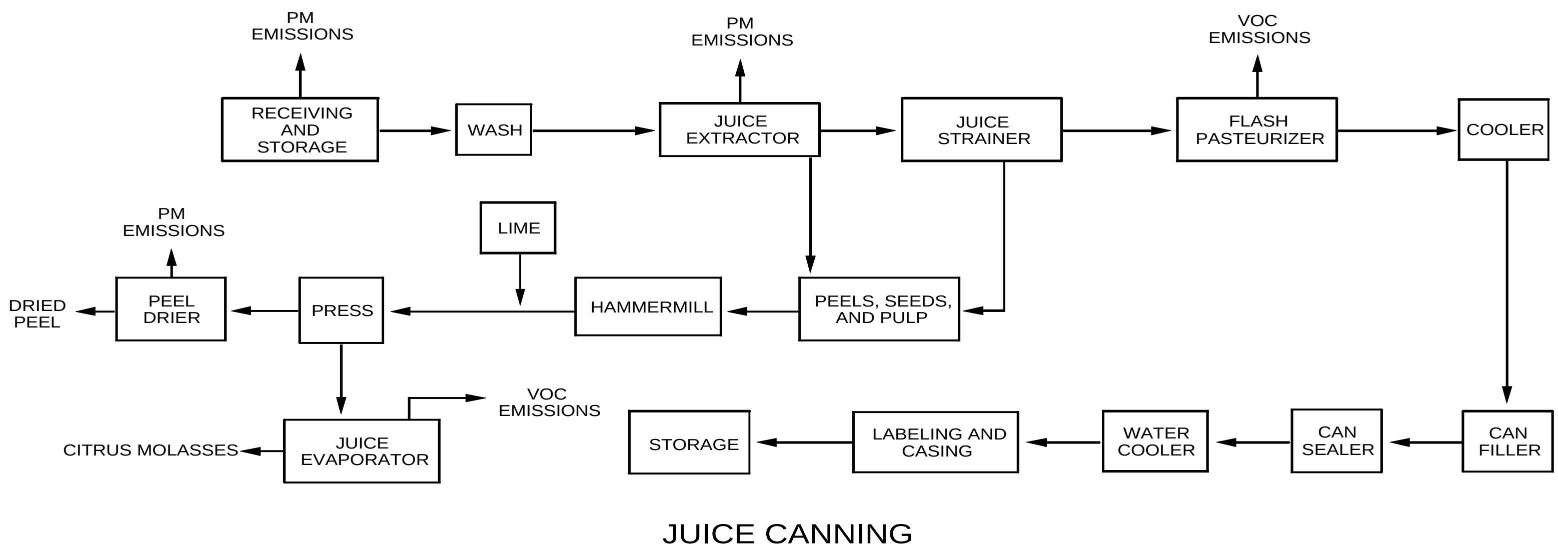

Figure 2-3: Generic process diagram for juice canning

2.2.4 Exhausting

The objective of exhausting containers is to remove air so that the pressure inside the container following heat treatment and cooling will be less than atmospheric. The reduced internal pressure (vacuum) helps to keep the can ends drawn in, reduces strain on the containers during processing, and minimizes the level of oxygen remaining in the headspace. It also helps to extend the shelf life of food products and prevents bulging of the container at high altitudes.

Vacuum in the can may be obtained by the use of heat or by mechanical means. The tomatoes may be preheated before filling and sealed hot. For products that cannot be preheated before filling, it may be necessary to pass the filled containers through a steam chamber or tunnel prior to the sealing machine to expel gases from the food and raise the temperature of the contents. Vacuum also may be produced mechanically by sealing containers in a chamber under a high vacuum.

2.2.5 Sealing

In sealing lids on metal cans, a double seam is created by interlocking the curl of the lid and flange of the can. Many closing machines are equipped to create vacuum in the headspace either mechanically or by steam-flow before lids are sealed.

2.2.6 Heat Sterilization

During processing, microorganisms that can cause spoilage are destroyed by heat. The temperature and processing time vary with the nature of the product and the size of the container.

Acidic products, such as tomatoes, are readily preserved at 100°C. The containers holding these products are processed in atmospheric steam or hot-water cookers. The rotary continuous cookers, which operate at 100°C (212°F), have largely replaced retorts and open-still cookers for processing canned tomatoes. Some plants use hydrostatic cookers and others use continuous-pressure cookers.

2.2.7 Cooling

After heat sterilization, containers are quickly cooled to prevent overcooking. The two options for quick cooling are adding water to the cooker under air pressure and conveying the containers from the cooker to a rotary cooler equipped with a cold-water spray.

2.2.8 Labeling and Casing

After the heat sterilization, cooling, and drying operations, the containers are ready for labeling. Labeling machines apply glue and labels in one high-speed operation. The labeled cans or jars are then packed into shipping cartons.

2.3 EMISSIONS[4,6-9]

Air emissions may arise from a variety of sources in the canning of fruits and vegetables. Particulate matter (PM) emissions result mainly from solids handling, solids size reduction, and drying (e.g., citrus peel driers). Some of the particles are dusts, but others (particularly those from thermal processing operations) are produced by condensation of vapors and may be in the low-micrometer or submicrometer particle-size range.

The VOC emissions may potentially occur at almost any stage of processing, but most usually are associated with thermal processing steps, such as cooking and evaporative concentration. The cooking technologies in canning processes are very high moisture processes so the predominant emissions will be steam or water vapor. Glue used in the labeling process may also be a source of VOC emissions but any emissions from this source would be expected to be extremely small. The waste gases from these operations may contain PM or, perhaps, condensable vapors, as well as malodorous VOC. Particulate matter, condensable materials, and the high moisture of canning emissions may interfere with the collection or destruction of these VOC. The condensable materials also may be malodorous.

Wastewater treatment ponds may be another source of VOC, even from processing of materials that are not otherwise particularly objectionable. Details on the processes and technologies used in wastewater collection, treatment, and storage are presented in AP-42 Section 4.3. That section should be consulted for detailed information on the subject.

No emission data quantifying VOC, HAP, or PM emissions from the canned fruits and vegetable industry are available for use in the development of emission factors. Any data on the emissions from fruit and vegetable canning operations is extremely limited. Van Langenhove, et al, identified VOC emitted during the blanching process of Brussels sprouts and cauliflower in laboratory and industrial conditions. The data represent only the relative concentration of compounds in the vapors from the rotary blanching drum and cannot be used for estimating emission factors. No data were presented for the total VOC content of the vapors emitted from the blanching drum; therefore, no information is available for the actual concentrations of any compound in the vapor stream. Aldehydes were the most abundant volatiles from cauliflower and isothiocyanates and nitriles were the most abundant from Brussels sprouts. In the industrial blanching process for cauliflower, a total of nine compounds were identified: four aldehydes, three isothiocyanates, one nitrile, and one organodisulfide. In the industrial blanching process for Brussels sprouts, a total of 12 compounds were identified: 5 aldehydes, 3 organosulfur compounds, 2 isothiocyanates, and 2 nitriles.

About 400 volatile compounds have been identified in tomatoes from studies conducted by numerous authors spanning several decades involving a number of different tomato varieties, growing conditions, and processing operations. Buttery, et al., identified 21 additional volatile aroma compounds in tomato paste that had not been previously reported as tomato components. Of the 21 compounds, the identification of 14 were confirmed and 7 were tentative identifications. There were 9 ionone-related compounds, 2 terpenoids, 4 sulfur-containing compounds, 4 nitrogen-containing compounds, 1 aldehyde, and 1 ketone. Each of the 21 compounds were present at concentrations less than 10 parts per billion (ppb) and 3 were less than 1 ppb.

Woodroof and Luh discussed the presence of VOC in apricots, cranberry juice, and cherry juice. The principal acid in cherry juice is malic acid; other acids are citric, succinic, and lactic. No concentration estimates were provided. Eight VOC were identified in apricots: five lactones, benzyl alcohol, caproic acid, and epoxy-dihydrolinalool IV. No concentration estimates were presented. Cranberry juice was found to have 43 identifiable compounds: 9 aliphatic alcohols, 8 aliphatic aldehydes and ketones, 7 terpene derivatives, 15 aromatic compounds, and 4 acids and esters.

2.4 EMISSION CONTROL TECHNOLOGY[9]

A number of VOC and particulate emission control techniques are potentially available to the canning industry. These options include the traditional approaches of wet scrubbers, dry sorbants, and cyclones. Other options include condensation and chemical reaction. No information is available for the actual controls used at canning facilities. The controls presented in this section are ones that theoretically could be used. The specific type of control device or combination of devices would vary from facility to facility depending upon the particular nature of the emissions and the pollutant loading in the gas stream. The VOC emissions from canning operations are likely to be very low and associated with a high air moisture content.

Control of VOC from a gas stream can be accomplished using one of several techniques but the most common methods are absorption, adsorption, and afterburners. Absorptive methods encompass all types of wet scrubbers using aqueous solutions to absorb the VOC. The most common scrubber systems are packed columns or beds, plate columns, spray towers, or other types of towers. Gas absorption is a diffusion controlled, gas-liquid mass transfer process. Most scrubber systems require a mist eliminator downstream of the scrubber.

Adsorptive methods could include one of four main adsorbents: activated carbon, activated alumina, silica gel, or molecular sieves. Of these four, activated carbon is the most widely used for VOC control while the remaining three are used for applications other than pollution control. Gas adsorption is a relatively expensive technique and may not be applicable to a wide variety of pollutants. The adsorbent is regenerated by heating or use of steam, which gives rise to new emissions to be controlled.

Particulate control commonly employs methods such as venturi scrubbers, dry cyclones, wet or dry electrostatic precipitators (ESPs), or dry filter systems. The most common controls are likely to be the venturi scrubbers or dry cyclones. Wet or dry ESPs could be used depending upon the particulate loading of the gas stream. These three systems are commonly used for particulate removal in many types of processing facilities.

Condensation methods and scrubbing by chemical reaction may be applicable techniques depending upon the type of emissions. Condensation methods may be either direct contact or indirect contact with the shell and tube indirect method being the most common technique. It also offers heat recovery as a bonus for certain applications. Chemical reactive scrubbing may be used for odor control in selective applications. The major problem with this technique is that it is very specific.

References for Section 2

1. U.S. Department of Commerce, International Trade Administration. U.S. Industrial Outlook 1992--Food and Beverages.

2. 1987 Census of Manufacturers, MC87-1-20-C, Industries Series, Preserved Fruits and Vegetables.

3. B. S. Luh and J. G. Woodroof, ed., Commercial Vegetable Processing, 2nd edition. Van Nostrand Reinhold, New York, 1988.

4. J. L. Jones, et al. "Overview of Environmental Control Measures and Problems in the Food Processing Industries." Industrial Environmental Research Laboratory, Cincinnati, Ohio, Kenneth Dostal, Food and Wood Products Branch. Grant No. R804642-01, January 1979.

5. N. W. Deroiser, The Technology of Food Preservation, 3rd edition. The Avi Publishing Company, Inc., Westport, CT, 1970.

6. J. G. Woodroof and B. S. Luh, ed., Commercial Fruit Processing, The Avi Publishing Company, Westport, Connecticut, 1986.

7. H. J. Van Langenhove, et al. "Identification of Volatiles Emitted During the Blanching Process of Brussels Sprouts and Cauliflower." Journal of the Science of Food and Agriculture, 55:483-487, 1991.

8. R. G. Buttery, et al. "Identification of Additional Tomato Paste Volatiles." Journal of Agricultural and Food Chemistry, 38(3):792-795, 1990.

9. H. J. Rafson, "Odor Emission Control for the Food Industry." Food Technology, June 1977.

3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

Review of emissions data began with a literature and source test search. First, EPA literature and data were reviewed including 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), the VOC/PM Speciation Data Base Management System (SPECIATE), and the Air Chief CD-ROM. New references were identified primarily through reviews of literature describing changes in fruit and vegetable canning technology.

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]

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.

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.

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

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*, EPA-454/B-93-050, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, October 1993.

4. POLLUTANT EMISSION FACTOR DEVELOPMENT

This section describes the references and test data that were evaluated to determine if pollutant emission factors could be developed for AP-42 Section 9.8.1, Canned Fruits and Vegetables.

4.1 REVIEW OF SPECIFIC DATA SETS

No source tests or other documents that could be used to develop emission factors for the AP-42 section were located during the literature search.

4.2 DEVELOPMENT OF CANDIDATE EMISSION FACTORS

No emission factors were developed because no source tests or emissions data were found.

5. PROPOSED AP-42 SECTION 9.8.1

A proposed AP-42 Section 9.8.1 Canned Fruits and Vegetables is presented in the following pages as it would appear in the document.

[Not presented here. See instead final AP-42 Section 9.8.1]