Emission Factor Documentation for AP-42 Section 9.12.1

Malt Beverages

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. IV-04

MRI Project No. 4604-04

October 1996

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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

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PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U. S. Environmental Protection Agency (EPA), under Contract No. 68-D2-0159, Work Assignment Nos. I-08, II-03, III-01, and IV-04. Mr. Dallas W. Safriet was the EPA Work Assignment Manager.

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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 routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors usually are expressed as the weight of pollutant divided by the unit weight, volume, distance, or duration of the activity that emits the pollutant. The emission factors presented in AP-42 may be appropriate to use in a number of situations, such as making source-specific emission estimates for areawide inventories for dispersion modeling, developing control strategies, screening sources for compliance purposes, establishing operating permit fees, and making permit applicability determination. The purpose of this background report is to provide information to support preparation of AP-42 Section 9.12.1, Malt Beverages.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the malt beverage industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from malt beverage production. Section 3 is a review of emission data collection and laboratory analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details revisions to the existing AP-42 section narrative and pollutant emission factor development. It includes the review of specific data sets and the results of data analysis. Section 5 presents the AP-42 Section 9.12.1, Malt Beverages.

2. INDUSTRY DESCRIPTION

Malt beverage production operations are classified under standard industrial classification (SIC) code 2082, Malt Beverages. The primary product of malt beverage production is beer, and secondary products include brewers grain (sold for use as livestock feed) and ethanol. Beer, as referred to in this document, includes pilsners, ales, stouts, malt liquors, and other types of beers. Five eight-digit source classification codes (SCC) are currently assigned for malt beverage production operations: 3-02-009-01 (Grain Handling), 3-02-009-02 (Drying Spent Grains), 3-02-009-03 (Brewing), 3-02-009-04 (Aging), and 3-02-009-05 (Malt Drying).

2.1 CHARACTERIZATION OF THE INDUSTRY[1-3]

A recent trend in the malt beverage industry is the growth of microbreweries, which are small breweries that produce beer for on-site consumption or limited local distribution. The number of microbreweries operating in the United States has increased from 29 in 1985 to about 350 in 1993. During this same period, microbrewery beer production has increased from about 75,000 to over 1.2 million barrels (bbl) per year (yr). Recent changes in State laws have encouraged the creation of microbreweries in some States. The increase in the number and production of microbreweries increases the dispersion of ethanol emissions across the country.

The 1992 Census of Manufactures reports 194 malt beverage establishments in the United States. This number includes some microbreweries, but the exact number is not clear. Seventy-five of the 194 facilities employed 20 or more people in 1992. Data from the U.S. Department of the Treasury, Bureau of Alcohol, Tobacco, and Firearms, show a total of 879 breweries in the U.S. in 1995. In 1995, the States with the largest number of malt beverage producing facilities were California, Colorado, Oregon, and Washington. Table 2-1 lists the number of establishments by State as reported in the 1992 Census of Manufactures and the number as reported by the Bureau of Alcohol, Tobacco, and Firearms (1995).

2.2 PROCESS DESCRIPTION[4-6,8]

The production of malt beverages, or beer, comprises four main stages: brewhouse operations, fermentation, aging or secondary fermentation, and packaging. Figures 2-1, 2-2, 2-3, and 2-4 show the various stages of a typical brewing process, including potential emission points.

Breweries typically purchase malted grain (malt) from malting operations. In the malting process, grain is first soaked in water-filled steeping tanks for softening. After softening, the grain is transferred to germination tanks, in which the grain germinates, typically over a 1-week period. From the germination tanks, the grain enters a kiln, which halts germination by drying the grain. To begin the brewing process, malt (usually barley malt) is transported by truck or rail to a brewery and is conveyed to storage silos. The malt is then ground into malt flour by malt mills and is transferred to milled malt hoppers. Many small breweries purchase malt flour (malted and milled grain) from facilities with malt mills. Malt provides the starch-splitting and protein-splitting enzymes that are necessary to convert grain starches into fermentable sugars.

From the milled malt hoppers, the malt, along with hot water, is fed to the mash tun and heated to convert grain starches to fermentable sugars. Some large facilities use high-temperature mashing, which reduces the time required to convert the starches to sugars, but lowers the quantity of fermentable sugars produced. Most breweries use one of the three principal mashing processes; these are: double mashing, decoction, and infusion. Double mashing uses grains other than barley (typically corn and rice) as starch adjuncts. Before being added to the mash tun, the adjunct grains are broken down through cooking in a cereal cooker for about 1 hour at temperatures ranging from 40° to 100°C (104° to 212°F). Some plants do not use cereal cookers, but use additives such as corn syrup that function as adjunct grains. The malt and adjuncts are then mixed and heated in the mash tun. Decoction is a method of boiling portions of the mixture (mash) and adding the boiling portions to the mash tun to raise the overall temperature to about 75°C (167°F). The infusion process mixes the malt with hot water to maintain a uniform temperature (65° to 75°C [149° to 167°F]) until starch conversion is complete. Mixing, heating times, and temperatures vary among breweries. The finished product of mashing is a grain slurry, called mash.

From the mash tun, the mash is pumped to a straining tank called a lauter tun, which separates insoluble grain residues from the mash. The mash enters the lauter tun through a false bottom where the insoluble grain residues are allowed to settle. The grain sediment acts as a filter for the mash as it enters the tank. Various other filter agents, such as polypropylene fibers, are also used. Some large breweries use strainmasters, which are a variation of lauter tuns. The spent grain by-products from the lauter tun or strainmaster are conveyed to holding tanks, dried (by some breweries), and sold as animal feed. The product of the lauter tun is called wort.

The strained wort from the lauter tun is transferred to the brew kettle and is boiled, typically for about 90 to 120 minutes. Boiling stops the starch-to-sugar conversion, sterilizes the wort, precipitates hydrolyzed proteins, concentrates the wort by evaporating excess water, and facilitates chemical changes that affect beer flavor. Hops are added to the wort during the boiling process. Hops are high in iso-α acids, which impart the characteristic bitter flavor to beer. Some breweries add only hop extracts (that contain the desired iso-α acids), and some breweries add hop extracts during or after the fermentation process. After brewing, the hops are strained from the hot wort, and the hot wort is pumped to a large settling tank, where it is held to allow the remaining insoluble material (trub) to settle. The trub is transferred to the spent grain holding tanks. After settling, the hot wort is pumped to a cooling system (typically a closed system), which cools the liquid to temperatures ranging from about 7° to 12°C (44° to 54°F). Following cooling, yeast is added to the cooled wort as it is pumped to the fermenters.

Fermentation takes place in large tanks (fermenters--typically with capacities $\geq$1,000 barrels for medium to large breweries) that can be either open or closed to the atmosphere. Most closed-tank fermenters include CO_2 collection systems, which recover CO_2 for internal use and remove organic impurities from the CO_2; water scrubbers and activated carbon adsorption systems are used to remove impurities. The scrubber water is commonly discharged as process wastewater, and the activated carbon is typically recharged (regenerated) on-site (the impurities are typically vented to the atmosphere during regeneration).

Fermentation is a biological process in which yeast converts sugars into ethyl alcohol (ethanol), carbon dioxide (CO_2), and water. Yeasts can ferment at either the bottom or the top of the fermenter. *Saccharomyces carlsbergensis* are common bottom-fermenting yeasts used to produce lager beers. Bottom-fermenting yeasts initially rise to the top of the fermenter, but then flocculate to the bottom during rapid fermentation. When fermentation moderates, the beer is run off the top of the fermenter, leaving the bottom-fermenting yeasts at the bottom of the tank. *Saccharomyces cerevisiae* are top-fermenting yeasts commonly used to produce ales, porters, and stout beers. Top-fermenting yeasts rise to the top of the fermenter during rapid fermentation and are skimmed or centrifuged off the top when fermentation moderates. The type of yeast used and the length of the fermentation process vary among breweries and types of beer. Most pilsner beers ferment at temperatures varying from 6° to 20°C (43° to 68°F).

After primary fermentation, waste yeast is typically removed from the liquid (by centrifuges or other means), and the liquid proceeds to a secondary fermentation or aging process. The liquid is pumped to aging tanks, a small quantity of freshly fermenting wort is added (at some breweries), and the mixture is stored at low temperatures (below about 5°C [41°F]).

Several methods are used for the disposal of yeast, including: recovery of viable yeast for reuse in the fermentation process, sale to animal feed processors, distillation to recover residual ethanol, and disposal as process wastewater.

After the beer is aged, solids are typically removed by centrifugation or filtration with diatomaceous earth filters, and the beer is pumped to final storage (beer storage tanks). From final storage, the beer is pumped to the packaging (canning and bottling) facility.

Packaging facilities typically include several canning and bottling lines, as well as a keg filling operation. Most facilities pasteurize beer after canning or bottling, although some facilities package nonpasteurized products using sterile filling lines. Beer that spills during packaging is typically collected by a drainage system, and can be processed to remove or recover ethanol before discharge as process wastewater. Damaged and partially filled cans and bottles are typically collected, crushed, and recycled. Beer from the damaged cans and bottles can be processed to remove or recover ethanol before discharge as industrial sewage. The final steps in the process are labeling, packaging for distribution, and shipping.

Microbreweries typically produce beer for on-site consumption, although some have limited local keg distribution. The beer production process is similar to that of large breweries, although several processes may be excluded or combined. Most microbreweries purchase bags of either malted barley or malt flour for use in beer making. Malt flour requires no processing and is added directly to the mash tun. The facilities that use malted barley typically have a small "cracker" that cracks the grain prior to mashing. Brewhouse operations (mashing, brewers grain settling, brewing, and trub settling) may be combined to decrease the number of tanks required. Fermentation tanks and storage tanks are much smaller than large brewery tanks, with capacities as small as a few barrels. Many microbrews are held in fermentation tanks for three to four weeks (far longer than most mass-produced beers). Canning and bottling operations typically are not found in microbreweries.

TABLE 2-1. NUMBER OF BREWERY ESTABLISHMENTS BY STATE[1,2]

State	Number of breweries, Census of Manufactures, 1992	Number of breweries, Bureau of Alcohol, Tobacco, and Firearms, 1995
Alabama	0	6
Alaska	0	6
Arizona	0	11
Arkansas	0	3
California	35	157
Colorado	13	57
Connecticut	0	4
Delaware	0	2
Florida	4	46
Georgia	2	5
Hawaii	0	5
Idaho	0	14
Illinois	0	19
Indiana	4	8
Iowa	0	5
Kansas	0	9
Kentucky	0	4
Louisiana	0	2
Maine	0	18
Maryland	1	10
Massachusetts	0	24
Michigan	0	20
Minnesota	5	16
Missouri	4	10
Montana	0	12
Nebraska	0	7
Nevada	0	5
New Hampshire	2	11

TABLE 2-1. (continued)

State	Number of breweries, Census of Manufactures, 1992	Number of breweries, Bureau of Alcohol, Tobacco, and Firearms, 1995
New Jersey	4	6
New Mexico	0	11
New York	9	39
North Carolina	3	24
North Dakota	0	1
Ohio	6	25
Oklahoma	0	7
Oregon	11	55
Pennsylvania	15	25
Rhode Island	0	6
South Carolina	0	9
South Dakota	0	2
Tennessee	2	13
Texas	8	35
Utah	0	12
Vermont	0	11
Virginia	5	10
Washington	14	53
Washington,	0	1
West Virginia	0	2
Wisconsin	11	31
Wyoming	0	5
Total	158[a]	879

[a] An additional 36 facilities are reported in the census but are not classified by State.

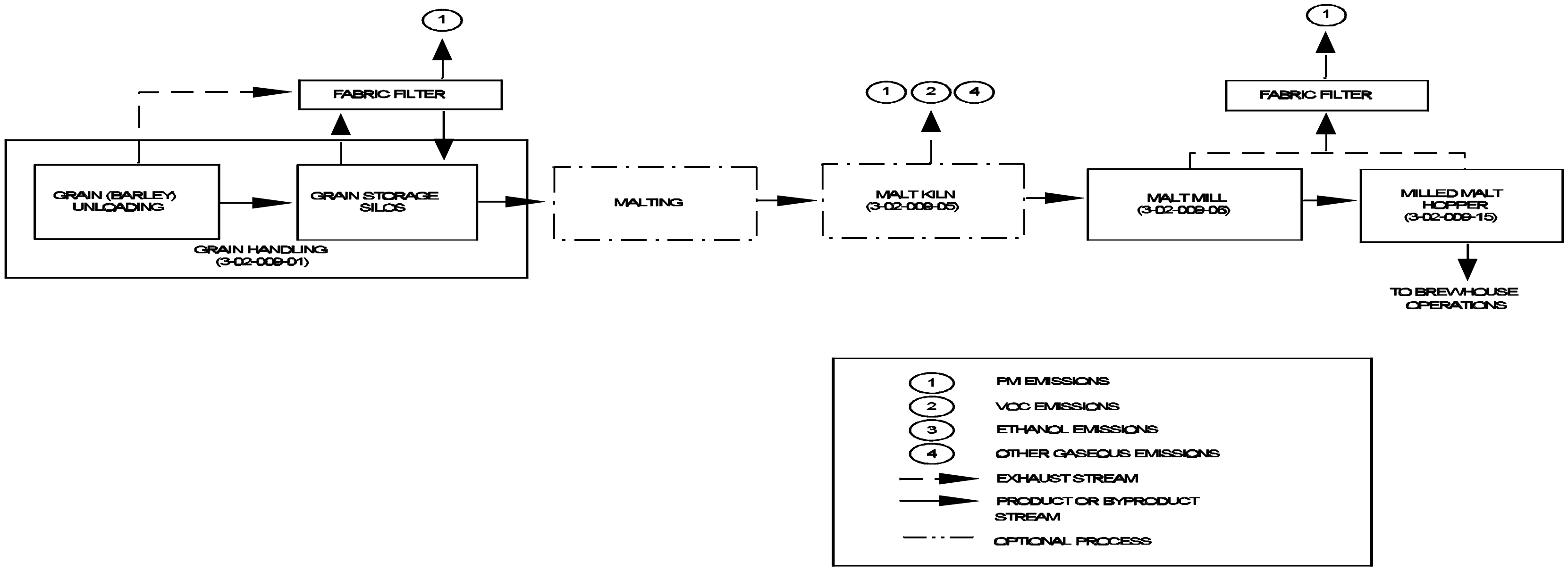

Figure 2-1. Typical brewery grain handling and malting operations.
(Source Classification Codes in parentheses.)

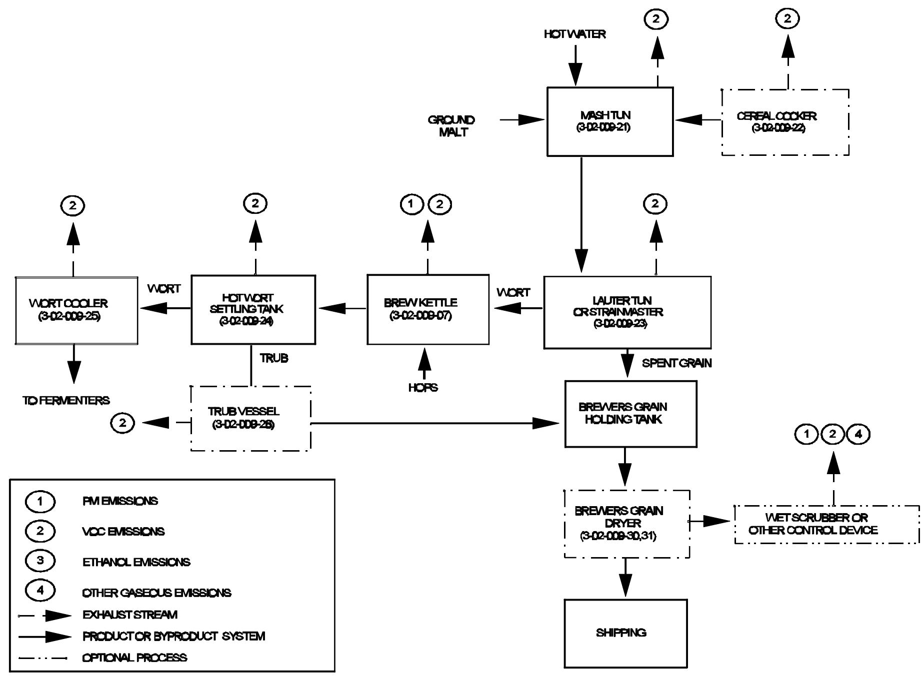

Figure 2-2. Typical brewhouse operations.
(Source Classification Codes in parentheses.)

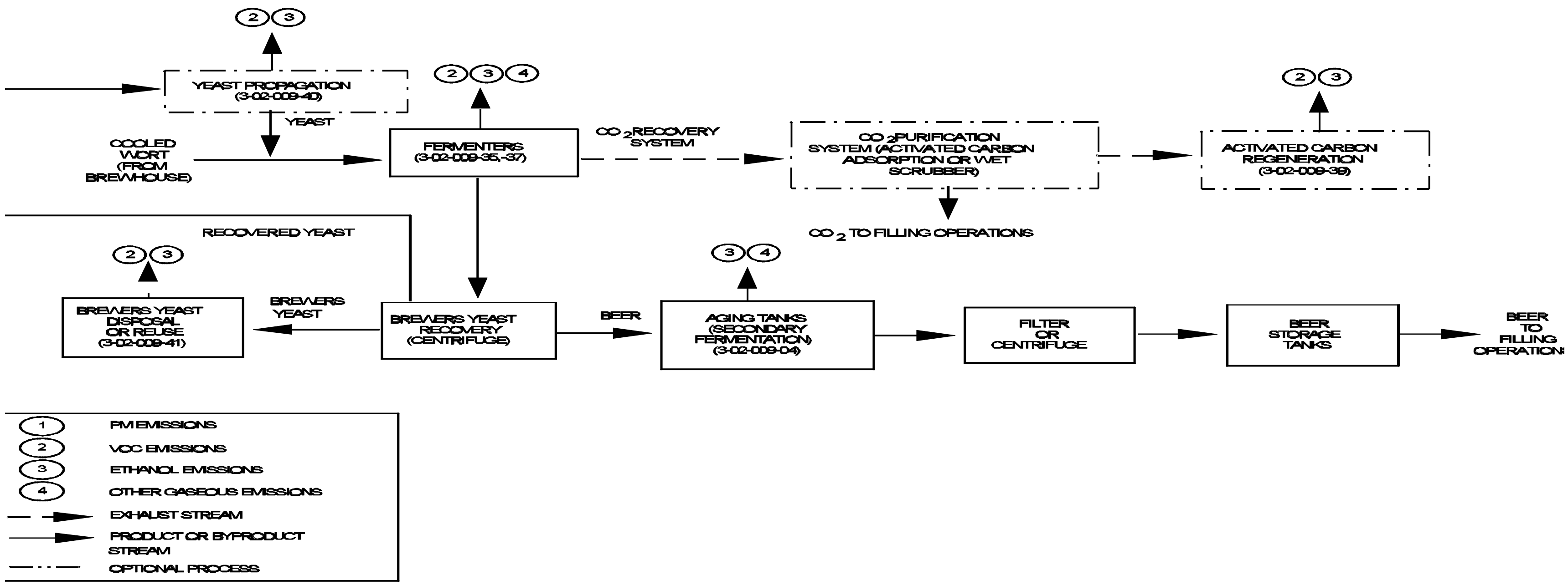

Figure 2-3. Typical fermentation and post-fermentation brewery operations.
(Source Classification Codes in parentheses.)

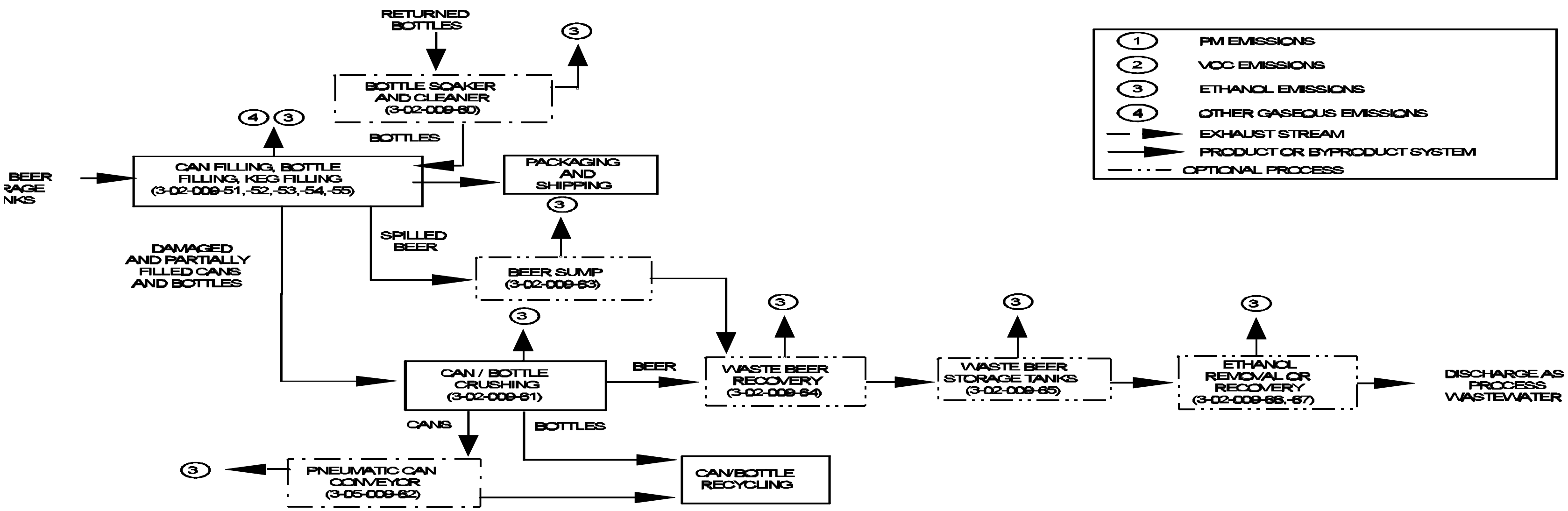

Figure 2-4. Typical filling room operations.
(Source Classification Codes in parentheses.)

2.3 EMISSIONS AND CONTROLS[4-8]

2.3.1 Emissions

Ethanol is the primary volatile organic compound (VOC) emitted from the production of malt beverages. Aldehydes, ethyl acetate, other VOC's, CO_2, and particulate matter (PM) are also generated and potentially emitted.

Potential VOC emission sources include mash tuns, cereal cookers, lauter tuns or strainmasters, brew kettles, hot wort settling tanks, yeast storage and propagation (see AP-42 Section 9.13.4), fermenters, spent grain holding tanks, activated charcoal regeneration systems (at breweries with CO_2 recovery), aging tanks (sometimes referred to as "ruh" storage tanks), other storage tanks, and packaging operations. The operations that precede fermentation are sources of various species of VOC. Post-fermentation operations emit primarily ethanol; however, small quantities of ethyl acetate and various aldehydes may also be emitted from fermenters and post-fermentation operations. Other VOC that are emitted from cooking processes (mash tuns, hot wort tanks, and brew kettles) may include dimethyl sulfide, C_5-aldehydes, and myrcene (a hop oil emitted from brew kettles).

Fermenters are a source of ethanol, other VOC, and CO_2; large breweries typically recover CO_2 for internal use. However, smaller breweries and microbreweries typically vent CO_2 to the atmosphere.

Potential sources of PM emissions from breweries include the grain malting, handling, and processing operations (see AP-42 Section 9.9.1), brewhouse operations, and spent-grain drying.

Emissions from microbreweries consist of the same pollutants as large brewery emissions. No test data are available to quantify these emissions, but they are expected to be negligible based on the amount of beer produced in these facilities. Emission control devices are not typically used by microbreweries.

2.3.2 Control Technology

Process loss controls are used to reduce emissions from malt beverage production. Add-on emission controls are used to recover CO_2 in the fermentation process and to control PM emissions from grain handling and brewers grain drying. Large breweries typically use CO_2 recovery systems, which include wet scrubbers and activated carbon beds to remove impurities from the CO_2. The scrubber water is typically discharged as process wastewater, and organic impurities collected by the activated carbon beds are typically released to the atmosphere.

Wet scrubbers could potentially be used to control ethanol emissions. However, scrubber efficiency is based, in part, on the pollutant concentration (200 to 300 parts per million by volume [ppmv] is needed for minimal efficiency), and the ethanol concentrations in fermentation rooms are typically very low (about 100 ppmv). Incineration is also an inefficient control measure if pollutant concentrations are low. Recovery of ethanol vapor by carbon adsorption or other methods is another control alternative, although the cost of recovery may be high.

Grain handling and processing operations (unloading, conveying, milling, and storage) are typically controlled by fabric filters. Many smaller breweries purchase malt flour, and do not have milling operations.

REFERENCES FOR SECTION 2

1. *1992 Census of Manufactures: Beverages*, U. S. Department of Commerce, Bureau of Census, April 1995.

2. Written communication from J.R. McCollum, Department of the Treasury, Bureau of Alcohol, Tobacco, and Firearms, Atlanta, GA, to Tom Lapp, Midwest Research Institute, Cary, NC, October 16, 1996.

3. *A Macro Demand for Microbrews*, USA Today, October 8, 1993.

4. Written communication from Brian Shrager, Midwest Research Institute, Cary, NC, to Dallas Safriet, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 5, 1994.

5. Richard D. Rapoport et al., *Characterization of Fermentation Emissions from California Breweries*, Science Applications, Inc., Los Angeles, CA, October 26, 1983.

6. Written communication from Jere Zimmerman, Adolph Coors Company, Golden, CO, to David Reisdorph, Midwest Research Institute, Kansas City, MO, March 11, 1993.

7. *Air Emissions Investigation Report*, Miller Brewing Company, Fulton, NY, February 24, 1994.

8. Written communication from Arthur J. DeCelle, Beer Institute, Washington, D.C., to Dallas Safriet, U. S. Environmental Protection Agency, Research Triangle Park, NC, February 15, 1995.

3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The AP-42 background files located in the Emission Factor and Inventory Group (EFIG) were reviewed for information on the industry, processes, and emissions. The Factor Information and Retrieval (FIRE), Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF), and VOC/PM Speciation Data Base Management System (SPECIATE) data bases were searched by SCC code for identification of the potential pollutants emitted and emission factors for those pollutants. A general search of the Air CHIEF CD-ROM also was conducted to supplement the information from these data bases.

Information on the industry, including number of plants, plant location, and annual production capacities, was obtained from the *Census of Manufactures* and other sources. The Aerometric Information Retrieval System (AIRS) data base also was searched for data on the number of plants, plant location, and estimated annual emissions of criteria pollutants. A number of sources of information were investigated specifically for emission test reports and data. A search of the Test Method Storage and Retrieval (TSAR) data base was conducted to identify test reports for sources within the malt beverage industry. However, no test reports were located using the TSAR data base. The EPA library was searched for additional test reports. Using information obtained on plant locations, individual facilities and State and Regional offices were contacted about the availability of test reports. Publications lists from the Office of Research and Development (ORD) and Control Technology Center (CTC) were also searched for reports on emissions from the malt beverage industry. In addition, representative trade associations, including the Beer Institute, were contacted for assistance in obtaining information about the industry and emissions. Individual companies were also contacted to request test data. All of the test reports that were located were provided by individual companies.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study should contain test results based on more than one test run. If results from only one run are presented, the emission factors must be down rated.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 DATA QUALITY RATING SYSTEM[1]

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:

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

2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front half with EPA Method 5 front and back half);

3. Test series of controlled emissions for which the control device is not specified;

4. Test series in which the source process is not clearly identified and described; and

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EFIG for preparing AP-42 sections. The data were rated as follows:

A—Multiple test runs that were performed using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B—Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C—Tests that were based on an unproven or new methodology or that lacked a significant amount of background information.

D—Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

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

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

2. <u>Sampling procedures</u>. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. 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 contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was 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 quality of the emission factors developed from analysis of the test data was rated using the following general criteria:

A—Excellent: Developed from A- and B-rated source test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B—Above average: Developed only from A- or B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A-, B- and/or C-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.

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

E—Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do 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 these criteria is somewhat subjective and depends to an extent upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Section 4.

REFERENCE FOR SECTION 3

1. *Procedures for Preparing Emission Factor Documents, Second Revised Draft Version*, EPA-454/R-95-___, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1995.

4. AP-42 SECTION DEVELOPMENT

4.1 REVISION OF SECTION NARRATIVE

The AP-42 section for malt beverages was revised and a new section number was assigned (old number 6.5.1, new number 9.12.1). The narrative was revised to provide a more clear and complete description of the process and emissions and to reflect the addition of new emission factors. Emission factors were revised using available emission data.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

A total of 30 references were obtained for use in developing new emission factors for malt beverages. In addition, the FIRE, XATEF, and SPECIATE data base records on beer brewing and the Toxic Release Inventory (for evidence of hazardous air pollutants) were examined for useful data. References 1 through 7 are the primary references cited in the existing section (6.5.1) and are not used for emission factor development because they lack original source test data. Reference 8 is a summary of two source tests conducted at two breweries in California and also provides survey data from nine breweries operating in California. Reference 9 is a memorandum (from the AIR CHIEF Bulletin Board System) that discusses the California source tests and emission factors, but does not provide any new data and therefore is not used for emission factor development. References 10 through 24, 27, and 30 are reports of various source tests and studies performed at a brewery in Colorado. Reference 25 is a report summarizing the results of a testing program conducted at a New York brewery; the data are used in the document to develop an emission inventory for the facility. Reference 26 is a source test report for a compliance test conducted at an Ohio brewery. Reference 28 is the original source test report summarized in Reference 25, and Reference 29 is a report of a source test conducted at another brewery in Colorado. Table 4-1 lists the references that were not used for emission factor development and the reasons that these references were not used.

4.2.1 Review of Specific Data Sets

4.2.1.1 Reference 8. Science Applications, Inc., performed a brewery survey and two brewery source tests for the California Air Resources Board (Contract No. A2-73-32) in 1982 and 1983. The survey was designed to determine total production, temporal operating cycles, air pollution controls, by-product handling practices, and fermentation gas handling practices. All nine breweries operating in California at the time of the survey responded. Four of the breweries were producing over 60,000 barrels per year (bbl/yr) and five were producing less than 60,000 bbl/yr. The survey indicated that the large breweries operate 24 hours per day (hr/d), 365 days per year (d/yr), while small breweries typically operate 8 to 10 hr/d, 3 to 5 days per week (d/wk) year-round. Production rates vary little by season—summer, 26.7 percent of total production; fall, 25.6 percent; spring, 24.5 percent; and winter, 23.2 percent. None of the respondents used air pollution control devices to control fermentation emissions, although the large breweries did collect carbon dioxide for use in the process.

The survey was followed by two source tests: one conducted at a small brewery operated by Anchor Brewing Company and the other conducted at a large brewery that was not identified (by company name) in the report. Both source tests consisted of two phases.

TABLE 4-1. REFERENCES NOT USED FOR EMISSION FACTOR DEVELOPMENT

Reference	Reason for rejection
1	No source test data
2	No source test data
3	No source test data
4	No source test data
5	No source test data
6	No source test data
7	No source test data
8	Test methods not comparable to EPA reference methods
9	Not original data source
13	No process data
25	Not original data source
30	Not original data source

Phase I monitoring identified the significant emission sources, qualitatively characterized the VOC emitted, and determined the most effective sampling and analytical techniques for measuring emissions. Tedlar bags, Tenax traps, and portable organic vapor analyzers were found to be ineffective in collecting and analyzing samples due to the high moisture content of the emissions. Charcoal tubes and water-filled impingers were found to be effective at collecting samples for analysis. The significant emission sources that were identified by preliminary sampling include the mash tun or cooker, lauter tun or strainmaster, rice cooker, the brew kettle, the hot wort tank, fermentation, the activated carbon regeneration (carbon dioxide purification system), and the beechwood chip washer. Samples collected in the Phase I monitoring were analyzed by gas chromatography (GC) using flame ionization detection (FID) and mass spectrometry (MS). The VOC species were identified as ethanol, ethyl acetate, dimethyl sulfide, monoterpenes, and aldehydes and ketones. Since some of the species are not readily soluble in water, a decision was made to add XAD resin to the impinger sampling train for Phase II monitoring.

Phase II monitoring was designed to quantify the emissions from the sources identified in Phase I monitoring and to enable the development of source emission factors for breweries. Sampling for Phase II monitoring used two types of sampling trains: a charcoal tube sampling train and a water and XAD resin impinger train. Analysis was conducted using the same equipment discussed above for Phase I monitoring.

The samples were analyzed by both packed column GC/FID for volatile compounds and solvent extraction followed by capillary column GC/FID for semivolatile compounds. The impinger train contents were extracted using EPA Method 625.

Using the data presented in this document, emission factors for VOC and ethanol (for processes where emissions were identified as greater than 99 percent ethanol) were developed from the test data. The emission factors were calculated for each process using the equation:

$$\frac{\text{emission factor}}{\text{C/10}^3\text{ bbl beer produced)}} = \left[\frac{\text{(VOC concentration in the sample, mg/m}^3\text{) (exhaust flow rate, m}}{(4.54 \times 10^5 \text{ mg/lb})} \times \frac{\text{(process cycle time, min) (1,000)}}{\text{(amount of beer produced per cycle, bbl)}}\right] \quad (4\text{-}1)$$

All of the emission factors are expressed in units of lb of pollutant per 1,000 bbl of beer packaged. Emission factors based on grain throughput were not developed because grain throughput data were considered confidential and were not provided by the plants.

Test data and the calculated emission factors for small breweries are presented in Table 4-2, and analogous test results for large breweries are given in Table 4-3.

The data from this reference are not rated for use in developing emission factors because the test methods used are not EPA reference methods, run-by-run test data are not presented in the document, and the document is a secondary reference.

4.2.1.2 Reference 10. This document summarizes the emission tests presented in References 11 through 24. Emission factor calculations, process rates, problems encountered during testing, and general discussions regarding the applicability of the emission factors to other facilities are included in this document. This document was used to supplement the information and data contained in References 11 through 24. Pertinent test data, process data, and emission factor calculations are provided in Appendix A.

4.2.1.3 Reference 11. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery from June 23 through July 20, 1992. The sources tested include a sterile can filling line, sterile bottle filling line, sterile keg filling line, crushed can conveyor, hot wort settling tank (whirlpool vent), wort cooler, trub vessels, beer loadout, and yeast drying. These processes were each tested for uncontrolled emissions of VOC (as propane) using EPA Method 25A and carbon dioxide (CO_2) using EPA Method 3 (with Orsat gas analyzer). Because organic emissions from the filling, can conveying, beer loadout, and yeast drying processes are believed to be primarily ethanol, the VOC emissions from these sources were converted to ethanol using conversion factors, which were developed by calibrating the FID for ethanol as well as propane. The individual tests are described in the following paragraphs.

The first test was conducted on the can filler room vent. Three test runs were conducted, and process rates in bbl/hr were measured during each run. The vent that was tested carried an average flow of 26,217 dry standard cubic feet per minute (dscfm), and the average flow into the filler room was 61,242 dscfm. Therefore, the emission rates measured in the vent were multiplied by the ratio of the flow into the room to the flow out of the vent. This calculation is based on the assumption that all of the air leaving the room has the same pollutant concentrations as the air sampled in the vent. These data are assigned a B rating because of the assumption discussed above. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

TABLE 4-2. EMISSION FACTOR CALCULATIONS FOR SMALL BREWERIES[a]

Parameter	Process site				
	Mash tun stack[b]	Lauter tun stack[c]	Brew kettle stack[d]	Hot wort tank vent[e]	Fermentation room exhaust vent[f]
VOC concentration in the sample, mg/m^3	104.71	29.50	173.78	299.05	211.53
Exhaust flow rate, m^3/min	1.08	1.98	10.50	2.90	22.12
Process cycle time, min	155	145	90	40	1,440
Amount of beer per cycle, bbl	96	96	96	96	288
Emission factor kg VOC/10^3 bbl (lb VOC/10^3 bbl)	0.183 (0.403)	0.088 (0.194)	1.711 (3.771)	0.361 (0.797)	23.395 (51.578)

[a]Reference 8. Small breweries are defined as breweries producing less than 60,000 bbl/yr. bbl = Barrels of beer (31 gal/barrel).
[b]Reported emissions include dimethyl sulfide, C5-aldehydes, ethanol, C5-alcohol, and other unidentified compounds.
[c]Reported emissions include ethanol, dimethyl sulfide, C5-aldehydes, and acetaldehyde.
[d]Reported emissions include dimethyl sulfide, C5-aldehydes, acetaldehyde, myrcene, ethanol, and other unidentified compounds.
[e]Reported emissions include myrcene, C5-aldehydes, ethanol, dimethyl sulfide, acetaldehyde, β-caryophyllene, furfural, phenyl acetaldehyde, cyclic hydrocarbons, and other unidentified compounds.
[f]Reported emissions are over 99 percent ethanol.

TABLE 4-3. EMISSION FACTOR CALCULATIONS FOR LARGE BREWERIES[a]

Parameter	Process site					
	Mash cooker stack[b]	Rice cooker stack[c]	Strainmaster stack[d]	Brew kettle stack[e]	Activated carbon regeneration vent[f]	Beechwood chip washer vent[g]
VOC concentration in the sample, mg/m^3	6.19	0.28	96.59	49.26	467.72	25.37
Exhaust flow rate, m^3/min	134.20	141.39	94.82	133.78	10.76	98.45
Process cycle time, min	120	45	25	90	NA	60
Amount of beer per cycle, bbl	800	800	800	800	5,600	343
Emission factor kg VOC/10^3 bbl (lb VOC/10^3 bbl)	0.125 (0.275)	0.00223 (0.00491)	0.286 (0.631)	0.741 (1.634)	0.300 (0.660)	0.437 (0.963)

[a]Reference 8. Large breweries are defined as breweries producing more than 60,000 bbl/yr. NA = not applicable.
[b]Reported emissions include ethanol, dimethyl sulfide, hexanal, and other unidentified compounds.
[c]Reported emissions are primarily hexanal with lesser amounts of other unidentified compounds.
[d]Reported emissions include dimethyl sulfide, C5-aldehydes, acetaldehyde, and other unidentified compounds.
[e]Reported emissions include myrcene, dimethyl sulfide, ethanol, C5-aldehydes, β-caryophyllene, acetaldehyde, aliphatic hydrocarbons, and other unidentified compounds.
[f]Reported emissions are primarily ethanol, with lesser amounts of ethyl acetate, C7-ester, C5-alcohol, dimethyl sulfide, and other unidentified compounds.
Measurements taken during first two hours of cycle.
[g]Reported emissions are about 99 percent ethanol.

The second test was conducted on the bottle and can filler bowl CO_2 vent, which is part of both the can and bottle filling lines. Three test runs were conducted, and process rates in bbl/hr were measured during each run. The average emission factor from this test is added to both the can filler vent and bottle filler vent emission factors to develop emission factors for the entire can filling line and bottle filling line. These data are assigned an A rating. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

The third test was conducted on the bottle filler room vent. Three test runs were conducted, and process rates in bbl/hr were measured during each run. The vent that was tested carried an average flow of 20,233 dscfm, and the average flow into the filler room was 28,056 dscfm. Therefore, the emission rates measured in the vent were multiplied by the ratio of the flow into the room to the flow out of the vent. This calculation relies on the assumption that all of the air leaving the room has the same pollutant concentrations as the air sampled in the vent. These data are assigned a B rating because of the assumption discussed above. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

The fourth test was conducted on the No. 3 keg line filler vent. Three test runs were conducted, and process rates in bbl/hr were measured during each run. However, the keg line was not operating during Run 1. Therefore, the average emission factor from this test was calculated using data from only two test runs. These data are assigned a B rating because only two valid test runs were conducted and a hot wire anemometer (not the reference method) was used to determine the stack gas velocities. The reference test methods were used (except for determining stack gas velocities), no problems were reported during the valid test runs, and adequate detail was provided in the report.

The fifth test was conducted on the crushed can pneumatic conveyor, which transports cans from an open system can crusher to a cyclone for collection. During testing, ethanol emission rates were relatively constant and did not appear to be affected by process throughput, possibly because the air stream was saturated with ethanol. Consequently, process throughput rates were not included for this test, and the emission factors presented are in units of pounds of pollutant per hour of conveyor operation. A subsequent test (Reference 24) showed that an incorrect assumption was made when determining emission factors from this test. Therefore, the results of this test are not used for emission factor development.

The sixth test was conducted on the whirlpool vent 7, which vents emissions from the hot wort settling tank. The hot wort settling tank is a large tank into which hot wort flows and is stored until the trub settles out of the wort. Two test runs were conducted during the quiescent and drain processing phase, and two test runs were conducted during filling. Ethanol is not emitted from this process, because the wort is not fermented. Therefore, the results of this test are reported as VOC (as propane). An average process rate (bbl/batch) was provided. These data are assigned a C rating because only two valid test runs were conducted, only an average process rate was provided, and a hot wire anemometer was used to determine the stack gas velocities. The reference test methods were used (except for determining stack gas velocities), no problems were reported during the valid test runs, and adequate detail was provided in the report.

The seventh test was conducted on the wort cooler, in which hot wort flows over a plate filled with cooling liquid. Three test runs were conducted, and the process capacity (bbl/hr) was provided. Actual process data are not provided. Ethanol is not emitted from this process, because the wort is not fermented. Therefore, the results of this test are reported as VOC (as propane). These data are assigned a C rating because the process was assumed to be operating at capacity and a hot wire anemometer (not the reference method) was used to determine the stack gas velocities. The reference test methods were used (except for determining stack gas velocities), no problems were reported during the valid test runs, and adequate detail was provided in the report.

The eighth test was conducted on the trub vessels (filling only), which serve as holding tanks for the trub that settles out of the hot wort. Three test runs were conducted during filling operations, and process throughputs for each run (bbl) were provided. Ethanol is not emitted from this process, because the grain is not fermented. Therefore, the results of this test are reported as VOC (as propane). These data are assigned a C rating because the average duration of the three test runs was only about 5 minutes. No other problems were reported, and adequate detail was provided in the report.

The final two tests were conducted on a beer loadout operation and a yeast drying plant. Process rates were not provided for either test. Therefore, these data are not rated and cannot be used to develop emission factors.

Pertinent test data, process data, and emission factor calculations are provided in Appendix B.

4.2.1.4 Reference 12. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on August 19, 1992. The fill-on-vent, which vents CO_2 and VOC emissions from six beer storage tanks during filling operations, was tested for uncontrolled emissions of VOC (as propane) using EPA Method 25A and CO_2 using EPA Method 3 (with Orsat gas analyzer). The VOC emission data were converted to an ethanol basis using a conversion factor that was developed by calibrating the FID for ethanol as well as propane. Three of six tanks were filled during testing, and a process rate was estimated by assuming that the tanks were initially empty and were filled to capacity during the four test runs (5,400 bbl total fill volume--finished product equivalent). Emission rates were doubled to represent all six tanks, and emission factors were calculated in units of lb/1,000 bbl of beer packaged. These data are assigned a B rating because the process rate was estimated and a hot wire anemometer (not the reference method) was used to determine the stack gas velocities. The reference test methods were used (except for determining stack gas velocities), and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix C.

4.2.1.5 Reference 14. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on June 16-21, 1992. The waste beer storage tanks, which emit CO_2 and VOC, were tested for uncontrolled emissions of VOC (as propane) using EPA Method 25A and CO_2 using EPA Method 3 (with Orsat gas analyzer). The VOC emission data were converted to an ethanol basis using a conversion factor that was developed by calibrating the FID for ethanol as well as propane. Single test runs were conducted on each of eight ducts that vent the eight storage tanks to a single stack. During testing, three of the tanks contained waste beer, and the other five tanks contained five different materials: live yeast, aging yeast (dead), aging yeast (live), lysed yeast, and ethanol condensate. Process rates were estimated using annual production data in conjunction with the assumption that production is constant throughout the year. Emission factors for the waste beer storage tanks were calculated in units of lb/1,000 bbl of beer produced. These data are not rated because only one complete test run (comprising one run on each of eight stacks) was conducted, several types of waste were contained in the tanks, and the process rate was estimated using annual production data. The reference test methods were used (except for determining stack gas flow rates), no problems were reported, and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix D.

4.2.1.6 Reference 15. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on October 14, 1992. The sources tested include a sterile can filling line and a sterile bottle filling line. These processes were each tested for uncontrolled emissions of VOC (as propane) using EPA Method 25A and CO_2 using EPA Method 3 (with Orsat gas analyzer). Because organic emissions from the filling are believed to be primarily ethanol, the VOC emissions from these sources were converted to ethanol using conversion factors that were developed by calibrating the FID for ethanol as well as propane. The individual tests are described in the following paragraphs.

The first test was conducted on the bottle filler room vent. Two test runs were conducted, and process rates in bbl/hr were measured during each run. To account for all of the emissions coming from the room, a correction factor from Reference 11 was used. (The vent that was tested carried an average flow of 9,830 dscfm, and the average flow into the filler room during the Reference 11 test was 28,056 dscfm. Therefore, the emission rates measured in the vent were multiplied by the ratio of the flow into the room to the flow out of the vent. This calculation is based on the assumption that all of the air leaving the room has the same pollutant concentrations as the air sampled in the vent.) These data are assigned a C rating because the assumption discussed above was implemented using data from another source test. No evidence is provided that indicates that the ratio of air into the room to air out of the vent would be the same during this test program as in the Reference 11 test. Also, only two test runs were performed. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

The second test was conducted on the can filler room vent. Two test runs were conducted, and process rates in bbl/hr were measured during each run. To account for all of the emissions coming from the room, a correction factor from Reference 11 was used. (The vent that was tested carried an average flow of 25,696 dscfm, and the average flow into the filler room during the Reference 11 test was 61,242 dscfm. Therefore, the emission rates measured in the vent were multiplied by the ratio of the flow into the room to the flow out of the vent. This calculation is based on the assumption that all of the air leaving the room has the same pollutant concentrations as the air sampled in the vent.) These data are assigned a C rating because the assumption discussed above was implemented using data from a test conducted at a later time. No evidence is provided that indicates that the ratio of air into the room to air out of the vent would be the same during this test program as in the Reference 11 test. Also, only two test runs were performed. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

Pertinent test data, process data, and emission factor calculations are provided in Appendix E.

4.2.1.7 Reference 16. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery from December 2 through 16, 1992. The sources tested include two sterile can filling lines and two sterile bottle filling lines. These processes were each tested for uncontrolled emissions of VOC (as propane) using EPA Method 25A. Because organic emissions from the filling are believed to be primarily ethanol, the VOC emissions from these sources were converted to ethanol using conversion factors that were developed by calibrating the FID for ethanol as well as propane. The individual tests are described in the following paragraphs.

The first three tests were conducted on the No. 3 bottle filler, the No. 5 can filler, and the No. 6 can filler. Three test runs were conducted on each source, and process rates in bbl/hr were measured during each test. To account for all of the emissions coming from the rooms, flowrates and VOC concentrations were measured at all of the inlets and at the vents to the filler rooms during testing. To obtain theoretical emission rates from the fillers, the inlet flow rates were multiplied by the inlet concentrations and were then subtracted from the product of the outlet concentrations and the inlet flow rates. This calculation is based on the assumption that all of the air leaving the room has the same pollutant concentrations as the air sampled in the vent. The data from these three tests are assigned a B rating because of the assumption discussed above. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

The fourth test was conducted on the No. 9 can filler. A single, continuous, 41-hour test run was conducted, and process rates in bbl/hr were measured during the test. Data from the first eight hours of testing are not included in the average for the test because the filler room was undergoing sterilization during this period. To account for all of the emissions coming from the room, flowrates and VOC concentrations were measured at all of the inlets and at the vents to the filler rooms during testing. To obtain theoretical emission rates from the fillers, the average inlet flow rates were multiplied by the average inlet concentrations and were then subtracted from the product of the average outlet concentration and the average total inlet flow rate. This calculation relies on the assumption that all of the air leaving the room has the same pollutant concentrations as the air sampled in the vent. During testing, grab samples were taken under the filler room door to estimate VOC concentrations from outlets other than the room vent. The concentrations were of the same order of magnitude as the vent concentrations, indicating that the above assumption is reasonable. These data are assigned a B rating because of the assumption discussed above. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

Pertinent test data, process data, and emission factor calculations are provided in Appendix F.

4.2.1.8 Reference 17. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on November 5 and 6, 1990. The sources tested were the north brew kettle stack and the north combined cooker stack. The brew kettle stack vents emissions from the brew kettles for four brew lines, and the combined cooker stack vents emissions from all of the other vessels from the same four brew lines. Three of the four brewlines were operating during testing. The processes were each tested for uncontrolled emissions of VOC (as propane) using EPA Method 25A, filterable PM using EPA Method 5 (front half analysis only), nitrogen oxides (NO_x) using EPA Method 7E, and sulfur dioxide (SO_2) using a modified EPA Method 6. In addition, integrated bag samples were taken during each Method 25A run and were analyzed for methane and ethane using a GC. In the report, the methane and ethane emissions were subtracted from the VOC emissions. However, documentation of the methane and ethane tests is incomplete. Therefore, the methane and ethane data are not included in the emission factors developed using data from this report. Results are reported as VOC (as propane). All of the NO_x concentrations measured were at or below the detection limit of the instrument. Therefore, these data are not discussed further and are not used for emission factor development. The individual tests are described in the following paragraphs.

The brew kettle stack was tested first with the heat reclaim system on, and then with the system off. Three test runs were conducted under each condition, and process rates for these tests were estimated from the annual production capacity of the three brewlines. These process rates were calculated with the assumption that the three brewlines were operating at capacity during testing. Because heat reclaim systems are not typical, the data for brew kettles with heat reclaim are not rated. The data for brew kettles (without heat reclaim) are assigned a C rating because the process rates are based on process capacity rather than actual data. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

Three test runs were conducted on the combined cooker stack, which vents emissions from the "cereal mash-in kettles," "malt mash-in kettles," cereal cookers, and mash tuns from three brew lines. Process rates for these tests were estimated from the annual production capacity of the three brewlines. These process rates were calculated with the assumption that the three brewlines were operating at capacity during testing. These data are not rated because they represent emissions from combined sources that may be unique in the industry.

Pertinent test data, process data, and emission factor calculations are provided in Appendix G.

4.2.1.9 Reference 18. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery from November 7 through 9, 1990. The sources tested were the fermentation CO_2 exhaust stack, the fermentation CO_2 vent stack, the yeast propagation stack, the aging vent stack, and the aging exhaust stack. The processes were each tested for uncontrolled emissions of VOC (as propane) using EPA Method 25A, CO_2 using EPA Method 3 (with Orsat gas analyzer), SO_2 using a modified EPA Method 6, hydrogen sulfide using EPA Method 11, and methane and ethane using EPA Method 18. In the report, the methane and ethane emissions were subtracted from the VOC emissions. However, documentation of the methane and ethane tests is incomplete. Therefore, the methane and ethane data are not included in the emission factors developed using data from this report. The VOC emissions were converted to VOC as ethanol using a theoretical correction factor. The individual tests are described in the following paragraphs.

The first two tests, conducted on the fermentation CO_2 exhaust stack and the fermentation CO_2 vent stack, represent total emissions from the fermentation process. However, during the CO_2 exhaust stack test, no fermenters were exhausting to the atmosphere. Therefore, the exhaust stack data are not rated and are not used for emission factor development. The fermenter venting data, which quantify emissions from a 24-hour venting period (prior to collection of CO_2), are used in conjunction with process data (based on a known relationship between venting hours and beer production) to develop emission factors for venting. Sulfur dioxide emissions were not detected in any test run. These data are assigned a C rating because the three test runs were performed during the same batch cycle. Continuous measurements over several 24-hour venting periods would more accurately quantify emissions from this source.

Data from the third test, which was conducted on the yeast propagation stack, were not used for emission factor development because a description of the process and process data are not contained in the report.

Tests four and five, conducted on the aging vent stack and the aging evacuation stack, represent total emissions from the aging process. However, only one test run was conducted on the evacuation stack. Therefore, these data are not rated and are not used for emission factor development.

Pertinent test data, process data, and emission factor calculations are provided in Appendix H.

4.2.1.10 Reference 19. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery from February 13 through 16, 1991. The sources tested include both uncontrolled and controlled brewers grain dryers. The dryers, which were steam-heated, were each tested for emissions of VOC (as propane) using EPA Method 25A, filterable PM using EPA Method 5 (front half analysis only), particle size analysis using cascade impactors, CO using EPA Method 10, and CO_2 using EPA Method 3 (with orsat gas analyzer). In addition, integrated bag samples were taken during each Method 25A run and were analyzed on a GC for methane and ethane. In the report, the methane and ethane emissions were subtracted from the VOC emissions. However, documentation of the methane and ethane test is incomplete. Therefore, the methane and ethane data are not used for emission factor development. Results are reported as VOC (as propane). The individual tests are described in the following paragraphs.

The first test was conducted following a wet scrubber that controls emissions from two brewers grain dryers. Three isokinetic test runs were conducted, and process rates were calculated using the number of brews per hour per dryer and the number of bbl per brew. The process rates are calculated assuming that all of the dryers receive the same amount of brewers grain. These data are assigned a B rating because of the assumption discussed above and because scrubber operating parameters were not provided in the report. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

The second test was conducted following a wet scrubber that controls emissions from a brewers grain dryer. Three isokinetic test runs were conducted, and process rates were calculated using the number of brews per hour per dryer and the number of bbl per brew. The process rates are calculated assuming that all of the dryers receive the same amount of brewers grain. These data are assigned a B rating because of the assumption discussed above and because scrubber operating parameters were not provided in the report. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

The third test was conducted prior to a wet scrubber that controls emissions from the K-1 brewers grain dryer. Three isokinetic test runs were conducted, and process rates were calculated using the number of brews per hour per dryer and the number of bbl per brew. The process rates are calculated assuming that all of the dryers receive the same amount of brewers grain. These data are assigned a B rating because of the assumption discussed above. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

The fourth test was conducted following a wet scrubber that controls emissions from the K-1 brewers grain dryer. Two isokinetic test runs were conducted, and process rates (dried grain produced, tons/hr) were calculated using the number of brews per hour per dryer and the number of bbl per brew. Run 2 was not within the specified isokinetic limits and was not included data averages. The process rates are calculated assuming that all of the dryers receive the same amount of brewers grain. These data are assigned a B rating because of the assumption discussed above and because scrubber operating parameters were not provided in the report. The reference test methods were used, no problems were reported, and adequate detail was provided in the report.

Pertinent test data, process data, and emission factor calculations are provided in Appendix I.

4.2.1.11 Reference 20. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on November 9 and 10, 1992. The source tested was a steam-heated brewers grain dryer. The dryer was tested for emissions of VOC (as propane) using EPA Method 25A.

The test was conducted prior to a wet scrubber that controls emissions from the brewers grain dryer. Six test runs were conducted, and process rates (dried grain produced, tons/hr) were calculated using the number of brews per hour per dryer and the number of bbl per brew. The process rates are calculated assuming that all of the dryers at the plant receive the same amount of brewers grain. These data are assigned a B rating because of this assumption. The reference test methods were used, no problems were reported, and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix J.

4.2.1.12 Reference 21. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on August 22 and 23, 1992. The source tested was the No. 9 steam-heated brewers grain dryer. The dryer was tested for emissions of filterable PM using EPA Method 5 and VOC (as propane) using EPA Method 25A.

Tests were conducted at the inlet and outlet of a wet cyclonic scrubber that controls emissions from the brewers grain dryer. Three test runs were conducted at each location, and process rates (dried grain produced, tons/hr) were calculated using the number of brews per hour per dryer and the number of bbl per brew. The process rates are calculated assuming that all of the dryers at the plant receive the same amount of brewers grain. The VOC test was conducted only at the scrubber outlet. These data are assigned a B rating because of this assumption and because scrubber operating parameters were not provided in the report. The reference test methods were used, no problems were reported, and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix K.

4.2.1.13 Reference 22. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on April 28, 1993. The source tested was the bottle wash soaker area, which prepares returned beer bottles for refilling. Ethanol emissions from the bottle wash soaker area were quantified using the Bay Area Air Quality Management District (BAAQMD) Method ST-32, in which a known gas volume is drawn through an impinger train (over a specified time interval) containing deionized water, and the water sample is analyzed by GC/FID. Process rates in cases (of bottles) throughput were recorded during testing.

Two exhaust ducts that vent emissions from the bottle wash soaker area were simultaneously sampled for ethanol emissions. Three test runs were conducted on each duct, and the combined emission measurements determined the total ethanol emission rate from the source. These data are assigned an A rating. The test method appears to be valid, no problems were reported, and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix L.

4.2.1.14 Reference 23. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on April 21 and August 31, 1993. The source tested was a bottle crusher, which was uncontrolled during the first test and controlled with water sprays and a larger dump bin (for the crushed bottles) during the second test. The process was tested for emissions of VOC (as propane) using EPA Method 25A. Because organic emissions from the bottle crushing are believed to be primarily ethanol, the VOC emissions from these sources were converted to ethanol using a conversion factor that was developed during an earlier test using the same FID.

During each test, three test runs were conducted, and process rates were reported in crushes per hour. However, the mass of the material crushed and the capacity of the crusher were not provided in the report. Also, the stack gas moisture content was assumed to be zero during all of the test runs. The water sprays and dump bin reduced ethanol emissions by about 73 percent. These data are assigned a C rating because details about the crusher are not documented in the report. The applicability of the data to other crushers is unclear because the process throughput was not provided. The reference test methods were used, no problems were reported, and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix M.

4.2.1.15 Reference 24. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on October 21, 1993. The source tested was the can crusher and pneumatic conveyor, which transports cans from the crusher to a cyclone for collection. During testing, ethanol emission rates were relatively constant and did not appear to be affected by process throughput, possibly because the air stream was saturated with ethanol. The process was tested for emissions of VOC (as propane) using EPA Method 25A. Because organic emissions from this source are believed to be primarily ethanol, the VOC emissions were converted to ethanol using a conversion factor that was developed during an earlier test using the same FID.

Three test runs were conducted on each of the two stacks serving the crushed can conveyor, and process rates were reported in gallons per hour of beer recovered. The stack gas moisture content was assumed to be zero during all of the test runs. These data are assigned a B rating. The reference test methods were used, no problems were reported, and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix N.

4.2.1.16 Reference 25. This reference is a summary document that presents the results of several emission tests conducted at the Miller Brewing Company brewery located in Fulton, New York. The document uses the results of the emission tests in conjunction with several assumptions to establish an emission inventory for the facility. The actual emission test is documented in Reference 28.

4.2.1.17 Reference 26. This test report documents emission testing performed at the Anheuser Busch, Columbus, Ohio, brewery from November 1 through 4, 1983. The source tested was a natural gas-fired brewers grain dryer. The dryer was tested for emissions of filterable PM using EPA Method 5 and CO_2 using EPA Method 3 (with Orsat gas analyzer). Process rates are provided in units of tons of dried grain produced.

Five test runs were conducted at the inlet and outlet of a Ducon wet scrubber that controls emissions from the dryer. Two runs (inlet and outlet) were conducted during typical process operating conditions, which are based on permit limitations. Three runs were conducted with the process operating at capacity. The PM control efficiency decreased from about 77 percent during the "typical" runs to about 24 percent during the "capacity" runs. Therefore, it is assumed that the scrubber was not designed to handle the increased loading, and the controlled PM data from the capacity runs are not used for emission factor development. The data that were used for emission factor development are assigned a B rating because scrubber operating parameters are not documented in the report. Also, problems with cyclonic flow were noted following the scrubber, but steps were taken to minimize the cyclonic flow at the sampling location. The reference test methods were used, no problems were reported, and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix O.

4.2.1.18 Reference 27. This test report documents emission testing performed at the Coors Brewing Company, Golden, Colorado, brewery on April 3 and 4, 1995. The sources tested include sterile bottle filling lines and a sterile can filling lines. Both sources were tested for uncontrolled emissions of VOC (as propane) using EPA Method 25A and ethanol using a Fourier Transform Infrared (FTIR) analyzer. Because organic emissions from filling are believed to be primarily ethanol, the VOC data were converted to ethanol using a conversion factor (2.12) that was developed by calibrating the FID for ethanol as well as propane. The results of the two tests were used to compare the test methods. The results of the FID and FTIR tests were similar and indicate that the use of an ethanol conversion factor for VOC is appropriate for this source.

The first test was conducted on the combined effluent from bottle filler room No. 1 through No. 4 quart; the second test was conducted on the combined effluent from can filler room No. 1 through No. 10. Three test runs were conducted for each source, and process rates in bbl/hr were measured during each test. These fill rooms are maintained under positive pressure. Consequently, a portion of the air exits the rooms from openings other than the exhaust duct. To account for the total emissions from the rooms, the measured emissions were multiplied by the ratio of the air flow entering the filler rooms to the exhaust vent air flow. This calculation is based on the assumption that all of the air exiting the rooms has the same ethanol concentration as the air in the exhaust vents. These data are assigned a B rating because of this assumption. The test methods used were valid, no problems were reported, and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix P.

4.2.1.19 Reference 28. This test report documents emission testing performed at the Miller Brewing Company, Fulton, New York, brewery in November 1993. Several sources were tested for VOC and ethanol emissions using test methods that are not EPA reference methods. Several of the tests (hot wort tank, fermentation, cold filter trap, primary filter trap, and spent yeast tank) included only one test run and are not used for developing emission factors. Several of the tests do not quantify emissions from specific processes (heat wheel, utilities ventilation, and cold services exhaust) and are not used for developing emission factors. The data for surge tanks do not represent direct emission measurements and are not used for emission factor development. The data for bottling and canning operations are not used because data from other breweries were gathered using EPA reference methods. The data for emissions from the brew kettle, cereal cooker, mash tun, lauter tun are reported as total VOC (TVOC), and the report indicates that these data represent TVOC as hexane or toluene. For consistency with other sections of AP-42, these data were converted to TVOC as propane. Emissions data for activated carbon regeneration are also used for emission factor development. All of the data used for emission factor development are assigned a D rating because the test methods used are not EPA reference methods. Pertinent test data, process data, and emission factor calculations are provided in Appendix Q.

4.2.1.20 Reference 29. This test report documents emission testing performed at the Anheuser Busch, Fort Collins, Colorado, brewery on July 26 through 28, 1994. A bottle filling line and a can filling line were tested. The uncontrolled emissions from both filling lines were tested for VOC (as propane) using EPA Method 25A and ethanol using both EPA Method 18 and an FTIR analyzer. The results of the three tests were used to compare the test methods and to establish emission factors for non-sterile filling operations.

Prior to emissions testing, a qualitative test was performed on the ventilation fans above two of the filling lines to determine if emissions from the lines could be reasonably quantified. By shutting off all of the building ventilation fans except for the two fans above canning line No. 61, it was observed that the two fans collected most of the smoke released by a smoke generator. The additional amount of building air drawn through the fans was not determined. The same type of test was performed with the fans above bottle line No. 20. Although these tests are strictly qualitative, a company representative stated that Anheuser-Busch believes that VOCs present in air (from other filling room operations) would be vented by the fans and a conservative (high) estimate of emissions from the filling lines tested would result.

The first test was conducted on ventilation fan Nos. 224 and 227, which vent emissions from bottle filling line No. 20. All other ventilation fans were turned off during testing. The second test was conducted on ventilation fan Nos. 211 and 214, which vent emissions from can filling line No. 61. Three test runs (using all three test methods) were conducted for each source, and process rates in bbl/hr were measured during each test.

During the testing, the Method 25A system exceeded the calibration drift criteria; contamination in the sample line is believed to have caused the drift. The FTIR results indicate that the contamination was a mixture of fluorinated compounds. Also, during system calibration and calibration checks, the FID response for ethanol was not a linear function of concentration, and no correction was made for ethanol FID response. This finding may have been the result of the reported sample line contamination. Because of the problems discussed above, the Method 25A data are not considered valid for emission factor development.

The Method 18 and FTIR data are averaged to determine an emission factor for each filling line. These data are assigned a C rating because it is unclear exactly how much of the ethanol measured was emitted from other filling lines and drawn into the exhaust fans of the lines being tested (the test results are probably conservative). Otherwise, the test methodology was sound, no problems were reported, and adequate detail was provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix R.

4.2.1.21 Reference 30. This report does not contain original test data, but the findings of the report are used to justify the presentation of separate emission factors for sterile and conventional filling lines. The report discusses the results of several emission tests. Data from these tests indicate that the air flow from filler shrouds associated with sterile filling lines increases ethanol emissions, and that this air flow should be minimized in order to minimize ethanol emissions.

4.2.2 Review of XATEF, SPECIATE, and FIRE Data Base Emission Factors

The emission factors contained in these data bases are the same factors that currently appear in AP-42. These emission factors are not based on test data and are not used in the revised AP-42 section.

4.2.3 Review of Test Data in AP-42 Background File

The background file references did not provide any original source test data. Therefore, the information in the background file is used only as background information.

4.2.4 Results of Data Analysis

This section discusses the analysis of the data and describes how the data were combined to develop average emission factors for the production of malt beverages. The test data used to develop emission factors are presented in Table 4-4, and a summary of the data combination and average emission factors is presented in Table 4-5. Most of the emission factors are based on a single test. All of the data used for emission factor development represent emissions from large breweries. Comparable data for emissions from small breweries are not available.

Emission factors were developed for the following pollutants: filterable PM, filterable PM-10, filterable PM-2.5, ethanol, VOC (the term VOC is used in place of TOC), CO, CO_2, and hydrogen sulfide.

In the test reports from different facilities, the emission factors for VOC were estimated based on one of three methods. The first method was based on the use of charcoal adsorption tubes to collect volatile and semi-volatile compounds. The samples were extracted from the tubes and analyzed using a GC/FID.

TABLE 4-4. SUMMARY OF TEST DATA FOR MALT BEVERAGE PRODUCTION

Source/control	Pollutant	No. of test runs	Data rating	Emission factor range[a]	Average emission factor[a]	Ref. No.
Sterilized can filling line	VOC as ethanol	3	B	35.1-41.1	39.1	11
Sterilized can filling line	CO_2	3	B	1,733-2,024	1,921	11
Sterilized bottle filling line	VOC as ethanol	3	B	35.2-42.8	38.7	11
Sterilized bottle filling line	CO_2	3	B	4,130-4,461	4,276	11
Keg filling line	VOC as ethanol	2	B	0.597-0.781	0.689	11
Keg filling line	CO_2	2	B	45.7-46.3	46.0	11
Hot wort settling tank	VOC as propane	2	C	0.0749-0.0750	0.075	11
Open wort cooler	VOC as propane	3	C	0.00833-0.0315	0.0221	11
Trub vessel--filling	VOC as propane	3	C	0.238-0.280	0.254	11
Aging tank--filling	VOC as ethanol	4	B	0.0709-1.43	0.570	12
Aging tank--filling	CO_2	4	B	5.10-83.3	26.1	12
Waste beer storage tank	VOC as ethanol	1	NR	NA	4.37	14
Waste beer storage tank	CO_2	1	NR	NA	7.03	14
Sterilized can filling line	VOC as ethanol	2	C	25.6-29.9	27.8	15
Sterilized bottle filling line	VOC as ethanol	2	C	38.0-39.4	38.7	15
Sterilized bottle filling line	VOC as ethanol	3	B	29.7-36.7	34.4	16
Sterilized can filling line	VOC as ethanol	3	B	32.5-37.4	35.5	16
Sterilized bottle filling line	VOC as ethanol	2	C	38.0-39.4	38.7	15
Sterilized bottle filling line	VOC as ethanol	3	B	29.7-36.7	34.4	16
Sterilized can filling line	VOC as ethanol	3	B	32.5-37.4	35.5	16
Sterilized can filling line	VOC as ethanol	3	B	29.0-50.4	36.4	16
Sterilized can filling line	VOC as ethanol	1	B	NA	39.0	16
Combined brewhouse operations	VOC as propane	3	NR	0.0508-0.161	0.120	17
Combined brewhouse operations	Filterable PM	3	NR	0.0706-0.145	0.114	17
Brew kettle with heat reclaim	VOC as propane	3	NR	0.668-0.743	0.711	17
Brew kettle with heat reclaim	Filterable PM	3	NR	0.134-0.240	0.201	17
Brew kettle with heat reclaim	SO_2	3	NR	0.0246-0.0431	0.0358	17
Brew kettle	VOC as propane	3	C	0.940-1.14	1.04	17
Brew kettle	Filterable PM	3	C	0.242-0.558	0.405	17
Fermenter venting[b]	VOC as ethanol	3	C	1.9-2.0	2.0	18
Fermenter venting[b]	CO_2	3	C	2,000-2,200	2,100	18

TABLE 4-4. (continued)

Source/control	Pollutant	No. of test runs	Data rating	Emission factor range[a]	Average emission factor[a]	Ref. No.
Fermenter venting[b]	Hydrogen sulfide	3	C	0.00048-0.037	0.015	18
Fermenter venting[b]	SO_2	3	NR	ND	ND	18
Brewers grain dryer--steam-heated, with wet scrubber[c]	Filterable PM	3	B	0.31-0.45	0.39	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	Filterable PM-10	3	B	0.10-0.21	0.16	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	Filterable PM-2.5	3	B	0.049-0.14	0.091	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	VOC as propane	3	B	0.81-1.1	0.99	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	CO_2	3	B	33-41	38	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	CO	3	B	0.41-0.69	0.53	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	Filterable PM	3	B	0.31-0.42	0.38	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	Filterable PM-10	3	B	0.040-0.059	0.052	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	Filterable PM-2.5	3	B	0.021-0.033	0.028	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	VOC as propane	3	B	0.46-0.56	0.50	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	CO_2	3	B	50-94	77	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	CO	2	B	0.11-0.41	0.24	19
Brewers grain dryer--steam-heated[c]	Filterable PM	2	B	78-104	91	19
Brewers grain dryer--steam-heated[c]	Filterable PM-10	2	B	0.29-0.36	0.33	19
Brewers grain dryer--steam-heated[c]	Filterable PM-2.5	2	B	0.078-0.10	0.091	19
Brewers grain dryer--steam-heated[c]	VOC as propane	3	B	0.21-0.28	0.24	19
Brewers grain dryer--steam-heated[c]	CO	3	B	0.012-0.022	0.019	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	Filterable PM	2	B	0.094-0.23	0.16	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	VOC as propane	3	B	0.43-0.62	0.55	19
Brewers grain dryer--steam-heated, with wet scrubber[c]	CO_2	3	B	25-59	45	19

TABLE 4-4. (continued)

Source/control	Pollutant	No. of test runs	Data rating	Emission factor range[a]	Average emission factor[a]	Ref. No.
Brewers grain dryer--steam-heated, with wet scrubber[c]	CO	3	B	0.080-0.22	0.11	19
Brewers grain dryer--steam-heated[c]	VOC as propane	6	B	0.50-0.75	0.60	20
Brewers grain dryer--steam-heated[c]	Filterable PM	3	B	2.4-8.0	5.6	21
Brewers grain dryer--steam-heated, with wet cyclonic scrubber[c]	Filterable PM	3	B	0.20-0.32	0.24	21
Brewers grain dryer--steam-heated, with wet cyclonic scrubber[c]	VOC as propane	3	B	1.2-1.8	1.5	21
Bottle soaker and cleaner[d]	Ethanol	3	A	0.156-0.231	0.201	22
Bottle crusher[e]	VOC as ethanol	3	C	0.338-0.567	0.482	23
Bottle crusher with water sprays[e]	VOC as ethanol	3	C	0.123-0.131	0.128	23
Can crusher with pneumatic conveyor[f]	VOC as ethanol	3	B	0.00807-0.248	0.0882	24
Activated carbon regeneration	Ethanol	7	D	0.021-0.050	0.035	25
Brewers grain dryer--natural gas-fired[g]	Filterable PM	2	B	3.23-4.69	3.96	26
Brewers grain dryer--natural gas-fired[g]	CO_2	2	B	605-1,414	1,010	26
Brewers grain dryer--natural gas-fired, with wet scrubber[g]	Filterable PM	2	B	0.802-1.02	0.909	26
Brewers grain dryer--natural gas-fired, with wet scrubber[g]	CO_2	2	B	605-812	709	26
Brewers grain dryer--natural gas-fired[h]	Filterable PM	3	B	4.49-6.25	5.14	26
Brewers grain dryer--natural gas-fired[h]	CO_2	3	B	736-976	818	26
Brewers grain dryer--natural gas-fired, with wet scrubber[h]	Filterable PM	3	NR	3.13-4.68	3.92	26
Brewers grain dryer--natural gas-fired, with wet scrubber[h]	CO_2	3	B	802-852	828	26
Sterilized can filling line	VOC as ethanol	3	B	26-33	30	27
Sterilized bottle filling line	VOC as ethanol	3	B	42-51	45	27
Sterilized can filling line	Ethanol	2	B	32-35	33	27
Sterilized bottle filling line	Ethanol	3	B	44-54	49	27
Cereal cooker	VOC as propane	3	D	0.0040-0.011	0.0075	28
Activated carbon regeneration	Ethanol	7	D	0.021-0.051	0.035	28

TABLE 4-4. (continued)

Source/control	Pollutant	No. of test runs	Data rating	Emission factor range[a]	Average emission factor[a]	Ref. No.
Lauter tun	VOC as propane	3	D	0.0030-0.0076	0.0055	28
Mash tun	VOC as propane	3	D	0.039-0.084	0.054	28
Brew kettle	VOC as propane	3	D	0.033-0.49	0.23	28
Bottle filling line	Ethanol	6	C	11.4-20.7	16.6	29
Can filling line	Ethanol	6	C	11.2-16.9	13.6	29

ND = No data available, NR = Not rated
[a]Emission factors in units of lb of pollutant per 1,000 bbl of beer packaged, unless noted.
[b]Emission factors are based on a 24-hour venting period prior to CO_2 collection.
[c]Emission factor in units of lb of pollutant per ton of dried grain produced.
[d]Emission factor in units of lb of pollutant per 1,000 cases of bottles washed.
[e]Emission factor in units of lb of pollutant per batch of bottles crushed. Crusher averages about 34 crushes per day.
[f]Emission factor in units of lb of pollutant per gallon of beer recovered.
[g]Process operating at conditions required by permit limits. Emission factor in units of lb of pollutant per ton of dried grain produced.
[h]Process operating at capacity. Emission factor in units of lb of pollutant per ton of dried grain produced.

TABLE 4-5. SUMMARY OF DATA COMBINATION AND AVERAGE EMISSION FACTORS FOR MALT BEVERAGE PRODUCTION

Source/control	Pollutant	No. of test runs	Data rating	Single test emission factor[a]	Average emission factor[a]	Emission factor rating	Ref. No.
Activated carbon regeneration	Ethanol	7	D	0.035	0.035	E	28
Aging tank--filling	CO_2	4	B	26.1	26	D	12
Aging tank--filling	VOC as ethanol	4	B	0.570	0.57	D	12
Bottle crusher[b]	VOC as ethanol	3	C	0.482	0.48	E	23
Bottle crusher with water sprays[b]	VOC as ethanol	3	C	0.128	0.13	E	23
Bottle filling line	Ethanol	6	C	16.6	17	E	29
Bottle soaker and cleaner[c]	Ethanol	3	A	0.201	0.20	D	22
Brew kettle	Filterable PM	3	C	0.405	0.41	E	17
Brew kettle	VOC as propane	3	C	1.04	0.64	E	17
Brew kettle	VOC as propane	3	D	0.23			28
Brewers grain dryer[d]	Filterable PM	2	B	3.96	4.9	D	26
Brewers grain dryer[e]	Filterable PM	3	B	5.14			26
Brewers grain dryer[f]	Filterable PM	3	B	5.6			21
~~Brewers grain dryer[f]~~	~~Filterable PM~~	~~3~~	~~B~~	~~91~~			~~19~~
Brewers grain dryer[f]	Filterable PM-10	3	B	0.33	0.33	D	19
Brewers grain dryer[f]	Filterable PM-2.5	3	B	0.091	0.091	D	19
Brewers grain dryer--steam-heated[f]	CO	3	B	0.019	0.22	D	19
Brewers grain dryer--steam-heated, with wet scrubber[f]	CO	3	B	0.11			19
Brewers grain dryer--steam-heated, with wet scrubber[f]	CO	3	B	0.24			19
Brewers grain dryer--steam-heated, with wet scrubber[f]	CO	3	B	0.53			19
Brewers grain dryer--steam-heated, with wet scrubber[f]	CO_2	3	B	38	53	D	19
Brewers grain dryer--steam-heated, with wet scrubber[f]	CO_2	3	B	45			19
Brewers grain dryer--steam-heated, with wet scrubber[f]	CO_2	3	B	77			19
Brewers grain dryer--natural gas-fired, with wet scrubber[f]	CO_2	2	B	709	840	D	26
Brewers grain dryer--natural gas-fired, with wet scrubber[e]	CO_2	3	B	828			26
Brewers grain dryer--natural gas-fired[e]	CO_2	3	B	818			26
Brewers grain dryer--natural gas-fired[d]	CO_2	2	B	1,010			26

TABLE 4-5. (continued)

Source/control	Pollutant	No. of test runs	Data rating	Single test emission factor[a]	Average emission factor[a]	Emission factor rating	Ref. No.
Brewers grain dryer with wet scrubber[f]	Filterable PM	2	B	0.16	0.42	D	19
Brewers grain dryer with wet cyclonic scrubber[f]	Filterable PM	3	B	0.24			21
Brewers grain dryer with wet scrubber[f]	Filterable PM	3	B	0.38			19
Brewers grain dryer with wet scrubber[f]	Filterable PM	3	B	0.39			19
Brewers grain dryer with wet scrubber[f]	Filterable PM	2	B	0.909			26
Brewers grain dryer with wet scrubber[f]	Filterable PM-10	3	B	0.052	0.11	D	19
Brewers grain dryer with wet scrubber[f]	Filterable PM-10	3	B	0.16			19
Brewers grain dryer with wet scrubber[f]	Filterable PM-2.5	3	B	0.028	0.060	D	19
Brewers grain dryer with wet scrubber[f]	Filterable PM-2.5	3	B	0.091			19
Brewers grain dryer[f]	VOC as propane	3	B	0.24	0.73	D	19
Brewers grain dryer[f]	VOC as propane	6	B	0.60			20
Brewers grain dryer with wet scrubber[f]	VOC as propane	3	B	0.50			19
Brewers grain dryer with wet scrubber[f]	VOC as propane	3	B	0.55			19
Brewers grain dryer with wet scrubber[f]	VOC as propane	3	B	0.99			19
Brewers grain dryer with wet scrubber[f]	VOC as propane	3	B	1.5			21
Can crusher with pneumatic conveyor[g]	VOC as ethanol	3	B	0.0882	0.088	D	24
Can filling line	Ethanol	6	C	13.6	14	E	29
Cereal cooker	VOC as propane	3	D	0.0075	0.0075	E	28
Fermenter venting[h]	VOC as ethanol	3	C	2.0	2.0	E	18
Fermenter venting[h]	CO_2	3	C	2,100	2,100	E	18
Fermenter venting[h]	Hydrogen sulfide	3	C	0.015	0.015	E	18
Hot wort settling tank	VOC as propane	2	C	0.075	0.075	E	11
Keg filling line	CO_2	2	B	46.0	46	D	11
Keg filling line	VOC as ethanol	2	B	0.689	0.69	D	11
Lauter tun	VOC as propane	3	D	0.0055	0.0055	E	28
Mash tun	VOC as propane	3	D	0.054	0.054	E	28
Open wort cooler	VOC as propane	3	C	0.0221	0.022	E	11

TABLE 4-5. (continued)

Source/control	Pollutant	No. of test runs	Data rating	Single test emission factor[a]	Average emission factor[a]	Emission factor rating	Ref. No.
Sterilized bottle filling line	CO_2	3	B	4,276	4,300	D	11
Sterilized bottle filling line	Ethanol	3	B	49	40	D	27
Sterilized bottle filling line	VOC as ethanol	3	B	34.4			16
Sterilized bottle filling line	VOC as ethanol	3	B	34.4			16
Sterilized bottle filling line	VOC as ethanol	3	B	38.7			11
Sterilized bottle filling line	VOC as ethanol	3	B	45			27
Sterilized bottle filling line	VOC as ethanol	2	C	38.7			15
Sterilized bottle filling line	VOC as ethanol	2	C	38.7			15
Sterilized can filling line	CO_2	3	B	1,921	1,900	D	11
Sterilized can filling line	Ethanol	2	B	33	35	D	27
Sterilized can filling line	VOC as ethanol	3	B	30			27
Sterilized can filling line	VOC as ethanol	3	B	35.5			16
Sterilized can filling line	VOC as ethanol	3	B	35.5			16
Sterilized can filling line	VOC as ethanol	3	B	36.4			16
Sterilized can filling line	VOC as ethanol	1	B	39.0			16
Sterilized can filling line	VOC as ethanol	3	B	39.1			11
Sterilized can filling line	VOC as ethanol	2	C	27.8			15
Trub vessel--filling	VOC as propane	3	C	0.254	0.25	E	11

ND = No data available, NR = Not rated

[a]Emission factors in units of lb of pollutant per 1,000 bbl of beer packaged, unless noted.

[b]Emission factor in units of lb of pollutant per batch of bottles crushed. Crusher averages about 34 crushes per day.

[c]Emission factor in units of lb of pollutant per 1,000 cases of bottles washed.

[d]Process operating at conditions required by permit limits. Emission factor in units of lb of pollutant per ton of dried grain produced.

[e]Process operating at capacity. Emission factor in units of lb of pollutant per ton of dried grain produced.

[f]Emission factor in units of lb of pollutant per ton of dried grain produced. If heat source is not specified, factor applies to both steam-heated and natural gas-fired dryers.

[g]Emission factor in units of lb of pollutant per gallon of beer recovered.

[h]Emission factors are based on a 24-hour venting period prior to CO_2 collection.

A second method, based on EPA Method 25A, was used to quantify emissions from pre-fermentation processes, which emit a variety of organic compounds. The VOC are reported on an "as propane" basis.

A third method, also based on EPA Method 25A, was used to quantify emissions from fermentation and post-fermentation processes, which primarily emit ethanol; the VOC emissions are reported on an "as ethanol" basis. Data obtained using Method 25A are reported on an "as propane" basis and were converted to the ethanol basis using conversion factors developed during the testing.

The emission factor ratings assigned to each of the average emission factors developed for malt beverages are based on the emission data ratings and the number of tests conducted. Of the 72 data sets from which emission factors were developed, 1 was A-rated, 51 were B-rated, 15 were C-rated, and 5 were D-rated. In general, A- and B-rated data are not averaged with C- and D-rated data, which are only used when A- and B-rated data are not available. The average emission factors developed are discussed below.

Emission factors based on a single test were developed for the following sources (pollutants): activated carbon regeneration (ethanol), aging tank--filling (VOC as ethanol, CO_2), bottle filling line (ethanol), sterilized bottle filling line (CO_2), bottle soaker and cleaner (ethanol), bottle crusher (VOC as ethanol), bottle crusher with water sprays (VOC as ethanol), brew kettle (filterable PM), can filling line (ethanol), sterilized can filling line (CO_2), cereal cooker (VOC as propane), can crusher with pneumatic conveyor (VOC as ethanol), fermenter venting (VOC as ethanol, CO_2, hydrogen sulfide), hot wort settling tank (VOC as propane), keg filling line (CO_2, VOC as ethanol), brewers grain dryer (natural gas-fired and steam-heated dryers) (filterable PM-10, filterable PM-2.5), lauter tun (VOC as propane), mash tun (VOC as propane), trub vessel--filling (VOC as propane), and open wort cooler (VOC as propane). These emission factors are assigned D ratings if the test data used are A- or B-rated, and if the test data used are C- or D-rated, the emission factors are assigned E ratings.

Emission factors based on data from more than one test were developed for the following sources (pollutants): sterilized bottle filling line (VOC as ethanol), brew kettle (VOC as propane), sterilized can filling line (VOC as ethanol), brewers grain dryer with wet scrubber (filterable PM, filterable PM-10, filterable PM-2.5), and brewers grain dryer (CO, CO_2, filterable PM, VOC as propane). Because these average emission factors are based on between two and six tests (in most cases the tests were conducted at the same facility), the emission factor ratings are based strictly on the corresponding data ratings. The emission factors are generally assigned D ratings if the test data used are A- or B-rated, and if the test data used are C- or D-rated, the emission factors are assigned E ratings. The emission factor for CO_2 from brewers grain dryers is assigned an E-rating because the data range over almost two orders of magnitude. The emission factor for VOC as ethanol from sterilized can filling lines is assigned a D rating although one of the seven data points is C-rated.

4.2.5 New Source Classification Codes for Malt Beverages

The current SCCs (and units) for malt beverages are:

3-02-009-01 Grain handling, lb/ton grain processed
3-02-009-02 Drying spent grains, lb/ton grain processed
3-02-009-03 Brewing, lb/1,000 gallons produced
3-02-009-04 Aging, lb/barrel-year product stored
3-02-009-05 Malt drying, lb/ton grain dried

3-02-009-06 Malt milling, lb/ton grain processed
3-02-009-10 Beer bottling: storage, lb/ton grain processed
3-02-009-11 Fugitive emissions: general, lb/1,000 gallons produced
3-02-009-12 Fugitive emissions: general, lb/ton processed
3-02-009-20 Raw material storage, lb/1,000 gallons produced
3-02-009-98 Other not classified, lb/gallon product
3-02-009-99 Other not classified, lb/ton grain processed

During the process of revising AP-42 Section 9.12.1, these SCCs were revised and new SCCs were created. The new and revised SCCs (and units) are presented in Table 4-6.

TABLE 4-6. NEW AND REVISED SCCs FOR MALT BEVERAGES

SCC	Name	Units
3-02-009-01	Grain handling (see also 3-02-005-xx)	tons grain processed
3-02-009-02	Drying spent grains** (use SCCs 3-02-009-30 & -31)	tons grain processed
3-02-009-03	Brew kettle** (use SCC 3-02-009-07)	1,000 gallons produced
3-02-009-04	Aging tank: Secondary Fermentation	barrel-year product stored
3-02-009-05	Malt kiln	tons dried malt produced
3-02-009-06	Malt mill	tons grain processed
3-02-009-10	Beer bottling: storage**	tons grain processed
3-02-009-11	Fugitive emissions: general	1,000 gallons produced
3-02-009-12	Fugitive emissions: general	tons grain processed
3-02-009-20	Raw material storage**	1,000 gallons produced
3-02-009-98	Other not classified**	1,000 gallons produced
3-02-009-99	Other not classified**	tons grain processed
3-02-009-07	Brew kettle	1,000 bbl beer packaged
3-02-009-08	Aging tank: Filling	1,000 bbl beer packaged
3-02-009-15	Milled malt hopper	tons malt throughput
3-02-009-21	Mash tun	1,000 bbl beer packaged
3-02-009-22	Cereal cooker	1,000 bbl beer packaged
3-02-009-23	Lauter tun or strainmaster	1,000 bbl beer packaged
3-02-009-24	Hot wort settling tank	1,000 bbl beer packaged
3-02-009-25	Wort cooler	1,000 bbl beer packaged
3-02-009-26	Trub vessel	1,000 bbl beer packaged
3-02-009-30	Brewers grain dryer--natural gas-fired	tons dried grain produced
3-02-009-31	Brewers grain dryer--fuel oil-fired	tons dried grain produced
3-02-009-32	Brewers grain dryer--steam-heated	tons dried grain produced
3-02-009-35	Fermenter venting: closed fermenter	1,000 bbl beer packaged
3-02-009-37	Fermenter venting: open fermenter	1,000 bbl beer packaged
3-02-009-39	Activated carbon regeneration	1,000 bbl beer packaged
3-02-009-40	Yeast propagation	1,000 bbl beer packaged

TABLE 4-6. (continued)

SCC	Name	Units
3-02-009-41	Brewers yeast disposal	1,000 bbl beer packaged
3-02-009-51	Can filling line	1,000 bbl beer canned
3-02-009-52	Sterilized can filling line	1,000 bbl beer canned
3-02-009-53	Bottle filling line	1,000 bbl beer bottled
3-02-009-54	Sterilized bottle filling line	1,000 bbl beer bottled
3-02-009-55	Keg filling line	1,000 bbl beer kegged
3-02-009-60	Bottle soaker and cleaner	1,000 cases bottles washed
3-02-009-61	Bottle crusher	1,000 cases bottles crushed
3-02-009-62	Can crusher with pneumatic conveyor	gal beer recovered
3-02-009-63	Beer sump	1,000 bbl beer packaged
3-02-009-64	Waste beer recovery	1,000 bbl beer packaged
3-02-009-65	Waste beer storage tanks	1,000 bbl beer packaged
3-02-009-66	Ethanol removal from waste beer	1,000 bbl beer packaged
3-02-009-67	Ethanol recovery from waste beer	1,000 bbl beer packaged

**Obsolete code

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