San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

2010 Area Source Emissions Inventory Methodology
420 – FOOD AND AGRICULTURE - BAKERIES

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I. Purpose

This document describes the Area Source Methodology used to estimate emissions of volatile organic compounds (VOC) from yeast leavened bread during baking at commercial and retail bakeries in the San Joaquin Valley Air Basin. The primary VOC emitted from the bakery operation is ethanol (ethyl alcohol). An area source category is a collection of similar emission units within a geographic area (i.e., a County) that are small and numerous and may not have been inventoried as specific point, mobile, or biogenic sources. The California Air Resources Board (CARB) has grouped these individual sources with other like sources into area source categories. These source categories are grouped in such a way that they can be estimated collectively using one methodology.

II. Applicability

The emission calculations from this Area Source Methodology apply to facilities that are identified by the following Category of Emission Source (CES) code and Reconciliation Emission Inventory Code (REIC):

Table 1. Emission inventory codes.

CES	REIC	Description
57349	420-412-6012-0000	Bakeries

III. Point Source Reconciliation

Emissions from the area source inventory and point source inventory are reconciled against each other to prevent double counting. This is done using relationships created by the California Air Resources Board (CARB) between the area source REIC and the point sources' Standard Industry Classification (SIC) code and emissions process Source Category Code (SCC) combinations. The area sources in this methodology reconcile against processes in our point source inventory with the SIC/SCC combinations listed in Appendix A.

IV. Methodology Description

This methodology estimates emissions of volatile organic compounds (VOC) during the baking of yeast-leavened bread in the San Joaquin Valley Air Pollution Control District (SJVAPCD). In this methodology, bread refers to yeast-leavened pan bread, rolls, buns, pretzels, sweet yeast goods such as doughnuts and Danish pastry, or similar yeast-leavened products. Baked goods that are chemically leavened are not included in this source category.

The basic ingredients in yeast-leavened bread are flour, water, yeast and salt. During fermentation of the dough, large starch molecules break down into simple sugars. The yeast metabolizes the simple sugars in anaerobic fermentation producing carbon dioxide, ethanol (ethyl alcohol), small amounts of other alcohols, esters and aldehydes.

There are two basic types of yeast dough processes used in bakeries: sponge-dough (SCC 30203201) and straight-dough (SCC 30203202). Generally, in the sponge dough process some of the flour is mixed together with some water and some yeast. The mixture is allowed to rise slowly which produces a “sponge”. The remaining flour and liquid are then mixed with the sponge to produce the dough for baking. A variant of this is the liquid ferment method where yeast and flour are fermented in a brew tank. After fermentation, the liquid ferment is cooled then mixed as needed to make bread dough. The straight dough process is a single-step process in which all ingredients are mixed together at one time and the dough is allowed to rise (or leaven) before baking. The sponge-dough process and liquid ferment methods are used most often by large commercial bakeries. Straight doughs are used for a few types of variety breads. (U.S. EPA, 1992) The critical difference between the straight-dough and the sponge-and-dough processes is the length of the fermentation time. Fermentation time starts when the yeast comes in contact with water, and stops when the bread enters the oven. However, fermentation can be retarded if the dough is held below 10^{o}C (50^{o}F). Refer to Appendix B for definitions of baking terms.

The primary emission source at a bakery is the oven. The VOC that is produced during fermentation (mostly ethanol) is bound in the dough and remains there until the internal temperature reaches the vaporization temperature of alcohol, 78.9^{o}C (174^{o}F). Although high concentrations of VOC exist in the proof boxes that are often used to raise the panned dough, the low airflow through those boxes minimizes emissions. (U.S. EPA, 1992) The amount of VOC generated in yeast-leavened dough is a function of the amount of yeast added to the formula and the amount of time the yeast is allowed to ferment before the bread is baked.

V. Activity Data

A survey of retail and commercial bakeries located in the eight counties that comprise the District (Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus and Tulare) was conducted to determine the 2010 annual production of yeast-leavened bread. Retail and commercial bakeries located within the District were identified through searches utilizing the California Department of Public Health Food and Drug Branch's Processed Food Registration Program, Manta, Yellow Pages, White Pages, and the websites of grocery chains located in California. Facilities with District permitted bakery ovens were not included in the survey as their emissions are already included in the point source inventory. A copy of the survey is included in Appendix C.

Table 2. Response to District's yeast leavened products survey (2010).

Bakery Location	Surveys		
	Mailed (no.)	Returned (no.)	Returned (%)
Fresno	95	15	
Kern	73	21	
Kings	19	3	
Madera	15	3	
Merced	28	8	
San Joaquin	78	17	
Stanislaus	59	8	
Tulare	44	7	
District Total	411	82	20

Of the bakeries responding, 83% reported baking yeast-leavened products.

VI. Emission Factors

A study performed by the American Institute of Baking (AIB) provided a mathematical model for predicting ethanol emissions from bakeries. Statistical analysis suggested that the factors correlating best with ethanol emissions were yeast concentration and total fermentation time (U.S. EPA, 1992). The relationship was described as:

$$ETOH = 0.40425 + 0.444585\,(Yt) \qquad \text{(Eq. 1)}$$

where:

ETOH = pounds ethanol per ton *of baked bread*
Y = baker's percent yeast
t = total time of fermentation

This formula includes a little known correction for the addition of spiking yeast:

$$Yt = (Y_i \times t_i) + (S \times t_i) \qquad \text{(Eq. 2)}$$

where:

Y_i = initial baker's percent yeast in sponge to the nearest tenth of a percent
t_i = total time of fermentation in hours to the nearest tenth of an hour
S = baker's percent yeast added to dough to the nearest tenth of a percent
t_i = proof time + floor time to the nearest tenth of an hour

The "percent yeast in sponge" and "percent yeast added to dough" are in terms of baker's percent of yeast to the nearest tenth of a percent. The "total time of fermentation" and "proof time + floor time" are the fermentation times in hours to the nearest tenth of an hour. (U.S. EPA, 1992)

In 1987, the American Institute of Baking developed a predictive model for ethanol emissions from yeast-leavened baked foods. (AIB Technical Bulletin, Volume XXXII, Issue 4, page 2). The Bay Area Air Quality Management District (BAAQMD) and the South Coast Air Quality Management District (SCAQMD) use the equation based on the AIB study to calculate ETOH (ethanol) emission factors if emission measurements are not available for a specific bakery product. However, the emission factors listed in BAAQMD, Regulation 8 Rule 42, Table I and SCAQMD, Rule 1153, Attachment A are identified as "Pounds VOC/ton bakery product." The BAAQMD and SCAQMD emission factor tables are included in Appendix D and Appendix E.

In 1991, the EPA and the American Bakers Association worked together to produce an *Alternative Control Technology Document for Bakery Oven Emissions (ACT)* (U.S. EPA, 1992). Because of increasing regulatory concern for certain constituents emitted in small quantities (such as acetaldehyde) from bakery oven exhausts and the need to predict total VOC emissions (rather than just ethanol emissions) from common baking parameters, emission data were gathered. Products sampled were selected to provide a range of yeast concentrations and fermentation times similar to the AIB study and representative of the baking industry. The resulting data was summarized and indicated that total VOC emissions from bakery ovens can best be described as:

$$EF_{VOC} = 0.95Yi + 0.195t_i - 0.51S - 0.86t_s + 1.90 \qquad \text{(Eq. 3)}$$

where:

EF_{VOC} = VOC emission factor is pounds VOC per ton of baked bread
Y_i = pounds of yeast per 100 pounds of flour to the nearest tenth of a pound. Note that the baker's percent yeast is input into the formula an integer and not a percentage; for example, 3.2 pounds of yeast per 100 pounds of flour is entered into the formula as 3.2, not 0.032.
t_i = total yeast action time in hours to the nearest tenth of an hour
S = final (spike) bakers percent of yeast to the nearest tenth of a percent
t_s = spiking time in hours to the nearest tenth of an hour

This equation can be used directly for sponge-dough products. For straight-dough products it can be simplified as:

$$EF_{VOC} = 0.95Yi + 0.195t_i + 1.90 \qquad \text{(Eq. 4)}$$

AP-42 Chapter 9.9.6 Bread Baking (U.S. EPA, 1997) recommends that the equations from the ACT (Eq. 3 and Eq. 4) be used for estimating emissions from yeast-raised bread baking point sources.

Following are additional guidelines for using Equations 3 and 4 for estimating VOC emissions:

- The formula is based on a baker's percent compressed yeast-- the weight of the yeast per 100 pounds of flour. If cream yeast or other forms of yeast are used, the amount of yeast must be converted to compressed yeast.

- The formula uses the amount of finished baked bread. If only dough weight is available from the company records, then 11% to 12% water weight needs to be subtracted. Dough waste or cripple, usually known as a percent, is not counted in the weight because it is not baked. Baked cripple is counted because the ethanol has been released."

- When using the formulae, input numbers are rounded to the nearest tenth or hundredth so that an unrealistic level of precision is not attributed to the estimate. Final numbers should be rounded to the nearest tenth or whole number as appropriate.

- *At the time the formulae were developed, the majority of the baked breads, rolls, and buns sold in the marketplace were made using a sponge-dough recipe. Therefore, the EPA formula for estimating VOC emissions best fits the production of sponge-dough, yeast-raised breads, rolls, and buns. The EPA formula is not as good at estimating VOC emissions from crackers, pretzels, sweet goods, sour dough, bagels, and English muffins. For example, when the EPA formula is used to estimate emissions for a dry product or a high-moisture product, the estimate may appear high or low* (Giesecke, 2010).

The detailed emission equation requires information on percent of yeast and yeast rising times. If detailed information is not available, U.S. EPA (1999) emission factors for the straight-dough and sponge-dough baking processes from can be used as follows:

Table 3. Yeast leavened bakery product emission factors.

Process	Baking Emission Factors (lbs VOC/2,000 lbs baked)[1]
Straight-dough	0.5
Sponge-dough	5 to 8

[1] The VOC emission factor unit label in EPA's EIIP abstract is not consistent with EPA's AP42 and Alternative Control Technology documents. After reviewing the EIIP abstract, Dr. Giesecke noted that the VOC emission factor label is in error, i.e. rather than stating "lbs VOC/1,000 lbs baked" the label should be "lbs VOC/2,000 lbs baked".

For sponge-dough emissions, the California Air Resources Board's area source methodology (CARB, 1998) recommends using the high end of the emission factor range. The EPA, however, suggests using the lower value of the range for sponge-dough emissions (U.S. EPA, 1992).

VII. Emissions Calculations

A. Responding Facilities

For facilities that responded to the District's survey, emissions were estimated using Equation 3 (for straight dough) and Equation 4 (for sponge dough).

Sample Calculation 1: Sponge-Dough

Given. Facility A bakes bread using the sponge-dough process, and reported the following activity in 2010:

Parameter	Value
Yeast leavened bread production	1,950,000 pounds (975 tons)[1]
Initial baker's percent yeast (Yi)	3.9
Total yeast action time in hours (t_i)	4.9
Final (spike) bakers percent yeast (S)	1.0
Spiking time in hours(t_s)	1.7

[1] 1 short ton = 2,000 pounds

Step 1. Calculate the VOC emission factor using Equation 3.

$$EF_{VOC} = 0.95Yi + 0.195t_i - 0.51S - 0.86t_s + 1.90$$

$$EF_{VOC} = 0.95(3.9) + 0.195(4.9) - 0.51(1.0) - 0.86(1.7) + 1.90$$

$$EF_{VOC} = \frac{4.6 \text{ lbs VOC}}{\text{ton baked bread}}$$

Step 2. Calculate VOC emissions in tons per year.

$$VOC\ \ Emissions\ = \left(\frac{tons\ \ bread\ \ baked}{year}\right)\times\left(\frac{lbs\ \ VOC}{ton\ \ bread}\right)\times\left(\frac{1\ ton\ VOC}{2{,}000\ \ lbs\ VOC}\right)$$

$$VOC\ \ Emissions\ = \left(\frac{975\ tons\ \ bread\ \ baked}{year}\right)\times\left(\frac{4.6\ \ lbs\ VOC}{ton\ \ bread}\right)\times\left(\frac{1\ ton\ VOC}{2{,}000\ \ lbs\ VOC}\right)$$

$$VOC\ \ Emissions\ = \frac{2.2\ tons\ VOC}{year}$$

Sample Calculation 2: Straight-Dough

Given. Facility B bakes bread using the straight-dough process, and reported the following activity in 2010:

Parameter	Value
Yeast leavened bread production	1,950,000 pounds (975 tons)[1]
Initial baker's percent yeast (Yi)	2.5
Total yeast action time in hours (t_i)	2.3

[1] 1 short ton = 2,000 pounds

Step 1. Calculate the VOC emission factor using Equation 4.

$$EF_{VOC} = 0.95Yi + 0.195t_i + 1.90$$

$$EF_{VOC} = 0.95(2.5) + 0.195(2.3) + 1.90$$

$$EF_{VOC} = \frac{4.7\ \ lbs\ VOC}{ton\ \ baked\ \ bread}$$

Step 2. Calculate VOC emissions in tons per year.

$$VOC\ \ Emissions\ = \left(\frac{tons\ \ bread\ \ baked}{year}\right)\times\left(\frac{lbs\ \ VOC}{ton\ \ bread}\right)\times\left(\frac{1\ ton\ VOC}{2{,}000\ \ lbs\ VOC}\right)$$

$$VOC\ \ Emissions\ = \left(\frac{975\ tons\ \ bread\ \ baked}{year}\right)\times\left(\frac{4.7\ \ lbs\ VOC}{ton\ \ bread}\right)\times\left(\frac{1\ ton\ VOC}{2{,}000\ \ lbs\ VOC}\right)$$

$$VOC\ \ Emissions\ = \frac{2.3\ tons\ VOC}{year}$$

B. Non-Responding Facilities

Assumptions

1. 83% of facilities that did not return a survey bake yeast-leaved bread.
2. The average VOC emissions from facilities that did not return surveys is the same as from those that did return surveys.
3. The average VOC emissions from facilities that returned surveys was 0.25 tons per year.

Sample Calculation: Non-Responding Facilities.

Given. There were 80 bakeries in Fresno County that did not return their survey.

Step 1. Calculate VOC emission in tons per year.

$$VOC\ Emissions = (80\ facilities)\ x\ (83\%\ baking\ yeast\ bread)\ x \left(\frac{0.25\ tons\ VOC}{facility} \right)$$

$$VOC\ Emissions = \frac{16.6\ tons\ VOC}{year}$$

VIII. Temporal Variation

Permitted facilities report temporal activity through the District's point source emissions inventory. For area wide sources, activity will be considered uniform.

1. Daily

CARB Code 24. 24 hours per day - uniform activity during the day.

2. Weekly

CARB Code 7. 7 days per week - uniform activity every day of the week

3. Monthly

Uniform monthly activity.

IX. Spatial Variation

Area source bakery emissions may be distributed within each county using the point density (bakeries within a grid cell divided by total bakeries in the county) of bakeries within the county using bakery addresses from InfoUSA business database.

X. Growth Factor

Growth factors are developed by either the District's Strategies and Incentives Department or CARB for each EIC. These factors are used to estimate emissions in future years. The growth factors associated with this emissions category may be obtained from the District's Strategies and Incentives Department.

XI. Control Level

Control levels are developed by either the District's Strategies and Incentives Department or CARB for each EIC. Control levels are used to estimate emissions reductions in future years due to implementation of District rules. These control levels take into account the effect of control technology, compliance and exemptions at full implementation of the rules.

Bakeries with a bakery oven operated at a major source which emits VOC during the baking of yeast leavened products may be subject to District Rule 4693. Control levels associated with this emissions category may be obtained from the District's Strategies and Incentives Department.

XII. CARB Chemical Speciation

CARB has developed organic gas profiles in order to calculate reactive organic gasses (ROG), volatile organic compounds (VOC) or total organic gas (TOG) given any one of the three values. For each speciation profile, the fraction of TOG that is ROG and VOC is given. The organic gas profile codes can also be used to lookup associated toxics. CARB's speciation profile for bakeries is presented in the table below.

Table 4. CARB organic gas speciation profiles 420-412-6012-0000

Profile Description	CARB Organic Gas Profile#	Fractions	
		ROG	VOC
Fermentation	211	1	1

XIII. Assessment Of Methodology

The accuracy of this methodology depends upon the following:

- The US EPA mathematical model used for regulatory purposes to predict total VOC emissions from the baking of yeast-leavened bread accurately predicts emissions from bakeries in the District.
- The data submitted on the yeast leavened products survey was accurate.
- The average VOC emissions (0.25 tons) emitted per facility is based on surveys.

- The average VOC emissions emitted at facilities that did not return surveys is the same as that emitted at facilities that did return surveys, whether they use the sponge-dough or the straight-dough method

- Of the bakeries that returned the District's survey, 83% baked yeast-leavened bread. The District assumes that the same proportion of facilities that did not respond to the survey baked with yeast-leavened bread.

- The District has estimated a default value of 0.25 tons of VOC per facility. This default emission rate is assumed to accurately represents emissions from bakeries that did not respond to the District's survey.

XIV. Emissions

Following is the 2010 area source emissions inventory for REIC 420-412-6012-0000 estimated by this methodology. Emissions are reported for each county in the District.

Table 5. Area source emissions for REIC 420-412-6012-0000 (2010).

County	Emissions (tons/year)					
	NOx	CO	SOx	VOC(1)	PM_{10}	$PM_{2.5}$(2)
Fresno	--	--	--	22.3	--	--
Kern	--	--	--	13.6	--	--
Kings	--	--	--	3.3	--	--
Madera	--	--	--	3.4	--	--
Merced	--	--	--	5.2	--	--
San Joaquin	--	--	--	16.5	--	--
Stanislaus	--	--	--	11.1	--	--
Tulare	--	--	--	10.0	--	--
TOTAL	--	--	--	85.40	--	--

(1) The District only reports ROG to CARB. As noted in Section XII, ROG is the same as VOC.
(2) At this time, the District does not calculate $PM_{2.5}$ emissions. $PM_{2.5}$ emissions can be estimated using the speciation profiles found in Section XII.

Following is the 2010 point source emissions inventory for REIC 420-412-6012-0000 as reported to the District by our permit holders. Emissions are reported for each county in the District.

Table 6. Point source emissions for REIC 420-412-6012-0000 (2010).

County	Emissions (tons/year)					
	NOx	CO	SOx	VOC(1)	PM_{10}	$PM_{2.5}$(2)
Fresno	--	--	--	4.54	--	--
Kern	--	--	--	11.33	--	--
Kings	--	--	--	0.00	--	--
Madera	--	--	--	0.00	--	--
Merced	--	--	--	0.00	--	--
San Joaquin	--	--	--	5.72	--	--
Stanislaus	--	--	--	1.76	--	--
Tulare	--	--	--	0.02	--	--
TOTAL	--	--	--	23.37	--	--

(1) The District only reports ROG to CARB. As noted in Section XII, ROG is the same as VOC.
(2) At this time, the District does not calculate $PM_{2.5}$ emissions. $PM_{2.5}$ emissions can be estimated using the speciation profiles found in Section XII.

Following is the 2010 total unreconciled (point source plus area source) emissions inventory for REIC 420-412-6012-0000. Emissions are reported for each county in the District.

Table 7. Total emissions for REIC 420-412-6012-0000 (2010).

County	Emissions (tons/year)					
	NOx	CO	SOx	VOC(1)	PM_{10}	$PM_{2.5}$(2)
Fresno	--	--	--	26.84	--	--
Kern	--	--	--	24.93	--	--
Kings	--	--	--	3.3	--	--
Madera	--	--	--	3.4	--	--
Merced	--	--	--	5.2	--	--
San Joaquin	--	--	--	22.22	--	--
Stanislaus	--	--	--	12.86	--	--
Tulare	--	--	--	10.02	--	--
TOTAL	--	--	--	108.77	--	--

(1) The District only reports ROG to CARB. As noted in Section XII, ROG is the same as VOC.
(2) At this time, the District does not calculate $PM_{2.5}$ emissions. $PM_{2.5}$ emissions can be estimated using the speciation profiles found in Section XII.

Following is the 2009 total unreconciled (point source plus area source) emissions inventory for REIC 420-412-6012-0000 from the California Air Resources Board's California Emission Inventory Development and Reporting System (CEIDARS). Emissions are reported for each county in the District.

Table 8. Total emissions for REIC 420-412-6012-0000 (2009).

County	Emissions (tons/year)					
	NO_x	CO	SO_x	VOC[(1)]	PM_{10}	$PM_{2.5}$[(2)]
Fresno	--	--	--	124.25	--	--
Kern	--	--	--	3.43	--	--
Kings	--	--	--	0.64	--	--
Madera	--	--	--	0.64	--	--
Merced	--	--	--	1.27	--	--
San Joaquin	--	--	--	67.86	--	--
Stanislaus	--	--	--	1.91	--	--
Tulare	--	--	--	2.04	--	--
TOTAL	--	--	--	202.05	--	--

(1) The District only reports ROG to CARB. As noted in Section XII, ROG is the same as VOC.
(2) At this time, the District does not calculate $PM_{2.5}$ emissions. $PM_{2.5}$ emissions can be estimated using the speciation profiles found in Section XII.

Following is the net change in total unreconciled emissions between this update (2010 inventory year) and the previous update (2009 inventory year) for REIC 420-412-6012-0000. The change in emissions are reported for each county in the District.

Table 9. Net emissions change for REIC 420-412-6012-0000 (2010-2009).

County	Emissions (tons/year)					
	NO_x	CO	SO_x	VOC[(1)]	PM_{10}	$PM_{2.5}$[(2)]
Fresno	--	--	--	-97.41	--	--
Kern	--	--	--	21.50	--	--
Kings	--	--	--	2.66	--	--
Madera	--	--	--	2.76	--	--
Merced	--	--	--	3.93	--	--
San Joaquin	--	--	--	-45.64	--	--
Stanislaus	--	--	--	10.95	--	--
Tulare	--	--	--	7.98	--	--
TOTAL	--	--	--	-93.27	--	--

(1) The District only reports ROG to CARB. As noted in Section XII, ROG is the same as VOC.
(2) At this time, the District does not calculate $PM_{2.5}$ emissions. $PM_{2.5}$ emissions can be estimated using the speciation profiles found in Section XII.

XV. Revision History

2010. This is a new District methodology.

XVI. Update Schedule

In an effort to provide inventory information to CARB and other District programs and maximize limited resources, the District has developed an update cycle based on emissions within the source category as shown in the following table:

Table 10. Area source update frequency criteria.

Total Emissions (tons/day)	Update Cycle (years)
<=1	4
>1 and <= 2.5	3
>2.5 and <=5	2
>5	1

Since VOC emissions are less than 1 ton per day, these area source estimates will be updated every 4 years.

XVII. References

1. Bay Area Air Quality Management District. 1994. Regulation 8, Rule 42: Large Commercial Bread Bakeries. Accessed online at http://www.baaqmd.gov/~/media/Files/Planning%20and%20Research/Rules%20and%20Regs/reg%2008/rg0842.ashx?la=en.

2. Bay Area Air Quality Management District. 1999. Source Inventory Categories # 28 & 935: Large and Small Bakeries. Accessed online at http://www.arb.ca.gov/ei/areasrc/districtmeth/BayArea/99SS028.pdf .

3. California Air Resources Board. 1998. Identification of Performance Standards for Existing Stationary Sources: Bakery Ovens. Accessed online at http://www.arb.ca.gov/ssps/Bakery.pdf .

4. California Department of Public Health, Food and Drug Branch. Processed Food Registration Program. Accessed online May 23, 2011 at http://www.cdph.ca.gov/programs/Pages/FDB%20Food%20and%20Drug%20Branch.aspx.

5. Giesecke, A. 2010. *Estimating Volatile Organic Compound Ethanol Emissions from Bakery Ovens*. AIB International Technical Bulletin. Volume XXXII, Issue 4. July/August 2010.

6. King Arthur Flour. 2011. Baker's Percentage. Accessed online May 5, 2011 at http://www.kingarthurflour.com/professional/bakers-percentage.html.

7. Recipe Tips. 2012. Chemical Leavening Agents. Accessed online January 5, 2012 at http://www.recipetips.com/glossary-term/t--38838/chemical-leavening-agents.asp.

8. Reed, G. 1966. *Yeast, What It Does and How*. In: Proceedings of the Forty-Second Annual Meeting of the American Society of Bakery Engineers. Chicago, Illinois. March 1966.

9. Sacramento Metropolitan Air Quality Management District. 1996. Rule 458: Large Commercial Bread Bakeries. Accessed online at http://www.airquality.org/rules/rule458.pdf

10. San Joaquin Valley Air Pollution Control District. 2002, Rule 4693: Bakery Ovens. Accessed online at http://www.valleyair.org/rules/1ruleslist.htm.

11. San Diego County Air Pollution Control District. 1996. Regulation IV, Rule 67.24: Bakery Ovens. Accessed online at http://www.sdapcd.org/rules/rules.html.

12. Sonoma Technology, Inc. Attachment D, Bakeries. Accessed online 5/09/11 at http://www.arb.ca.gov/ei/areasrc/ccosmeth/att_d_bakeries.doc

13. South Coast Air Quality Management District. 1995. Rule 1153: Commercial Bakery Ovens. Accessed online at http://www.aqmd.gov/rules/reg/reg11/r1153.pdf.

14. The Artisan. 2001. Yeast – A Treatise – Section I. Accessed February 8, 2012 online at http://www.theartisan.net/The_Artisan_Yeast_Treatise_Section_One.htm.

15. The Artisan. 2001. Yeast – A Treatise – Section II. Accessed February 8, 2012 online at http://www.theartisan.net/The_Artisan_Yeast_Treatise_Section_Two.htm .

16. United States Census Bureau. 2011. 2009 County Business Patterns (NAICS). Accessed February 6, 2012 online at http://www.census.gov/econ/cbp/index.html.

17. United States Environmental Agency. 1999. Area Sources Category Method Abstract – Bakeries. In: Emission Inventory Improvement Program Technical Report Series Volume 3. Accessed online at http://www.epa.gov/ttn/chief/eiip/techreport/volume03/bakeries.pdf.

18. United States Environmental Protection Agency. 1992. Alternative Control Technology Document for Bakery Oven Emissions. EPA document EPA-453/R-92-017. Accessed online at www.epa.gov/ttn/chief/ap42

19. United States Environmental Protection Agency. 1997. AP 42, Chapter 9.9.6: Bread Baking. Accessed online at http://www.epa.gov/ttnchie1/ap42/ch09/final/c9s09-6.pdf.

20. United States Environmental Protection Agency. 2010. Basic Concepts in Environmental Concepts, Module 6: Air Pollutants and Control Techniques - Volatile Organic Compounds - Control Techniques. Accessed online January 5, 2012 at http://www.epa.gov/apti/bces/module6/voc/control/control.htm#catalytic.

21. Gwirtz, J.A., M.R. Willyard and K.L. McFall. 2007. Wheat Flour Products in North America. In: Future of Flour – A compendium of Flour Improvement. Agrimedia GmbH.

XVIII. Appendix

Appendix A. Inventory Reconciliation Codes

Appendix B. Terms and Definitions

Appendix C. District Yeast Leavened Products Survey

Appendix D. BAAQMD Regulation 8 Rule 42: Table I

Appendix E. South Coast AQMD, Rule 1153: Attachment A

Appendix A. Inventory Reconciliation Codes

Table 10. EIC, SCC and SIC codes in the District's 2010 point source inventory that reconciled to REIC 420-412-6012-0000.

EIC	SCC	Point Source Type	SIC
420-412-6012-0000	30203201	BAKERIES - BREAD BAKING – SPONGE-DOUGH	2048, 2051
	30203202	BAKERIES - BREAD BAKING STRAIGHT-DOUGH	2051, 2052, 5141, 5411, 8062, 9223
	30203203	BAKERIES - BREAD BAKING –HANDLNG/TRANS	2051, 2052, 9223
	30203299	BAKERIES - NOT CLASSIFIED OTHER	2051, 2052, 2099
	30229998	MISCELLANEOUS – NOT CLASSIFIED OTHER	2051, 2052
	30299999	MISCELLANEOUS - NOT CLASSIFIED OTHER	2051, 2052
420-412-6037-0000	30203204	BAKERIES – BREAD BAKING – FLOUR STORAGE	2051, 2052, 9223
420-412-6038-0000	30203105	GRAIN ELEVATORS – ELEV – UNLOADING	2051
	30203107	GRAIN ELEVATORS – ELEV - BT	2051
420-412-6076-0000	30201501	PROCESS – GENERAL	2051, 2052
	30201599	PROCESS – NOT CLASSIFIED - OTHER	2051, 2052
420-412-6086-0000	30200731	GRAIN MILLING - WHEAT MILLING – GRAIN RECEIVING	2051

Appendix B. Terms and Definitions

Baker's Percentage: is not the same as true percent. In true percent, the total of the ingredients always add up to 100%. Each ingredient in a formula (recipe), including the liquid, is measured by weight. In Baker's Percentage, the weight of the flour in the formula equals 100%. All the other ingredients are calculated in proportion to the weight of flour.

The mathematical equation for Baker's Percentage is: weight of ingredient / weight of total flour) x 100 = ingredient %

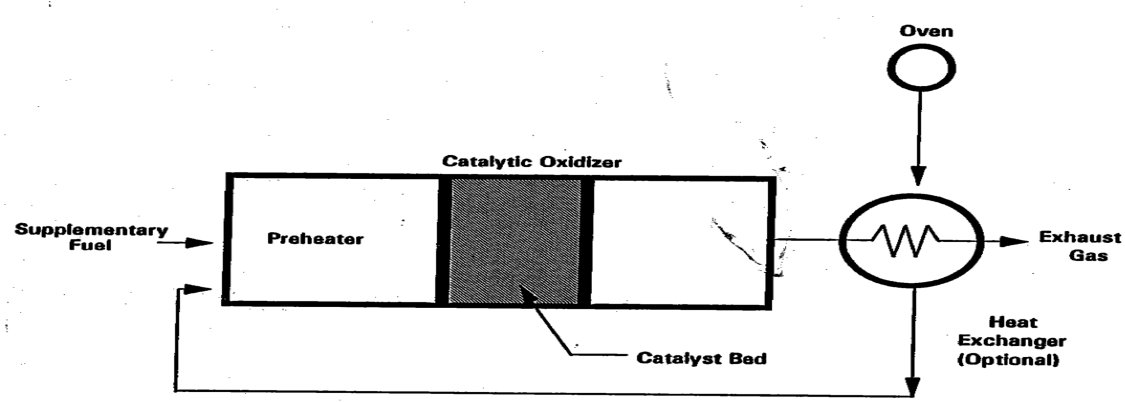
Example: Bakers percent – yeast = (10 grams yeast/500 grams flour) x 100 = 2%

Baker's Yeast: the common name for the strains of yeast commonly used as a leavening agent in baking bread and bakery products. Baker's yeast is of the species *Saccharomyces cerevisiae*, which is the same species commonly used in alcoholic fermentation, and it is also called brewer's yeast.

Bakery Oven: an enclosed compartment supplied with heat, typically from the combustion of natural gas, used to bake bread, buns and rolls. This does not include proofing boxes.

Bread: a perishable foodstuff prepared from a dough whose primary ingredients are flour, sugar, salt, water and yeast and which is baked into loaves, buns or rolls.

Catalytic Oxidation: a chemical oxidation process conducted over a catalyst in which volatile organic compounds are combined with oxygen at specific temperatures to yield carbon dioxide and water.



Chemical Leavening Agents: Chemical compounds such as baking powder and baking soda that react with other ingredients in an acid/base reaction which releases carbon dioxide causing the dough to rise without the formation of ethanol.

Compressed Yeast: *is also called "wet yeast" or "fresh yeast" and is usually sold in blocks. The yeast is characterized by a high moisture content of about 70%. Active Dry Yeast has a moisture content of about 8%. Cream yeast is a pumpable liquid with solids content of approximately 18% or a moisture content of 82%. (Giesecke, 2010)*

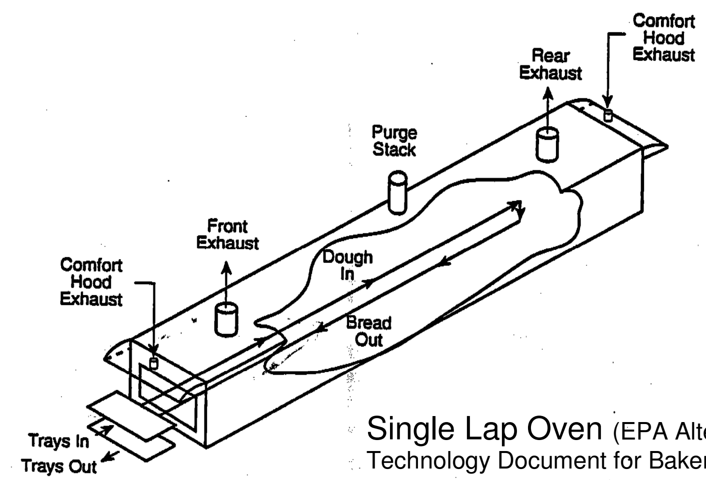
Destruction and Removal Efficiency (DRE): percent efficiency in causing the destruction and removal of particular targeted organic compound(s). Conversion of these compounds result in the formation of carbon dioxide, water and heat.

Dough retarder: a refrigerator used to control the fermentation of yeast when proofing dough. Lowering the temperature of the dough produces a slower, longer rise with more varied fermentation products, resulting in more complex flavors.

Fermentation: the anaerobic conversion of fermentable carbohydrates in the dough by yeast which produces carbon dioxide, ethanol (ethyl alcohol), small amounts of other alcohols, esters, and aldehydes.

Fermentation time: starts when the yeast is added to water and flour to make dough and ends when the product enters the oven. *Fermentation time in the cream yeast process starts when the liquid is added to the flour and ends when the product enters the oven. (Giesecke, 2010)*

Lap Oven: conveyor is "lapped" so that the doughs are both loaded and removed at the front of the oven after travelling the length of the oven and back. Usually has 2 or 3 exhaust stacks. Although shown in the 1992 diagram, a typical lap oven is closed in the back and has no comfort hood on the back of the oven.



Single Lap Oven (EPA Alternative Control Technology Document for Bakery Oven Emissions, 1992)

Leaven: to raise a dough by causing gas to permeate it through the use of a chemical agent such as baking powder or a fermentation-producing agent such as yeast.

Liquid Ferment: a process by which a small portion of flour is mixed with yeast in a brew tank where fermentation is allowed to take place for 1.5 – 3.0 hours at a controlled temperature. After fermentation, the liquid is chilled and then used as needed to mix bread dough.

Oven: An enclosed compartment supplied with heat, typically from the combustion of natural gas, used to bake bread, buns, and rolls. This does not include proofing boxes.

Proofing: the final dough-rise step before baking – the three basic control factors are temperature, humidity and time.

Proofing or Proof Box: a relatively large chamber equipped with temperature and humidity controls. A warm, humid chamber where yeast leavened dough is allowed to rise to the volume desired for baking.

Rack oven: An oven with the ability to produce steam internally and fitted with a motor-driven mechanism for rotating multiple pans fitted into one or more pan racks within the cavity.

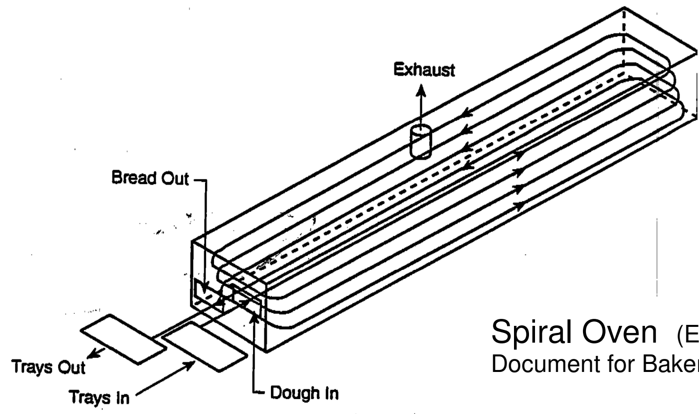
Rack Oven

Retarder / Proofer Unit: The unit provides a cool environment where the dough can rest before rising, i.e. slow the process of rising or proofing. When the dough is ready for proofing, the unit alters the temperature and humidity to allow the dough to rise.

Retarding: a second, slower rising of the dough. The dough is refrigerated which causes a slower fermentation or rise of the dough. The retarding stage is often used in sourdough bread recipes to allow the bread to develop it characteristic flavor.

Retarding Time: the time where the dough or sponge is refrigerated for the specific purpose of retarding the fermentation process. *Retarding time below 50^{o}Fahrenheit (F) (10^{o}Celsius (C)) does not encourage fermentation so that amount of time is subtracted from the fermentation time for the formula. (Giesecke, 2010)*

Spiral oven: conveyor path is spiraled so that doughs circle the oven latitudinally several times – requires only a single exhaust stack. Although not shown in the 1992 diagram, spiral ovens typically have a purge stack.

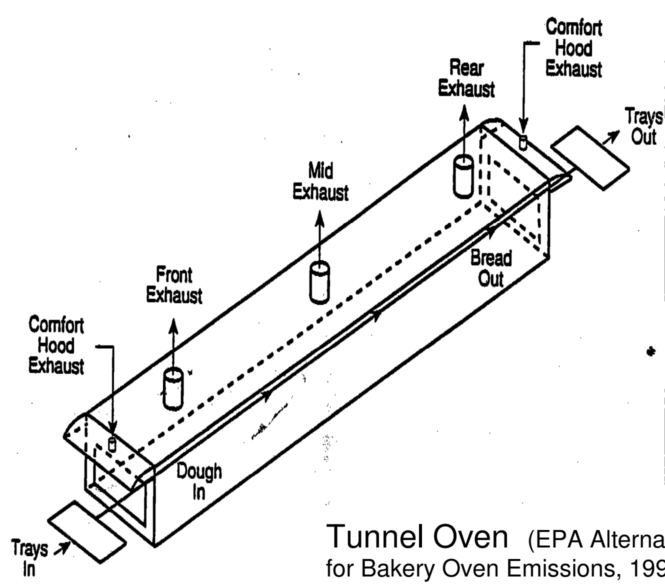


Spiral Oven (EPA Alternative Control Technology Document for Bakery Oven Emissions, 1992)

Sponge dough process: Generally, in the sponge dough process some of the flour is mixed together with some water and some yeast. The mixture is allowed to rise slowly which produces a “sponge”. The remaining flour and liquid are then mixed with the sponge to produce the dough for baking.

Straight dough process: is a single-step process in which all ingredients are mixed together at one time and the dough is allowed to rise (or leaven) before baking

Tunnel Oven: doughs are conveyed along the length of the oven from the front entrance to the rear exit – generally has 2 or more exhaust stacks and a purge stack.



Tunnel Oven (EPA Alternative Control Technology Document for Bakery Oven Emissions, 1992)

Appendix C. District Yeast Leavened Products Survey

San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

Bakery Survey for the 2010 Calendar Year
Yeast Leavened Products

The District is required by the State of California to periodically update our inventory of area-wide emissions. This inventory is vital to ensure that future air pollution control plans and rules reflect actual emissions and do not overestimate industrial emissions. We would appreciate your assistance in updating our inventory of emissions from yeast leavened products by completing the survey below and returning it to the District's Central Region office or FAX to (559) 230-6065 before **May 1, 2011**. If you have any questions, please call Georgia Stewart at (559) 230-5937.

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1. Does your facility bake yeast leavened products (circle one)? YES NO (go to #4)

2. Maximum operating schedule: Hours per day __________ Days per week __________

3. Annual Process rates for yeast leavened products:

Product Type	Annual Production (lbs/year)	Initial Bakers Yeast (%) (Lbs yeast per 100 lbs flour)	Total Yeast Action Time (in hours)	Method Used Sponge(Sp) Straight (St)	Final (additional) yeast	
					Final (Spike) Baker's Yeast (%)	Secondary Yeast Action Time (in hours)
Bread						
Buns						
Other:						
Other:						

4. Number of natural gas baking ovens: __________

Oven Rating (BTU)	Hours Operated per Day
Oven 1:	
Oven 2:	
Oven 3:	

5. Control Equipment Used (circle one): YES NO

Control Type: Thermal Oxidizer: _______ Other: _____________

Destruction or Removal Efficiency (%) of Control Device: _____________

6. This information is considered confidential (circle one): YES NO

7. Facility Contact: ______________________ Phone No: __________________

Central Region (Main Office) • 1990 E. Gettysburg Avenue • Fresno, CA 93726-0244 • (559) 230-6000 • fax (559) 230-6065

Appendix D. BAAQMD Regulation 8 Rule 42

8-42-602 Emission Calculation Procedures: If emission measurements conducted in accordance with Section 8-42-601 are not available for a specific bakery product, oven emissions shall be calculated using the emission factors in Table I.

TABLE I

Yt*	Pounds VOC/ton bakery product	Yt*	Pounds VOC/ton bakery product
1.0	.8488	16.0	7.5176
1.5	1.0711	16.5	7.7399
2.0	1.2934	17.0	7.9622
2.5	1.5157	17.5	8.1845
3.0	1.7380	18.0	8.4068
3.5	1.9603	18.5	8.6291
4.0	2.1826	19.0	8.8514
4.5	2.4049	19.5	9.0737
5.0	2.6272	20.0	9.2959
5.5	2.8495	20.5	9.5182
6.0	3.0718	21.0	9.7405
6.5	3.2941	21.5	9.9628
7.0	3.5163	22.0	10.1851
7.5	3.7386	22.5	10.4074
8.0	3.9609	23.0	10.6297
8.5	4.1832	23.5	10.8520
9.0	4.4055	24.0	11.0743
9.5	4.6278	24.5	11.2966
10.0	4.8501	25.0	11.5189
10.5	5.0724	25.5	11.7412
11.0	5.2947	26.0	11.9635
11.5	5.5170	26.5	12.1857
12.0	5.7393	27.0	12.4080
12.5	5.9616	27.5	12.6303
13.0	6.1839	28.0	12.8526
13.5	6.4061	28.5	13.0749
14.0	6.6284	29.0	13.2972
14.5	6.8507	29.5	13.5195
15.0	7.0730	30.0	13.7418
15.5	7.2953		

*Yt = (yeast percentage) x (fermentation time).
If yeast is added in 2 steps, Yt = [(initial yeast percentage) x (total fermentation time) + (remaining yeast percentage) x (remaining fermentation time)].

Bay Area Air Quality Management District — June 1, 1994

8-42-4

Appendix E. South Coast Air Quality Management District, Rule 1153

Rule 1153 (Cont.) **(Amended January 13, 1995)**

ATTACHMENT A

Yt*	Pounds VOC/ton Bakery Product	Yt*	Pounds VOC/ton Bakery Product
1.0	0.8488	16.0	7.5176
1.5	1.0711	16.5	7.7399
2.0	1.2934	17.0	7.9622
2.5	1.5157	17.5	8.1845
3.0	1.7380	18.0	8.4068
3.5	1.9603	18.5	8.6291
4.0	2.1826	19.0	8.8514
4.5	2.4049	19.5	9.0737
5.0	2.6272	20.0	9.2959
5.5	2.8495	20.5	9.5182
6.0	3.0718	21.0	9.7405
6.5	3.2941	21.5	9.9628
7.0	3.5163	22.0	10.1851
7.5	3.7386	22.5	10.4074
8.0	3.9609	23.0	10.6297
8.5	4.1832	23.5	10.8520
9.0	4.4055	24.0	11.0743
9.5	4.6278	24.5	11.2966
10.0	4.8501	25.0	11.5189
10.5	5.0724	25.5	11.7412
11.0	5.2947	26.0	11.9635
11.5	5.5170	26.5	12.1857
12.0	5.7393	27.0	12.4080
12.5	5.9616	27.5	12.6303
13.0	6.1839	28.0	12.8526
13.5	6.4061	28.5	13.0749
14.0	6.6284	29.0	13.2972
14.5	6.8507	29.5	13.5195
15.0	7.0730	30.0	13.7418
15.5	7.2953		

* Yt = (yeast percentage) x (fermentation time)
If yeast is added in 2 steps, Yt = (initial yeast percentage) (total fermentation time) + (remaining Yeast percentage) (remaining fermentation time)