San Joaquin Valley
Unified Air Pollution Control District

Emission Inventory Methodology
052 – ORCHARD HEATERS

III. Purpose

This document describes the method used to estimate emissions from orchard heaters commonly known as "smudge pots" in the San Joaquin Valley Air Basin.

IV. Applicability

This emissions source category applies to orchard heaters commonly known as "smudge pots". Other types of orchard heaters, such as wind machines, are not included in this category. The emissions calculations from this Area Source Methodology applies to the following CES and EIC code(s):

CES	EIC	Description
47233	052-995-1000-0000	Food and Agricultural Processing - Liquid Fuel (Unspecified)

V. Point Source Reconciliation

This emission category doesn't reconcile against the point source inventory.

VI. Methodology Description

The type of orchard heaters commonly known as "smudge pots", are used to prevent frost damage to fruit trees, nursery plants and other crops. Currently they have limited utilization because they are not the most efficient means of preventing frost damage and are labor intensive. Usage tends to be very crop-specific and localized; sometimes occurring on very cold nights to augment other forms of frost protection such as wind machines, sprinkler irrigation, running water or helicopters. Protection of orchards, vineyards, and crops from frost damage is accomplished by the operation of wind machines or application of well water (50 to 60 F) to the ground at the base of the trees. Water can also be applied to trees directly with the goal of protecting the trees (in this case, the crop will be lost if the crop is frozen). This category includes orchard heaters that burn any type of fuel, charcoal briquettes, or similar substances by an open flame capable of being used for the purpose of giving orchards, vineyards, and crops protection from frost damage. The typical fuel used in orchard heaters in the San Joaquin Valley is diesel fuel.

VII. Activity Data

Agricultural agencies were contacted to obtain activity data for orchard heaters. The following table lists results of the telephone survey of County Agricultural Commissioner offices and University of California Cooperative Extension Farm Advisors.

County	Orchard Heater Survey Results	Process Rate 2004 (heater-hr / year)
San Joaquin	Not used	0
Stanislaus	Not used	0
Merced	100 heaters in almond orchards and tomato fields (first crop) - one night per year.	600
Madera	Negligible use by nurseries	Assumed near 0
Fresno	100 heaters - one night per year	600
Kings	Not used	0
Tulare	Not used	0
Kern	Not used	0

VIII. Temporal Variation

Daily: ARB Code 6. Primarily nighttime activity for 6 hours when in use.
Weekly: ARB Code 7. Uniform activity.
Annual: Activity is mainly from November 15 to February 15, with December and January each having 37.5% of the activity and November and February each having 12.5% of the activity. The remaining months are assumed to have zero activity.

IX. Spatial Variation

Orchard heaters are mainly used in Merced and Fresno counties in agricultural areas.

X. Emission Factors

Emission factors are as follows:

Process	Emission Factor (pounds per heater hour)				
	CO	NO_x	SO_2	VOC	PM
Orchard Heaters	0.005	Negligible	0.007	16.0	0.132

The orchard heater VOC emission factor was taken from EPA's AP-42 document (EPA, 1995a). The SO_x emission factor was calculated from the weight percentage of sulfur in diesel fuel (see section IX). Nearly all hydrocarbon emissions result from evaporative losses from the heater fuel reservoir. Because of low flame temperatures, NO_x emissions are considered to be negligible. Although there is no reliable CO emission factor available for orchard heaters, it is assumed that they would be similar to external combustion boilers. The CO emission factor was then taken from EPA's AP-42 document (EPA, 1995b). The PM emission factor was determined by the San Joaquin Valley Unified Air Pollution Control District regulations in Rule 4303 restricting the use of orchard heaters to those which produce no more than one (1) gram per minute of unconsumed solid carbonaceous materials. The PM_{10} and $PM_{2.5}$ emission factors are determined by their respective speciation factors (see section XIV).

XI. Sample Calculations

For Merced County:

VOC emissions:

$$Emissions = (Number\ of\ heaters) \times \left(\frac{Hours}{Day}\right) \times \left(\frac{Days}{Year}\right) \times (Emission\ Factor) \times \left(\frac{1\ ton}{2000\ lbs}\right)$$

$$100\ heaters \times \frac{6\ hours}{day} \times \frac{1\ day}{year} \times \frac{16\ lb\ VOC}{heater - hr} \times \frac{1\ ton}{2000\ lbs} = \frac{4.8\ tons\ VOC}{year}$$

PM and PM_{10} Emissions:

$$Emissions = (\#\ of\ heaters) \times \left(\frac{Hours\ of\ Use}{Day}\right) \times \left(\frac{Days\ of\ Use}{Year}\right) \times (Emission\ Factor) \times \left(\frac{1\ ton}{2000\ lbs}\right)$$

$$100\ heaters \times \frac{6\ hours}{day} \times \frac{1\ day}{year} \times \left[\frac{1\ gram\ PM}{heater - \min} \times \frac{60\ \min}{heater - hr} \times \frac{1\ lb}{453.6\ grams}\right] \frac{1\ ton}{2000\ lbs}$$

$$= \frac{0.0396\ tons\ PM}{year}$$

PM_{10} Emissions = (PM Emissions) X (PM_{10} Speciation factor)

$$\frac{0.0396\ tons\ PM}{year} \times \frac{0.976\ tons\ PM_{10}}{1\ ton\ PM} = \frac{0.0386\ tons\ PM_{10}}{year}$$

SO_2 Emission Factor:

$$Percent\ S\ by\ weight = \frac{0.0005\ lbs\ S}{1\ lb\ fuel}$$

Assuming a fuel consumption rate of 1 gallon/heater-hr, that 1 gallon of diesel weighs 7.1 lbs., and that 2 lbs of SO_2 are produced for every 1 lb of S emissions:

$$Emission\ Factor = \frac{0.0005\ lb\ S}{1\ lb\ fuel} \times \frac{7.1\ lbs\ fuel}{gallon} \times \frac{1\ gallon}{heater-hr} \times \frac{2\ lbs\ SO_2}{1\ lb\ S} = \frac{0.007\ lbs\ SO_2}{heater-hr}$$

SO_2 Emissions:

$$Emissions = (Number\ of\ heaters) \times \left(\frac{Hours}{Day}\right) \times \left(\frac{Days}{Year}\right) \times (Emission\ Factor) \times \left(\frac{1\ ton}{2000\ lbs}\right)$$

$$100\ heaters \times \frac{6\ hours}{day} \times \frac{1\ day}{year} \times \frac{0.007\ lbs\ SO_2}{heater-hr} \times \frac{1\ ton}{2000\ lbs} = \frac{0.0021\ tons\ SO_2}{year}$$

CO Emission Factor:

Assuming a fuel consumption rate of 1 gallon/ heater-hr:

$$\frac{5\ lbs\ CO}{1000\ gallons\ of\ fuel} \times \frac{1\ gallon}{heater-hr} = \frac{0.005\ lbs\ CO}{heater-hr}$$

CO Emissions:

$$Emissions = (Number\ of\ heaters) \times \left(\frac{Hours}{Day}\right) \times \left(\frac{Days}{Year}\right) \times (Emission\ Factor) \times \left(\frac{1\ ton}{2000\ lbs}\right)$$

$$100\ heaters \times \frac{6\ hours}{day} \times \frac{1\ day}{year} \times \frac{0.005\ lbs\ CO}{heater-hr} \times \frac{1\ ton}{2000\ lbs} = \frac{0.0015\ tons\ CO}{year}$$

XII. Assumptions

Orchard heater activity is based on a San Joaquin Valley Unified Air Pollution Control District survey of agricultural agencies with knowledge of current agricultural practices. In Merced County, there is very limited use in almond orchards and tomato fields. Use in tomato fields is limited to early first planting,

when frost damage is possible. Use in almond orchards tends to be in the spring when trees are in bloom and there is a late frost.

1. During the winter and spring, frost protection is required on an average of 1 night in a typical year.

2. Orchard heaters are used six hours per night.

3. Fuel sulfur content is 0.05%.

4. Hydrocarbon emissions primarily are evaporative; NO_x emissions are negligible.

5. Orchard heaters are assumed to be the return stack type.

6. An estimated total of 100 orchard heaters are in use in Merced and Fresno County, for an average of one night per year.

7. Use of orchard heaters by nurseries in Madera County is negligible and process rate will be set to zero for Madera County.

8. Maximum particulate matter emissions for orchard heaters meet the 1 gram/minute per heater limitation in the San Joaquin Valley Unified Air Pollution Control District regulations in Rule 4303.

9. There are 2 (two) lbs of SO_2 produced for every 1 (one) lb of S.

10. All Sulfur in the fuel is assumed to be converted to SO_2.

11. Diesel fuel is the only fuel used and it is used at a rate of 1 gallon / heater-hr.

12. The amount of ROG is equal to the amount of VOC.

13. For the purposes of CO emissions, Orchard Heaters are treated as External Combustion Boilers using distillate fuel. The emission factor is 5 lb / 1000 gallons of fuel.

XIII. Frequency of Update

The emissions for this methodology will be collected by contacting the Agricultural Commissioners/Departments in each respective county. Due to the relatively low emissions from this source along with the decreasing usage (see section XII), it is recommended that this methodology be updated on a 5 year basis (or as necessary).

EIC	Frequency (In years)	Source of Emissions (Point Source Inventory / Data Gathering)
052-995-1000-0000	5	Data Gathering

XIV. Growth Factor

Use of orchard heaters has been decreasing in past years to the point that they are no longer used in many San Joaquin Valley counties. The growth factor will be assumed to be 1.0 (which represents no growth), because there is currently very limited use and no increase in future use is expected.

XV. Control Factor

San Joaquin Valley Unified Air Pollution Control District regulations in Rule 4303 pertain to use of orchard heaters in the San Joaquin Valley, and imposes an emissions limit of one gram per minute of unconsumed carbonaceous matter. A control factor was not developed because orchard heaters are rarely used.

XVI. Chemical Speciation

Profile Description	ARB Profile#		Fractions			
	Organic Gas	PM	ROG	VOC	PM_{10}	$PM_{2.5}$
Orchard Heaters		151			0.976	0.967
External Combustion Boilers - Distillate or Residual	504		0.8347	0.8347		

XVII. Assessment Of Methodology

Orchard heater activity is based on information obtained from agricultural agencies, and is a very rough estimate. The confidence in the emissions estimate could be improved by conducting a more detailed survey of agricultural operations to determine the type of frost protection that is used. The method used to calculate CO emissions is questionable since an emission factor was not available and an alternate was selected (see section X).

A phone conversation with Terry Schaeffer, Ventura County Agricultural Commission consulting meteorologist was also conducted to aid in the development of this methodology.

XVI. Emissions Comparison

County	CEIDARS Inventory Year 2003 Emissions (tons/year)[1]					
	NOx	CO	SOx	VOC	PM_{10}	$PM_{2.5}$
Orchard Heaters						
Fresno	0	151.9	3.6	3.3	6.4	6.4
Kern	0	218.7	5.2	3.7	9.4	9.3
Kings	0	0	0	0	0	0
Madera	0	0	0	0	0	0
Merced	0	3667.7	26.1	143.1	5.4	5.3
San Joaquin	0	20.5	14.7	1.3	0	0
Stanislaus	0	0	0	0	0	0
Tulare	0	158.4	3.7	11.7	6.7	6.7
TOTAL	0	4217.2	53.3	163.1	27.9	27.7

[1] Emissions in CEIDARS are reported in tons per day to 1/100th of a ton. Therefore, emissions of less than 0.005 tons per day (0.18 tons per year) are reported as zero.

County	Current Emissions 2004 Emissions (tons/year)					
	NOx	CO	SOx	VOC	PM_{10}	$PM_{2.5}$
Orchard Heaters						
Fresno	0	0.0015	0.0021	4.8	0.0386	0.0383
Kern	0	0	0	0	0	
Kings	0	0	0	0	0	
Madera	0	0	0	0	0	
Merced	0	0.0015	0.0021	4.8	0.0386	0.0383
San Joaquin	0	0	0	0	0	
Stanislaus	0	0	0	0	0	
Tulare	0	0	0	0	0	
TOTAL	0	0.0030	0.0042	9.6	0.0773	0.0766

County	Change in Emissions from 2003 to 2004 Emissions Changed (tons/year)					
	NOx	CO	SOx	VOC	PM_{10}	$PM_{2.5}$
Orchard Heaters						
Fresno	0.0	-151.9	-3.6	1.5	-6.4	
Kern	0.0	-218.7	-5.2	-3.7	-9.4	
Kings	0.0	0.0	0.0	0.0	0.0	
Madera	0.0	0.0	0.0	0.0	0.0	
Merced	0.0	-3667.7	-26.1	-138.3	-5.4	
San Joaquin	0.0	-20.5	-14.7	-1.3	0.0	
Stanislaus	0.0	0.0	0.0	0.0	0.0	
Tulare	0.0	-158.4	-3.7	-11.7	-6.7	
TOTAL	0.0	-4217.2	-53.3	-153.5	-27.8	-27.6

[++] Emission increased from zero value previously reported in CEIDARS for this pollutant
[--] Emission decreased to zero for this pollutant

XVII. References

a. California Air Resources Board (1984), "Methods for Assessing Area Source Emissions in California", Section D-06, December 1984

b. California Air Resources Board (2006). CEIDARS Emission Inventory Categorization Reports, <http://www.arb.ca.gov/app/emsinv/dist/rpts/sub_eic.php> (June 13, 2006)

c. United States Environmental Protection Agency (1995a), AP-42 Section 1.3 "Fuel Oil Combustion", January 1995.

d. United States Environmental Protection Agency (1995b), AP-42 Section 9.2.3 "Orchard Heaters", January 1995.

e. State of California, Health and Safety Code: Section 41860

f. Ventura County Air Pollution Control District (2000), Orchard Heater Emissions Inventory Methodology, 2000.

XVIII. Appendix X. California Air Resources Board Growth Parameters for EIC 052-995-1000-0000.

Year	Growth Activity Parameter by County							
	Fresno	Kern	Kings	Madera	Merced	San Joaquin	Stanislaus	Tulare
2000	970402	970402	970402	970402	970402	970402	970402	970402
2001	967491	967491	967491	967491	967491	967491	967491	967491
2002	964588	964588	964588	964588	964588	964588	964588	964588
2003	961694	961694	961694	961694	961694	961694	961694	961694
2004	958809	958809	958809	958809	958809	958809	958809	958809
2005	955933	955933	955933	955933	955933	955933	955933	955933
2006	953065	953065	953065	953065	953065	953065	953065	953065
2007	950206	950206	950206	950206	950206	950206	950206	950206
2008	947355	947355	947355	947355	947355	947355	947355	947355
2009	944513	944513	944513	944513	944513	944513	944513	944513
2010	941680	941680	941680	941680	941680	941680	941680	941680
2015	927639	927639	927639	927639	927639	927639	927639	927639
2020	913808	913808	913808	913808	913808	913808	913808	913808
2025	900063	900063	900063	900063	900063	900063	900063	900063
2030	886318	886318	886318	886318	886318	886318	886318	886318