SECTION 8.1

AGRICULTURAL AIRCRAFT
(Updated August 22, 1990)

ASSIGNMENT OF CATEGORIZATION

EMISSION INVENTORY SOURCE CATEGORY
OTHER MOBILE SOURCES

SOURCE CATEGORY CODES AND DESCRIPTION:
47563 AGRICULTURAL AIRCRAFT . CROP DUSTING.

EMISSION INVENTORY CODES AND DESCRIPTION:
810-806-1140-0000 AGRICULTURAL AIRCRAFT . CROP DUSTING.

METHOD AND SOURCES

This category is used to inventory the combustion emissions from commercial aircraft used for crop dusting. This does not include emissions from materials sprayed which are inventoried under pesticide application (Section 4-1).

Statewide fuel consumption by agricultural aircraft is estimated from data based on a schedule III document prepared by the Division of Tax Administration.[1] This document was prepared for the 1989-1990 fiscal year, and the column titled "prior year to date" contains the information on crop dusting for the 1988-1989 fiscal year. The total gallons of fuel consumed was then apportioned to the counties according to the ratio of the number of acres sprayed by aerial applications in each county. The number of acres sprayed was taken from the Pesticide Use Report (PUR).[2]

There are seven types of agricultural aircraft:[3,4,5,6,7,8] Teledyne/Continental 0-200; Avco/Lycoming 0-320; Pratt & Whitney (P&W) R1340; P&W R985; PT6A-34 (Pratt & Whitney fixed wing turbine); Helicopter - piston; Helicopter - turbine OH-58. These aircraft emission factors for CO, HC, NOx, and SOx were weighted for average emission factors based on EPA [9,10] values for these seven types of aircraft.

The emission factor for PM for these particular aircrafts was not available from the two EPA documents.[9,10] The average of the PM emission factors for other aircraft with similar fuel consumption rates and emission factors to the seven agricultural aircraft mentioned earlier.

The emission factors used were those corresponding to the "approach" mode. This mode was used because most of the activity in crop dusting occurs close to the ground and involves many quick and small changes in elevation. This mode also corresponds to the average fuel consumption of these aircraft in crop dusting.

The density of aircraft gasoline and jet fuel, 6.0 lb/gallon and 7.0 lb/gallon respectively, was supplied by a Chevron quality control lab supervisor.[11] These values were used to convert the emission factors to the units of pounds per 1000 gallons of fuel.

The fractional use of each type of aircraft is given in Table I. These fractions were derived from a number of sources.

Table I

Fractional Use of Aircraft[3,4,5,6,7,8]

Aircraft type	Fractional Use
Telydyne/Cont. 0-200	0.03
Avco/Lycoming 0-320	0.03
P&W R1340	0.63
P&W R985	0.11
PT6A-34	0.08
Helicopter-piston	0.11
Helicop.-turb. OH-58	0.01

The derivation of emission factors and weighted averages are shown in Table II. The emission factors are converted into lb/1000 gallons.

Table II
Derivation of Emission Factors[9,10]

Aircraft type	Fuel[3,4,5,6,7,8] Consmpt. Rate (lb/hr)	CO EF (lb/hr)	HC EF (lb/hr)	NOx EF (lb/hr)	PM EF (lb/hr)	SOx EF (lb/hr)
Telydyne/Cont. 0-200	21.3	23.8	0.4	0.05	0.01	0.02
Avco/Lycoming 0-320	23.1	24.3	0.5	0.05	0.01	0.02
P&W R1340	210.0	80.8	1.2	1.37	0.07	0.22
P&W R985	168.0	64.6	0.9	1.09	0.06	0.18
PT6A-34	245.0	5.3	4.0	0.81	0.08	1.31
Helicopter-piston	90.0	30.4	0.6	0.06	0.03	0.09
Helicop.-turb. OH-58	112.0	3.2	0.6	0.84	0.04	0.60
Weigthed Average	182.7	63.2	1.3	1.1	0.06	0.28
EF in lb/1000 gal.		2105	42.45	35.56	2.05	9.37
EF in 10^{-5} ton/acre		5.44	0.11	0.09	0.0053	0.024

ASSUMPTIONS

1. The emission factors in EPA's documents[9,10] and from EPA's representative, Rich Wilcox,[12] for the seven types of agricultural aircraft are representative of the aircraft used for crop dusting.

2. The amount of fuel consumed by the aircraft is proportional to the total number of acres sprayed statewide by air application.

3. Emission factors for the "approach" mode are applicable to agricultural aircraft operations.

4. The PM emission factors for aircraft with similar fuel use rates are applicable to agricultural aircraft.

5. The radial engines used in agricultural aircraft include P&W R1340 and the P&W R985, and the corresponding emission factors can be extrapolated from EPA emission factors from the R1820-82 engine manufactured by Curtis-Wright.[8]

6. The PT6A-34 engine emission factors can be estimated based on EPA emission factors from the PT6A-27 engine. The ratio of the maximum fuel flow rates for these two engines are applied to the emission factors of the PT6A-27 engine; hence, the emission factors for the PT6A-34 engine are derived.[8]

7. The piston helicopter engine emission factors were estimated based on emission factors from the 4-cylinder Avco/Lycoming 0-320 multiplied by 1.25 to account for a 6 cylinder engine found in the piston helicopter engine.[7]

8. The helicopter turbine OH-58 Kiowa using engine T63-A-5A is representative of the helicopter turbines.[7]

9. The percent usage of each type of aircraft is correct.

10. The fuel consumption from crop dusters listed in the Tax Administrative Schedule III for the 1988-9 fiscal year is representative of the corresponding acreage sprayed by aerial application in 1988.[1]

11. The acreage sprayed by aerial application and fuel consumed in 1988 corresponds directly to the 1989 values using the assumption of no growth between 1988 and 1989.

12. The estimates of fuel consumption rates of each agricultural aircraft were correctly estimated by a number of experts in agricultural aircraft.[3,4,5,6,7,8]

COMMENTS AND RECOMMENDATIONS

The year 1978 was the last year that a survey was performed on gallons of fuel purchased for use in agricultural aircraft. An alternative source of fuel consumption was to rely on tax claims made on fuel use, and this method was employed for the 1989 year. Starting in 1990 there will be no more tax claims made on fuel use for agricultural aircraft due to changes in tax laws.

CHANGES IN METHODOLOGY

For the 1979, 1983, and 1987 methodology, the process rate was in terms of gallons of fuel consumed based on the 1978 survey. The source of the fuel consumption data for 1989 differs from the previous inventory, for in the 1989 methodology the tax administration fuel consumption data was incorporated. The 1989 distribution of fuel consumption was estimated based on the assumption that gallons of fuel used is relative to the county-wide acres of farmland sprayed by air application.

The emission factors for the 1989 were based on seven types of aircraft: Teledyne/Continental 0-200, Avco/Lycoming 0-320, P&W R1340, P&W R985, PT6-34, Helicopter-piston, Helicopter-turbine OH-58 (Kiowa). The average emission factors were derived based on a distribution of aircraft type being used in California.[3,4,5,6,7,8]

DIFFERENCE BETWEEN 1987 AND 1989 EMISSION ESTIMATES

The 1987 emission estimates are higher than the 1989 estimates. This is due to different aircraft being used for agriculture; "approach" emission factors being used rather than "takeoff" values; fuel consumption data source based on tax returns and not an actual survey as perfomed in 1978.

TEMPORAL ACTIVITY

The annual activity occurs primarily during the late spring and summer. The weekly activity is nearly uniform, with reduced activity on weekends. The daily activity occurs during daylight hours only.

SAMPLE CALCULATIONS

The statewide consumption by agricultural aircraft in 1989 is estimated based on the assumption that gallons of fuel used is proportional to the total acres of farmland sprayed by air application.

Total acres sprayed by air application in 1988 = 20,563,826

Total statewide fuel consumption in 1988 = 1,063,566

Calculating the numbers of acres/gal in 1988 as follows:

$$\frac{20,563,826 \text{ acres}}{1,063,566 \text{ gal}} = 19.33 \text{ acres/gal} = 19,330 \text{ acres/1000 gal}$$

Extrapolations of data to estimate emission factors

The emission factors used for two radial engine aircraft needs to be derived from a similar larger engine aircraft. Emission factor data for the R1820 engine is available from the EPA.[9]

Fuel rate (lb/hr)	Engine type	Horsepower
322.8	R1820	1200
210	R1340	600
168	R985	450

The ratio of the R1340 and the R985 fuel rates to the R1820 fuel rate will allow the emission factors associated with the R1820 engine to be converted to the other radial engines by applying these ratios.

$$\frac{210 \text{ lb/hr}}{322.8 \text{ lb/hr}} = 0.6505 \text{ for R1340 engine}$$

$$\frac{168 \text{ lb/hr}}{322.8 \text{ lb/hr}} = 0.5204 \text{ for R985 engine}$$

Emission Factors for the R985, R1340, and R1820 engines

Engine	CO lb/hr	HC lb/hr	NOx lb/hr	PM lb/hr	SOx lb/hr
R1820	124.2	1.80	2.10	NA	NA
R1340	80.8	1.17	1.37	0.07	0.22
R985	64.6	0.94	1.09	0.06	0.18

The emission factors for PM and SOx are calculated separately. These PM emission factors were taken from aircraft with similar fuel consumption rates. The SOx emission factors were calculated based on the sulfur content in the aviation fuel. The SOx emission factor sample calculation follows this section.

The PT6A-34 emission factors are estimated based on the emission factors and maximum fuel use rate comparison of the PT6A-27 engine.

$$\frac{\text{maximum fuel rate for PT6A-34} = 446 \text{ lb/hr}}{\text{maximum fuel rate for PT6A-27} = 410 \text{ lb/hr}} = 1.088$$

The emission factors for the PT6A-34 are estimated by multiplying the ratio of 1.088 to the PT6A-27 emission factors. The results are in Table II.

Engine	CO lb/hr	HC lb/hr	NOx lb/hr	PM lb/hr	SOx lb/hr
PT6A-27	4.84	3.7	0.74	NA	NA
PT6A-34	5.30	4.0	0.81	0.08	1.31

The PM and SOx emission factors are calculated separately. The SOx emission factor calculations are shown in the next section of the sample calculations.

The Helicopter-piston engine is a 6-cylinder engine that compares to the Avco/Lycoming 0-320 4-cylinder engine with a 25% increase in emission factors.[7] The fuel use rates for the Helicopter-piston engine were estimated separately by San Joaquin Helicopter.[7] The results are in Table II.

The fuel use rate of the Helicopter-turbine OH-58 was estimated by San Joaquin Helicopter. The corresponding emission factors were developed by the EPA.[9]

Calculation of SOx Emission Factors

$$\text{SOx emissions} = \frac{(\text{fuel consumption})\times(\text{sulfur content})\times(\text{conversion factor})}{(\text{conversion factor})}$$

The sulfur content of aviation gasoline is 500 ppm maximum. The sulfur content of Jet Fuel A is 3000 ppm maximum.

The SOx emission factor of the R1340 engine follows:

$$0.22 \text{ lb/hr} = \frac{0.035(1000 \text{ gal/hr})\times 500\text{ppm} \times (525{,}000\times 2000)(\text{lb}/1000 \text{ gal})}{8.4 \times 10^{10}(\text{ppm})}$$

SOx emission factor= 0.22 lb/hr

Calculation of CO emissions for Fresno

The CO emission factor is a weighted average of the various aircraft engine CO emission factors. The weighted average of the CO emission factor (lb/hr) divided by the weighted average of the fuel consumption rate (lb/hr) and multiplied by 6090 which is the weighted average density multiplied by 1000 gallons.

(63.17lb/hr/182.73lb/hr)x6090lb/1000gal = 2105 lb/1000 gal

Converting the emission factor into tons CO/Acre:

((emission factor)/(acres/1000 gal))/2000 lb/ton

((2105 lbs/1000 gal)/(19,330 acres/1000 gal))
/2000 lb/ton

$= 5.44 \times 10^{-5}$ ton CO/acre

Using the PUR data for Fresno spraying by air application, the following is a calculation of CO emissions:

$$5.44 \times 10^{-5} \text{ton CO/acre} \times 4,366,364.6 \text{ acres} = 237.7 \text{ tons/yr}$$

The above calulations are repeated for each of the pollutants.

REFERENCES

1. California State Controller, Division of Tax Administration Collectionsand Refunds, <u>Analysis of Claims Approved for Refund by Industry 1989-1990 fiscal year.</u> Schedule III.

2. California Department of Food and Agriculture. <u>Pesticide Use Report</u>, (1988).

3. Air Resources Board, <u>1983 Methodology for Ag Aircraft.</u>

4. Personal communications with staff of Aero Engines in Los Angeles. (April 1991).

5. Personal communications with Norm B. Akesson, Project Director of Department of Health Services Contract Grant 85-00183, and Retired Professor of UC Davis.

6. Personal communication with Russel Stocker, B.S. Environmental Toxicology (April 1991)

7. Personal communication with Jim Josephson from San Joaquin Helicopter (805) 725-1898. (April 1991)

8. Personal communication with Mr. Eatock from Pratt & Whitney. (514) 647-7574 (April 1991)

9. EPA, Air Pollutant Emission Factors for Military and Civil Aircraft (EPA-450/3-78-117) October 1978.

10. EPA, AP-42, Compilation of Air Pollutant Emission Factors, Sec. II-1 (1985)

11. Personal communication with Ron Anderson from Chevron, Inc. (June 1991) (415) 620-2100

12. Personal communication with Rich Wilcox from EPA. (June 1991) (313)668-4390.

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TABLE - I

1990 AREA SOURCE EMISSIONS

ACTIVITY:AGRICULTURAL SERVICES
PROCESS:AIRCRAFT
ENTRAINMENT:GASOLINE-CMBSTN
DIMN:COMMERCIAL (AIRCRAFT)

CES: 47563

PROCESS RATE UNIT: 1000 GALLONS BURNED

AB	COUNTY	PROCESS RATE	TOG EMISSIONS (TONS/YEAR)	CO EMISSIONS (TONS/YEAR)	NOX EMISSIONS (TONS/YAER)	SOX EMISSIONS (TONS/YEAR)	PM EMISSIONS (TONS/YEAR)
GBV	ALPINE	0	.00	.00	.00	.00	.00
	INYO	0	.00	.00	.00	.00	.00
	MONO	0	.00	.00	.00	.00	.00
LC	LAKE	0	.00	.00	.00	.00	.00
LT	EL DORADO	0	.00	.00	.00	.00	.00
	PLACER	0	.00	.00	.00	.00	.00
MC	AMADOR	0	.00	.00	.00	.00	.00
	CALAVERAS	0	.00	.00	.00	.00	.00
	EL DORADO	0	.00	.10	.00	.00	.00
	MARIPOSA	0	.00	.00	.00	.00	.00
	NEVADA	0	.00	.00	.00	.00	.00
	PLACER	0	.00	.00	.00	.00	.00
	PLUMAS	0	.00	.20	.00	.00	.00
	SIERRA	0	.00	.00	.00	.00	.00
	TUOLUMNE	0	.00	.00	.00	.00	.00
NC	DEL NORTE	0	.00	.30	.00	.00	.00
	HUMBOLDT	0	.00	.30	.00	.00	.00
	MENDOCINO	0	.00	.20	.00	.00	.00
	SONOMA	0	.00	.00	.00	.00	.00
	TRINITY	0	.00	.00	.00	.00	.00
NCC	MONTEREY	51	1.10	53.50	.90	.20	.10
	SAN BENITO	2	.00	1.90	.00	.00	.00
	SANTA CRUZ	2	.00	1.60	.00	.00	.00
NEP	LASSEN	0	.00	.30	.00	.00	.00
	MODOC	3	.10	3.60	.10	.00	.00
	SISKIYOU	3	.10	3.40	.10	.00	.00
SC	LOS ANGELES	0	.00	.50	.00	.00	.00
	ORANGE	0	.00	.10	.00	.00	.00
	RIVERSIDE	15	.30	15.80	.30	.10	.00
	SAN BERNARDINO	1	.00	1.30	.00	.00	.00
SCC	SAN LUIS OBISPO	6	.00	6.20	.10	.00	.00
	SANTA BARBARA	7	.20	7.50	.10	.00	.00
	VENTURA	8	.20	8.30	.10	.00	.00
SD	SAN DIEGO	1	.00	.70	.00	.00	.00
SED	IMPERIAL	160	3.40	167.80	2.80	.70	.20
	KERN	11	.20	11.60	.20	.10	.00
	LOS ANGELES	1	.00	.90	.00	.00	.00
	RIVERSIDE	25	.50	26.10	.40	.10	.00
	SAN BERNARDINO	0	.00	.40	.00	.00	.00
SJV	FRESNO	226	4.80	237.50	3.90	1.10	.20
	KERN	103	2.20	108.70	1.80	.50	.10
	KINGS	120	2.60	126.60	2.10	.60	.10
	MADERA	22	.50	23.20	.40	.10	.00
	MERCED	41	.90	43.50	.70	.20	.00
	SAN JOAQUIN	32	.70	33.90	.60	.20	.00
	STANISLAUS	20	.40	20.80	.30	.10	.00
	TULARE	43	.90	45.20	.80	.20	.00
SV	BUTTE	21	.50	22.30	.40	.10	.00
	COLUSA	30	.70	32.00	.50	.10	.00
	GLENN	20	.40	21.20	.40	.10	.00
	PLACER	2	.00	2.10	.00	.00	.00
	SACRAMENTO	8	.20	8.40	.10	.00	.00
	SHASTA	0	.00	.40	.00	.00	.00
	SOLANO	2	.00	2.00	.00	.00	.00
	SUTTER	26	.60	27.00	.50	.10	.00
	TEHAMA	2	.10	2.40	.00	.00	.00
	YOLO	25	.50	26.80	.40	.10	.00
	YUBA	6	.10	6.70	.10	.00	.00
	TOTAL* FOR 47563	1045	22.20	1,103.30	18.10	4.70	.70

FRACTION OF REACTIVE ORGANIC GASES (FROG): .9676

(REACTIVE ORGANIC GASES (ROG) EMISSIONS = TOG X FROG)

FRACTION OF PM10 (FRPM10): .9940

(PM10 EMISSIONS = PM X FRPM10)