CHAPTER 6

FUTURE RESEARCH

6.1 Introduction

Improvement of urban air quality by deliberate control of emission sources requires a thorough understanding of the phenomena associated with air pollution. It has been the objective of this work to further this knowledge, specifically for atmospheric fine aerosol carbon, by characterizing the existing pollution levels, and by developing methods that can be used by engineers to design aerosol carbon abatement programs. In the course of this work, a number of questions requiring further study have been identified. In this chapter, suggestions for future research into the behavior of atmospheric carbon particle air pollution are outlined.

6.2 Air Quality Observations

In Chapter 2, it was concluded that primary emissions are responsible for the majority of long-term average carbon particle concentrations in the Los Angeles area during 1982. The formation of secondary aerosol carbon in the atmosphere is expected to occur, and the reasons for not finding an obvious enrichment in organic aerosol relative to elemental carbon during summer months needs to be investigated further. The ambient aerosol monitoring program executed as part of this study involved collection of 24-hour average filter
samples. Further insight into the importance of secondary formation of particulate carbon may be gained by contrasting these long-term average results with the conditions present during summer months in the middle of the day, when photochemical reactions are expected to be at their peak. Examination of the ratio of fine total carbon to fine elemental carbon for a number of summer mid-day events would help one to determine the extent to which secondary formation is occurring under photochemical smog episode conditions.

A more complete identification of the organic compounds present in atmospheric aerosols would aid in the understanding of pathways of secondary particulate matter formation. The extent to which secondary aerosol formation is occurring in the atmosphere could be better quantified, and information regarding the nature of toxic materials in the atmosphere would be enhanced, if aerosol samples representing a full annual cycle were analyzed for the details of the individual organic compound present. During the course of the air quality monitoring program described in Chapter 2, a quartz fiber filter was included in the sampling protocol that was intended to be reserved for organic compound identification. Detailed speciation of the organic material present on these filters may be achieved using high-resolution gas chromatography (GC) and high-resolution gas chromatography/mass spectrometry (GCMS) techniques. This work is in progress at present (Mazurek, 1985).
6.3 Air Quality Model Application

The air quality model described in Chapter 3 was used to predict long-term average fine primary carbon particle concentrations in the Los Angeles area during 1982. The computation of horizontal advective transport was based on a uniform wind field generated from data of a single wind monitoring location. The accuracy of the model predictions of fine primary carbon particle concentrations may be improved by employing a more sophisticated two-dimensional wind field. A considerable effort would then be required to gather more wind data and to generate continuous wind fields for every hour of the modeling period. In addition, the computer time required for computation will be greatly increased.

Further improvements of the air quality model application include reducing the size of the receptor grid cells which would provide a greater spatial resolution of model predictions. It would then be necessary to compile a more detailed spatially-resolved emissions inventory which matches the new receptor grid.

The model was designed to simulate the emission and transport of primary carbonaceous aerosol. A topic for future study would involve incorporating into the model an explicit secondary aerosol formation calculation. This would require a comprehensive knowledge of the physical and chemical kinetic mechanisms for organic aerosol formation. Also more detailed hydrocarbon emissions information would need to be compiled.
The modeling technique developed during this study has been shown to accurately simulate the long-term behavior of the transport of fine primary carbonaceous aerosol in the Los Angeles area. It would not be difficult to employ this model to simulate the transport of primary pollutants in other cities as well. The specific meteorological conditions in other urban air basins would have to be assessed to determine whether the assumptions built into the model are consistent with the nature of transport in that air basin. The model accounts for different physical processes independently of each other, so that it is possible to modify the computation of a single process without destroying the integrity of the model.

6.4 Emission Control Strategies

In Chapter 5, strategies for atmospheric carbon particle control were evaluated. Many of the control measures have implications regarding the control of other aerosol pollutant species as well. Local control agencies are faced with the problem of controlling a variety of pollutants. It would be desirable to incorporate source to receptor information for many aerosol species to design a control strategy for simultaneously reducing concentrations of sulfates, nitrates, carbonaceous species, and other toxic species which are present in urban atmospheres. A difficulty encountered in a multi-attribute control program is in assigning a weight to each species present regarding its detriment to the environment. Assumptions about the trade-offs between toxicity, overall mass
burden, and visibility degradation must be made to determine the effectiveness of a proposed control strategy.

Results from an air quality model which accounts for secondary aerosol formation could be used to evaluate control strategies for the abatement of secondary carbonaceous aerosol concentrations in the atmosphere. However, then a non-linear programming approach would be required. A further improvement to the control strategy optimization technique would involve the use of an integer program which would inhibit the selection of fractions of control measures when such a choice is infeasible.

Application of the linear programming technique presented in Chapter 5 demonstrates the usefulness of the air quality model for designing aerosol carbon pollution abatement strategies. More detailed information on the costs and emission reduction capabilities of control technologies is needed. In the future, when more complete information concerning control technologies is available, the air quality model results from this study may be directly applied to the optimization of a strategy for control of a number of primary pollutants, including fine primary carbon particles, in the Los Angeles area.

6.5 Conclusions

In this chapter, avenues for future research have been discussed. Scientific investigations into the phenomena of atmospheric processes will improve the capabilities of the air quality
model. Application of the model to evaluation of emission control programs promises to contribute toward the improvement of urban air quality.
6.6 References for Chapter 6

APPENDIX A

1982 EMISSIONS ESTIMATES IN THE 50×50-MILE MODELING GRID
<table>
<thead>
<tr>
<th>MOBILE SOURCES</th>
<th>Estimated 1982 Fuel Use (10^7 Btu/day)</th>
<th>Estimated 1982 Thous. VMT/day (kg/10^7 Btu) (gm/mile)</th>
<th>Total Particulate Emissions (kg/day)</th>
<th>Total Particulate Mass Fraction (&lt; 2.1 μm)</th>
<th>Fine Particulate (kg/day)</th>
<th>%Total Carbon in (&lt; 2.1 μm) Fraction (kg)</th>
<th>Fine Organic Carbon</th>
<th>Volatile Non-volatile Carbon</th>
<th>Partition of Carbon</th>
<th>Fine Organic Elemental Carbon (kg/day)</th>
<th>Fine Elemental Carbon (kg/day)</th>
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<tr>
<td><strong>Highway Vehicles</strong></td>
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<td>Catalyst Autos</td>
<td>515.2(a)</td>
<td>86986(a)</td>
<td>0.016(k)</td>
<td>1391.9</td>
<td>86% (v)</td>
<td>1197.1</td>
<td>39% (ff)</td>
<td>466.9</td>
<td>55%</td>
<td>45% (ff)</td>
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<td>305.6(a)</td>
<td>33285(a)</td>
<td>0.32 (l)</td>
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<td>36.4% (e)</td>
<td>3888.7</td>
<td>76.4% (w)</td>
<td>2971.0</td>
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<td>2494(a)</td>
<td>0.48 (m)</td>
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<td>93% (x)</td>
<td>1133.3</td>
<td>83.7% (gg)</td>
<td>931.9</td>
<td>23.4%</td>
<td>76.6% (gg)</td>
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<td>124.8</td>
<td>93% (bb)</td>
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<td>23.4%</td>
<td>76.6% (bb)</td>
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<td>Non-catalyst Light Trucks</td>
<td>57.0(a)</td>
<td>4560(a)</td>
<td>0.46 (o)</td>
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<td>92% (ae)</td>
<td>152.2</td>
<td>83.7% (ii)</td>
<td>227.4</td>
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<td>141.7</td>
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<td>Catalyst Medium Trucks</td>
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<td>4993(a)</td>
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<td>86% (y)</td>
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<td>86% (bb)</td>
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<td>Gasoline Heavy Trucks</td>
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<td>3050(a)</td>
<td>0.77 (r)</td>
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<td>141.7</td>
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<td>Diesel Heavy Trucks</td>
<td>147.4(a)</td>
<td>5857(a)</td>
<td>1.39 (s)</td>
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<td>86% (y)</td>
<td>141.7</td>
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<td>1.6(a)</td>
<td>(c)</td>
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<td>(c)</td>
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<td>Jet Aircraft</td>
<td>47.0(a)</td>
<td>(c)</td>
<td>410.5(c)</td>
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<td>56% (bb)</td>
<td>394.1</td>
<td>13.4% (j)</td>
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<td>Aviation Gas</td>
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<td>(c)</td>
<td>43.0(c)</td>
<td>86.5% (c)</td>
<td>86.5% (c)</td>
<td>13.5% (c)</td>
<td>394.1</td>
<td>13.4% (j)</td>
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<td>Residual Oil-fired Ships</td>
<td>11.9(d)</td>
<td>85.50(b)</td>
<td>1017.5</td>
<td>72% (dd)</td>
<td>72% (dd)</td>
<td>72.6</td>
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<td>93% (ee)</td>
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<tr>
<td>Off Highway Diesel Vehicles</td>
<td>25.7(f)</td>
<td>78.67(f)</td>
<td>2024.1</td>
<td>93% (ee)</td>
<td>93% (ee)</td>
<td>1882.4</td>
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<td>Off Highway Gasoline Vehicles</td>
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<td>(g)</td>
<td>295.3(g)</td>
<td>36.4% (cc)</td>
<td>36.4% (cc)</td>
<td>107.3</td>
<td>76.4% (cc)</td>
<td>82.1</td>
<td>23.4%</td>
<td>76.4% (cc)</td>
<td>64.6</td>
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<td><strong>TOTAL MOBILE SOURCES</strong></td>
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</table>

Note: The table provides emissions estimates for mobile sources in the 50x50-mile grid, categorized by type of vehicle and other factors, including fuel use, emissions, and carbon partitioning.
Notes for Table A.1

(a) See Table A.6. Vehicle miles travelled (VMT) are computed for each vehicle type from traffic count data. Fuel use is then computed from mileage for each vehicle type, employing fuel economies from Table A.5.

(b) Based on fuel sales data for California from the Energy Information Administration (1983); see Appendix B, Table B.6.

(c) Average daily fuel use and particulate emissions at commercial airports were obtained from Federal Aviation Administration (1981) air traffic data plus U.S. Environmental Protection Agency (1982, section 3.2.1) calculation procedure.

(d) Based on procedure by Cass (1977).

(e) Consumption of fuel oil sold to railroads is assumed to be proportional to track mileage. Railroad track mileage in the 50X50-mile grid was measured on United States Geological Survey 7.5' minute topographic maps and was estimated to be 1047.9 miles. Track mileage in the state of California of 8446 miles was obtained from the Federal Railway Administration as reported by Cass (1977, p. 628). Fuel sales data from the Energy Information Administration (1983) indicate that 7138 thousand barrels of distillate fuel oil were used by railroads in the state of California in 1982; see Appendix B, Table B.6. The grid contains 12.4% of the track mileage in the state; therefore, the fuel use in the grid is estimated to be 7138 X 12.4% = 885.6 (1000 bbls/yr) or 14.1 X 10^9 Btu/day.

(f) Total particulate emissions from off-highway diesels is 2024.1 kg/day in the 50X50-mile grid from the California Air Resources Board 1982 inventory of area source emissions (Ranzieri 1983). Using the particulate emissions factor of 24 lb/10^9 gal or 78.67 kg/10^9 Btu, the fuel use is estimated to be 25.7 X 10^9 Btu/day.

(g) Total particulate emissions from off-highway gasoline consumption in the 50X50-mile grid from the California Air Resources Board 1982 inventory of area source emissions (Ranzieri 1983). No information is available on the fuel use.

(h) Industrial boiler emission factor of 21.64 kg/10^9 Btu at 0.4% sulfur in fuel was scaled up to 85.50 kg/10^9 Btu at 1.58% sulfur in bunker fuel based on evidence of Taback et al. (1979) that shows that the particulate emissions rate from residual oil-fired boilers is roughly proportional to the fuel oil sulfur content.
(i) U.S. Environmental Protection Agency (1982, Table 3.2.3–2) gives 15 lb/10^3 gal or 49.17 kg/10^9 Btu.

(j) U.S. Environmental Protection Agency (1982, Table 3.2.2–1) gives 25 lb/10^3 gal or 81.95 kg/10^9 Btu.

(k) Laresgoiti and Springer (1977), at 0.3% sulfur in unleaded gasoline, obtained 0.016 g/mile for oxidation catalyst car; Muhlbaier and Williams (1982) reported a similar emissions factor (0.014 g/mile); and Schuetzle (1983, Table 8) reported a weighted average of many published data for particulate emissions from catalyst automobiles (0.017 g/mile).

(l) 0.32 g/mile from Habibi (1973, Table VIII) (lead fuel cars) adjusted downward to 0.0402 g/mile lead emitted. Total particulate emissions is computed only to complete the table; fine carbon emissions are calculated independently. See note (w), below.

(m) Pierson (1979) cites numerous researchers on the particulate emission rate from a light-duty diesel and reports a value of about 300 mg/km (or 0.48 g/mile). Many other researchers (Schuetzle 1983; Hyde et al. 1983; Gabele et al. 1982; Gibbs, Hyde, and Byer 1980; Williams and Chock 1980) have found similar emission rates ranging from 0.36 to 0.89 g/mile for light-duty diesel automobiles.

(n) Assuming the same particulate emission rate per gallon of fuel burned as light-duty catalyst automobiles. The weighted average fuel economy is 0.0474 gal/mile for catalyst autos and 0.0647 gal/mile for light trucks; see Table A.6. Scaling upward from the emission rate of 0.016 g/mile for catalyst autos (see note [k], above), this gives 0.022 g/mile (0.016 g/mile / 0.0474 gal/mile = 0.338 g/gal; 0.338 g/gal X 0.0647 gal/mile = 0.022 g/mile).

(o) Assuming the same particulate emission rate per gallon of fuel burned as light-duty non-catalyst automobiles. The weighted average fuel economy is 0.0733 gal/mile for non-catalyst autos and 0.1000 gal/mile for non-catalyst light trucks; see Table A.6. Scaling upward from the emission rate of 0.032 g/mile for non-catalyst autos (see note [l], above), this gives 0.44 g/mile (0.32 g/mile / 0.0733 gal/mile = 4.37 g/gal; 4.37 g/gal X 0.1000 gal/mile = 0.44 g/mile).

(p) Assuming the same particulate emission rate per gallon of fuel burned as light-duty catalyst automobiles and trucks (0.338 g/gal); see note (n), above. The weighted average fuel per mileage for catalyst medium trucks is 0.0943 gal/mile; see Table A.6. This gives 0.032 g/mile (0.338 g/gal X 0.0943 gal/mile).
(q) Assuming the same particulate emission rate per gallon of fuel burned as light-duty non-catalyst automobiles and trucks (4.37 g/gal); see note (o), above. The weighted average fuel per mileage for non-catalyst medium trucks is 0.0943 gal/mile; see Table A.6. This gives 0.41 g/mile (4.37 g/gal × 0.0943 gal/mile).

(r) Assuming the same particulate emission rate per gallon of fuel burned as other leaded gasoline (non-catalyst) autos and trucks (4.37 g/gal); see note (o), above. The weighted average fuel per mileage for gasoline (non-catalyst) heavy trucks is 0.1754 gal/mile; see Table A.6. This gives 0.77 g/mile (4.37 g/gal × 0.1754 gal/mile). Tests done by Dietzman, as reported in Lang et al. (1982), give a range of 0.58–0.89 g/mile. U.S. Environmental Protection Agency (1982, Table 3.1.4–13) gives a value of 0.91 g/mile.

(s) Pierson and Brachaczek (1983, Table 2) give 865 ± 161 mg/km (or 1.39 ± 0.26 g/mile). U.S. Environmental Protection Agency (1982, Table 3.1.5–1) gives 1.3 g/mile; and Baines, Somers, and Harvey (1979) report a Los Angeles diesel usage emission factor of 0.83 g/km (or 1.34 g/mile).

(t) U.S. Environmental Protection Agency (1982, pp. 3.1.7–1 and 3.1.7–2) report that 38% of the motorcycles in use have two-stroke engines emitting 0.33 g/mile and 62% have four-stroke engines which emit 0.046 g/mile. The weighted average is 0.15 g/mile.

(u) Total particulate emissions from LPG use for carburetion is 1.6 kg/day from the California Air Resources Board 1982 inventory of area source emissions (Ranzieri 1983). This source is very small and is hereafter neglected.

(v) Watson (1979, p. 100).

(w) The fine particle emission factor from leaded fuel auto fleet was assembled as follows: average lead content in 1982 was 0.82 g/gal (Shelton 1982–1983; 1/4 winter 1981–1982, 1/2 summer 1982, 1/4 winter 1982–1983). At 13.7 miles/gal (see Table A.5), lead consumption is 0.06 g/mile. From Huntzicker, Friedlander, and Davidson (1975), 70.5% of lead consumed in gasoline in Los Angeles is emitted as aerosol and 19% of aerosol lead emitted is in sizes less than 1 μm, giving 8.0 mg/mile fine aerosol lead or 13.5 mg/mile fine lead salts as 2PbBrCl·NH₄Cl. The emissions rate of particulate carbon for pre-catalyst autos burning leaded gasoline at low altitude is 89.0 mg/mile, from Gorse (1984). (Inference from Pierson and Brachaczek [1983, Table 2], gives 94.6 mg/mile, consistent with the emission rate from Gorse [1984].) Aerosol carbon is assumed to be concentrated in the
fine particle fraction of the auto exhaust. Fine elemental carbon emissions are estimated to be 19.0 mg/mile by applying an elemental/total carbon factor of 21.3%, which is an average of results from four researchers: Johnson et al. (1981) (8%), Muhlbaijer and Williams (1982) (26.5%), Gorse (1984) (37%—known to be overestimated by as much as a factor of 2), and Watson (1979) (13.8%). Organic carbon remaining is (89.0 mg/mile - 19.0 mg/mile) = 70.0 mg/mile which becomes about 84.0 mg/mile as organic material. Total auto fine particle emissions become 116.5 mg/mile (13.5 mg/mile lead salts, 19.0 mg/mile elemental carbon, 84.0 mg/mile organic material). This fine aerosol is about 36.4% of the total aerosol emission factor (i.e., 0.1165/0.32 = 0.364). The fraction of the fine aerosol which is carbon is therefore 76.4% (i.e., 89.0/116.5).

(x) Taback et al. (1979, table p. A-5).

(y) Assumed size distribution similar to catalyst autos (unleaded gasoline); see note (v).

(z) Other non-catalyst (leaded gasoline) vehicles assumed to have the same size distribution and chemical composition as leaded auto exhaust; see note (w).

(aa) Assumed size distribution similar to diesel autos; see note (x).


(cc) Assumed similar to leaded auto exhaust; see note (w).

(dd) Assumed similar to industrial boilers burning residual oil (Taback et al. 1979, table p. A-3).

(ee) Assumed size distribution similar to heavy-duty diesel highway vehicles; see notes (aa) and (x).

(ff) Muhlbaijer and Williams (1982) report that catalyst equipped cars at low elevation emit aerosol with the following properties: total mass 14 mg/mile, organic carbon 3.0 mg/mile, elemental carbon 2.5 mg/mile.

(gg) Average of nine source tests performed on light-duty diesels by Japar et al. (1984, Table I) (FTP runs only; carbon determination by thermal-optical method of Johnson et al. [1981], with pyrolysis correction). The value of 83.7% carbon is in excellent agreement with the results of Pierson and Brachaczek (1983) for the 1977 Tuscarora Tunnel experiment which yielded 83.8% carbon for heavy-duty diesel trucks. The organic/elemental carbon ratio (23.4/76.6) is also in good agreement with both Pierson and Brachaczek (1983) (29./71.) and Johnson et al. (1981) (27./73.).
(hh) Assumed chemical composition similar to catalyst autos (unleaded gasoline); see note (ff).

(ii) Assumed chemical composition similar to diesel autos; see note (gg).

(jj) Jet aircraft emissions measured in this manner are all "soot" (Heywood, Fay, and Linden 1971); assume chemical composition looks like diesel soot (Flagan 1980).

(kk) Johnson et al. (1981).
## Table A.2

### Emissions Estimates for Stationary Combustion Sources in 30x30-mile grid

<table>
<thead>
<tr>
<th>Source Type</th>
<th>Estimated 1982 Fuel Use (10^8 Btu/day)</th>
<th>Total Particulate Emissions (kg/10^9 Btu)</th>
<th>Total Particulate Emissions (kg/day)</th>
<th>Mass Fraction (2.1 μm)</th>
<th>Fine Total Particulate (kg/day)</th>
<th>%Total Carbon in &lt; 2.1 μm Fraction</th>
<th>Fine Total Carbon in &lt; 2.1 μm</th>
<th>Partition of Carbon</th>
<th>Organic Carbon (kg/day)</th>
<th>Elemental Carbon (kg/day)</th>
</tr>
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<td>6.3</td>
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<td>601.6</td>
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<td>550.8</td>
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<td>96.4</td>
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<td>62% (oo)</td>
<td>100.8</td>
<td>96% (qq)</td>
<td>96.7</td>
<td>78%</td>
<td>22% (xx)</td>
<td>75.5</td>
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</table>

**TOTAL FUEL COMBUSTION**

| 1678.2                              | 1276.3                                  | 402.0                                  |
Notes for Table A.2

(a) See Appendix B, except for stationary gasoline and distillate internal combustion engines; see notes (m) and (n).

(b) Danielson and Graves (1976, p. 77); 0.015 lb/equivalent bbl (1.08 kg/10^9 Btu) from Los Angeles tests.

(c) U.S. Environmental Protection Agency (1982, Table 3.3.1-2) gives 14 lb/10^6 ft^3 or 5.99 kg/10^9 Btu.

(d) Taback et al. (1979, pp. 2-9); 3 lb/1000 gal (9.09 kg/10^9 Btu) used for 0.25% sulfur oil.

(e) U.S. Environmental Protection Agency (1982, Table 3.3.1-2) gives 5 lb/10^3 gal or 16.35 kg/10^9 Btu.

(f) Electric utility boiler natural gas combustion emission factor used; see note (b).

(g) Danielson and Graves (1976, p. 77); 0.126 lb/equivalent bbl (9.07 kg/10^9 Btu).

(h) Danielson and Graves (1976, p. 77); 0.30 lb/equivalent bbl (21.64 kg/10^9 Btu) for combustion of industrial residual fuel oil.

(i) Danielson and Graves (1976, p. 77); 0.105 lb/equivalent bbl (7.56 kg/10^9 Btu). LPG combustion is assumed to emit at the same rate as industrial natural gas combustion on an equivalent heat input basis. This is the same assumption as made by the U.S. Environmental Protection Agency (1982, Table 1.5-1) except that the natural gas emission factor of Danielson and Graves (n.d.) is lower.

(j) Taback et al. (1979, Table 2-1), KVB data, 7.2 lb/10^3 gal (23.55 kg/10^9 Btu).

(k) Average of two tests by Taback et al. (1979, p. 4-100) performed on digester gas-fired IC engine; 0.045 lb/10^6 Btu (20.41 kg/10^9 Btu).

(l) Assumed similar to industrial natural gas combustion on an equivalent heat input basis.

(m) Fuel use is derived from total particulate emissions (106.6 kg/day) which is from the Air Resources Board of California inventory of industrial point and area source emissions (Ranzieri 1983). U.S. Environmental Protection Agency (1982, Table 3.3.3-1) gives 6.47 lb/10^3 gal or 23.49 kg/10^9 Btu.
(n) Fuel use is derived from total particulate emissions (596.0 kg/day) which is from the Air Resources Board of California inventory of industrial point and area source emissions (Ranzieri 1983). U.S. Enviromental Protection Agency (1982, Table 3.3.3-1) gives 33.5 lb/10^3 gal or 109.81 kg/10^9 Btu.

(o) Danielson and Graves (1976, p. 77); 0.112 lb/equivalent bbl (8.06 kg/10^9 Btu).

(p) Assumed same as residential natural gas on an equivalent heat input basis. This is the same assumption as made by the U.S. Environmental Protection Agency (1982, Table 1.5-1) except that the natural gas emission factor of Danielson and Graves (n.d.) is lower.

(q) Assumed same as industrial boiler burning residual fuel oil; see note (h).

(r) U.S. Environmental Protection Agency (1982, Table 1.1-2), assuming hand-fired stove use, 20 lb/ton coal (378.0 kg/10^9 Btu).

(s) Assumed similar to size distribution from large refinery heaters burning natural gas; see note (v).

(t) Taback et al. (1979, table p. A-8).

(u) Assumed similar to size distribution from industrial boiler burning distillate oil; see note (y).


(w) Assumed similar to size distribution from industrial boiler burning residual fuel oil; see note (x).

(x) Taback et al. (1979, table p. A-3).

(y) Taback et al. (1979, table p. A-4).

(z) Taback et al. (1979, table p. 4-99).

(aa) Taback et al. (1979, table p. A-6).


(cc) Assumed similar to fireplace wood combustion profile from Watson (1979). Possibly a poor assumption, but data on fireplace coal combustion are lacking.
(dd) Assumed based on refinery heater test by Taback et al. (1979); see note (gg). Electric utility source test by Manfredi and Mansour (1975) showed that particulate matter emitted from LADWP Scattergood Unit 3 when burning natural gas consisted mostly of Fe, Na, Si, and Ca compounds. Mansour (n.d.) confirms that power plant samples when burning gas during that test were not dark in color.

(ee) Taback et al. (1979, table p. A-8).

(ff) Assumed similar to industrial boiler burning distillate oil; see note (kk).


(hh) Assumed similar to refinery heaters burning natural gas; see note (gg).

(ii) Assumed similar to industrial boiler burning residual fuel oil; see note (jj).

(jj) Taback et al. (1979, table p. A-3).

(kk) Taback et al. (1979, table p. A-4).

(ll) Taback et al. (1979, table 4-36, p. 4-101); average of impinger catches.

(mm) Taback et al. (1979, table p. A-6).


(oo) Muhlbauer and Williams (1982) report that 12% of aerosol mass is carbon from ten samples taken downstream of a small furnace. Note that the overall emission factor for carbonaceous aerosol from domestic natural gas combustion becomes $$(8.06 \text{ kg/10}^7 \text{ Btu} \times 0.12) = 0.97 \text{ kg C/10}^7 \text{ Btu} = 0.97 \mu \text{g C/Btu}.$$ Source tests by Hansen, Benner, and Novakov (1978) show that domestic natural gas combustion sources emit carbon at a rate of between 0.2 to 2.5 \mu g C/Btu, in good agreement with the emission rate used in this study.

(pp) Assumed similar to residential natural gas combustion; see note (oo).

(qq) No data are available on carbon mass as a fraction of fine particle mass emissions from coal combustion in fireplaces; therefore, an extreme upper limit has been used.
(rr) Assumed similar to large refinery heaters burning natural gas; see note (uu).

(ss) Johnson et al. (1981) for residual fuel oil combustion with pyrolysis correction.

(tt) Johnson et al. (1981) for distillate fuel oil combustion with pyrolysis correction.

(uu) Taback et al. (1979, table p. A-29). All carbon collected during source test was volatile.

(vv) Taback et al. (1979, table p. A-5). Volatile carbon collected during source test was less than 0.1% of total carbon.

(ww) Muhlbaier and Williams (1982) report that two-thirds of the carbon found on ten samples taken downstream of a small furnace was present as organics.

(xx) Chemical composition of carbon present is based on volatile organic to non-volatile carbon ratio for fine particles from fireplace combustion of wood given by Watson (1979). Assumptions made for this source class are poor, but the source class is very small.
Table A.3
Emissions Estimates for Industrial Processes
in 30X30-mile grid

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<th></th>
<th>Total Emissions (kg/day)</th>
<th>Mass Fraction (kg/day)</th>
<th>Fine Suspended Particulate &lt; 2.1 µm (kg/day)</th>
<th>% Total Carbon in Fine Suspended Particulate</th>
<th>Fine Total Carbon (kg/day)</th>
<th>Partition of Carbon</th>
<th>Fine Organic Carbon (kg/day)</th>
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<td>335.2</td>
<td>(83%) (q)</td>
<td>278.2</td>
<td>100%</td>
<td>0% (q)</td>
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<td>100%</td>
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<td>25.6% (j)</td>
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<td>223.8</td>
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<td>70% (k)</td>
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<td>96%</td>
<td>4% (n)</td>
<td>80.8</td>
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<td>2.2</td>
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<td>1.8</td>
<td>100%</td>
<td>0% (q)</td>
<td>1.8</td>
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<td>35.7</td>
<td>100%</td>
<td>0% (q)</td>
<td>35.7</td>
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<td>7.2% (p)</td>
<td>393.4</td>
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Notes for Table A.3

(a) Total particulate emissions data are from the Air Resources Board of California inventory of industrial point and area source emissions (Ranzieri 1983).

(b) Based on FCC unit CO boiler profile from Taback et al. (1979, table p. A-30).

(c) Assumed to be all fine, < 2.1 μm.

(d) Based on paint spray booth profile (oil-based paint) from Taback et al. (1979, table p. A-24).

(e) Based on urea manufacturing profile as a typical organic chemical product; Taback et al. (1979, table p. A-26).

(f) Assumed similar to size distribution for organic chemical manufacturing; see note (e).

(g) The total particulate matter from primary metallurgical production is from many sources. Size distribution and chemical profile data are available from Taback et al. (1979, tables pp. A-14, A-15, and A-33) for steel sinter operations, open hearth furnace, and basic oxygen furnace. Additionally, coke oven volatiles are assumed to be < 2.1 μm organics. These four sources account for 43% of the total particulate emissions from primary metals production. Data used in this table represent a composite of these four profiles, in proportion to the contribution of each source to the total particulate emissions in the SCAB (32.0% sinter plant profile, 3.6% open hearth furnace profile, 12.8% basic oxygen furnace profile, and 51.6% coke oven volatiles).

(h) Based on aluminum foundry profile from Taback et al. (1979, table p. A-13).

(i) Based on steel abrasive blasting profile from Taback et al. (1979, table p. A-12). Total carbon collected during source test was reported to be less than 0.1% of fine particulate matter.

(j) Profiles are available from Taback et al. (1979) for eight processes which account for 30.5% of the total particulate emissions from mineral processes; calcination of gypsum (p. A-16), brick grinding and screening (p. A-17), cement production (p. A-18), glass melting furnace (p. A-19), rock crushers (p. A-35), rock screening (p. A-36), asphaltic concrete batch plant (p. A-22), and fiberglass forming line (p. A-20). Data used in this table represent a composite of these eight profiles, in
proportion to the contribution of each source to the total particulate emissions in the SCAB (2.7% gypsum, 18.3% brick grinding, 36.8% cement, 17.5% glass, 7.9% rock crushers, 0.4% rock screening, 10.6% asphalt batch plant, and 5.8% fiberglass).

(k) Based on wood waste boiler profile from Taback et al. (1979, table p. A-7). These emissions are probably from special purpose permitted incinerators for which local source test data on chemical composition are lacking.

(l) Based on an average of wood resawing and wood sanding operations from Taback et al. (1979, tables pp. A-26 and A-28).

(m) Based on feed and grain operations profile from Taback et al. (1979, table p. A-31). Source category actually includes emissions from wool and cotton fabrications, meat packing, rendering, cooking, etc. All carbon present is assumed to be organic carbon.

(n) Taback et al. (1979, table p. A-21).

(o) Size distribution data are not available for particulate emissions from fabric production. It is assumed that almost all particles emitted are larger than 2.1 μm.

(p) No data; value assumed to be the average of all other industrial process point sources listed above (in the SCAB; see Appendix C, Table C.3).


(r) Petroleum coke is 89.2% carbon and 10.4% volatile material, based on proprietary information from a Long Beach area coke supplier. Similar results may be found in Kerr McGee Corporation (1982). The volatile (organic material) is removed during the calcining process, leaving the remaining 89.6% of the mass to be emitted to the atmosphere as fine particulate matter. The 10.4% of petroleum coke, which is organic material, becomes about 8.7% as carbon; therefore, the elemental carbon fraction of the coke is 89.2 - 8.7 = 80.5%. The carbon fraction of the emissions is then 80.5/89.6 = 89.8% (all elemental carbon).
Table A.4
Emissions Estimates for Fugitive Sources
in 50X50-mile grid

<table>
<thead>
<tr>
<th>Fugitive Sources</th>
<th>Total Particulate Emissions (kg/day)</th>
<th>Mass Fraction &lt; 2.1 μm</th>
<th>Fine Particulate (kg/day)</th>
<th>% Total Carbon in &lt; 2.1 μm Fraction</th>
<th>% Total Carbon % OC</th>
<th>Fine Volatile Carbon % EC</th>
<th>Fine Non-volatile Carbon % EC</th>
<th>Fine Organic Carbon (kg/day)</th>
<th>Fine Elemental Carbon (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road and Building Construction</td>
<td>6906.2 (a)</td>
<td>32% (g)</td>
<td>21410.0</td>
<td>0% (g)</td>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Agricultural Tilling</td>
<td>2737.7 (a)</td>
<td>30.5% (b)</td>
<td>831.9</td>
<td>0% (b)</td>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Livestock Feedlots</td>
<td>1886.1 (a)</td>
<td>54% (l)</td>
<td>1018.5</td>
<td>2% (l)</td>
<td>20.4</td>
<td>100%</td>
<td>0% (l)</td>
<td>20.4</td>
<td>0</td>
</tr>
<tr>
<td>Unpaved Road Dust</td>
<td>4039.6 (a)</td>
<td>24% (j)</td>
<td>969.5</td>
<td>0% (j)</td>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Paved Road Dust</td>
<td>12970.5 (a)</td>
<td>27% (k)</td>
<td>35020.4</td>
<td>12.1% (k)</td>
<td>5288.1</td>
<td>96.7%</td>
<td>3.3% (k)</td>
<td>5113.6</td>
<td>174.5</td>
</tr>
<tr>
<td>Tire Attrition</td>
<td>4064.1 (b)</td>
<td>25% (l)</td>
<td>1151.0</td>
<td>8% (l)</td>
<td>1001.4</td>
<td>67%</td>
<td>33% (l)</td>
<td>680.9</td>
<td>330.5</td>
</tr>
<tr>
<td>Brake Lining Attrition</td>
<td>6445.7 (c)</td>
<td>100% (m)</td>
<td>6445.7</td>
<td>20% (m)</td>
<td>1804.8</td>
<td>82%</td>
<td>18% (m)</td>
<td>1479.9</td>
<td>324.9</td>
</tr>
<tr>
<td>Forest Fires (seasonal)</td>
<td>1722.3 (a)</td>
<td>86% (o)</td>
<td>1481.1</td>
<td>63% (o)</td>
<td>933.1</td>
<td>94%</td>
<td>6% (o)</td>
<td>977.1</td>
<td>56.0</td>
</tr>
<tr>
<td>Structural Fires</td>
<td>357.5 (a)</td>
<td>86.5% (o)</td>
<td>309.2</td>
<td>30% (o)</td>
<td>92.8</td>
<td>60%</td>
<td>32% (o)</td>
<td>63.1</td>
<td>29.7</td>
</tr>
<tr>
<td>Fireplaces</td>
<td>6556.1 (d)</td>
<td>42% (p)</td>
<td>2755.6</td>
<td>(s)</td>
<td>1612.6</td>
<td>6%</td>
<td>32% (p)</td>
<td>1269.6</td>
<td>343.0</td>
</tr>
<tr>
<td>Cigarettes</td>
<td>1669.0 (e)</td>
<td>100% (q)</td>
<td>1660.0</td>
<td>82.5% (q)</td>
<td>1376.9</td>
<td>97%</td>
<td>3% (q)</td>
<td>1335.6</td>
<td>41.3</td>
</tr>
<tr>
<td>Charcoal Broilers</td>
<td>5414.4 (r)</td>
<td>100% (r)</td>
<td>5414.4</td>
<td>82.3% (r)</td>
<td>4456.1</td>
<td>98.5%</td>
<td>1.5% (r)</td>
<td>4389.2</td>
<td>66.8</td>
</tr>
<tr>
<td>Agricultural Burning</td>
<td>5.8 (s)</td>
<td>94% (s)</td>
<td>5.5</td>
<td>52% (s)</td>
<td>2.8</td>
<td>91%</td>
<td>9% (s)</td>
<td>2.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Sea Salt</td>
<td>30131.3 (f)</td>
<td>8% (t)</td>
<td>2410.5</td>
<td>0% (t)</td>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Roofing Tar Pots</td>
<td>921.9 (a)</td>
<td>100% (u)</td>
<td>921.9</td>
<td>81.7% (u)</td>
<td>723.2</td>
<td>99.9%</td>
<td>0.1% (u)</td>
<td>752.4</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>TOTAL FUGITIVE SOURCES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17342.2</td>
<td>15974.4</td>
<td>1367.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Notes for Table A.4

(a) Total particulate emissions data are from the Air Resources Board of California spatially resolved inventory of point and area source emissions (Ranzieri 1983).

(b) See Table A.7.

(c) See Table A.8.

(d) See Table A.9.

(e) Taback et al. (1979, pp. 2-70, 2-71), estimate that each year an average of 0.1538 lb of particulate matter is emitted per person from cigarette smoke. There are 8,734,856 people in the 50X50-mile grid (see Appendix B, Table B.1) yielding $1.34 \times 10^6$ lb/yr or 1669.0 kg/day.

(f) Taback et al. (1979, pp. 2-85 to 2-92), estimate 20,000 tons/year of sea salt emissions (particles < 10 μm). The size distribution data indicate that 76% of particles are < 10 μm, yielding 26,316 tons/year or 65,406.9 kg/day of total particulate emissions in the SCAB. It is assumed that 46.1% of the SCAB emissions are in the 50X50-mile grid (shipping lane distance fraction from bunker fuel emissions calculation; see note [d], Table A.1) giving 30,131.3 kg/day in the grid. This estimate is not very precise, but the source class contributes no particulate carbon; see note (cc).

(g) Taback et al. (1979, table p. A-46).

(h) Taback et al. (1979, table p. A-50).

(i) Taback et al. (1979, table p. A-44); assumed to be organic carbon.


(k) Taback et al. (1979, figure p. 2-58).

(l) Average of data from Pierson and Brachaczek (1974, pp. 1295 and 1296).

(m) Assumed to be all fine, < 2.1 μm.

(o) Taback et al. (1979, table p. A-37).


(q) Taback et al. (1979, table p. A-41), give 100% in the fine fraction. Source tests on cigarettes (Gray, Cass, and Turpin 1985) yield 82.5% total carbon, and 97% of the carbon was found to be organic. Taback et al. (1979, table p. A-41) found similar results for the total carbon in the fine fraction (85%).

(r) The Air Resources Board of California uses an estimate of 3000 lb/year for the total particulate emissions rate from a typical charcoal broiler facility to compute annual emissions for this source class (Grisinger 1982). This value is checked against the results of a study by Bornstein (1978), which indicates an emission rate of 1360 kg (or 2998 lb) per facility per year (all in particle sizes less than 2.1 μm). Since these results are in agreement, the total particulate emissions inventory from the ARB is used. Source tests on charcoal broilers indicate that all material emitted is in the fine fraction. Of the 82.3% found to be carbon, 98.5% was organics (Gray, Cass, and Turpin 1985).

(s) Taback et al. (1979, table p. A-47).

(t) Taback et al. (1979, figure p. 2-92).

(u) Source tests on roofing tar pots indicate that all material emitted is in the fine fraction. Of the 81.7% found to be carbon, 99.9% was organics (Gray, Cass, and Turpin 1985).

(v) Source tests of paved road dust give 15.1% total carbon, and 96.7% of the carbon was found to be organics (Gray, Cass, and Turpin 1985). The carbon content of roadside soil was found to be 7.3% by Pierson and Brachaczeck (1983, table p. 18); and fine particle analysis on street dust by Watson (1979, table p. 94), gives 92% organics.

(w) 87% carbon computed from formula for oil extended synthetic tire rubber given by Morton (1973); 29% of tire tread batch is ISAF carbon black. Carbon present is thus found as about 67% organics, 33% elemental carbon.

(x) Based on automobile brake lining chemical composition given by Lynch (1968), plus the assumption that resins and polymers are 83% carbon by weight, and assuming that carbon present is emitted as aerosol without combustion or pyrolysis.

(y) Based on slash burning fine particulate matter analysis from Watson (1979, table p. 107).
(z) See Table A.9.

(aa) Based on simulated field burning fine particulate matter analysis from Watson (1979, table p. 109).


(cc) Based on carbon emission rates from soft wood from Muhlbaijer and Williams (1982, Table 2, p. 190).
### Table A.5
Fuel Economy Calculation for 1982 Automobile Fleet

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Model Year</th>
<th>% Vehicles in Use</th>
<th>% Diesel Vehicles per Year</th>
<th>% Gasoline Vehicles in Use</th>
<th>% Diesel Vehicles in Use</th>
<th>Annual Avg. Mileage</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1982</td>
<td>7.77</td>
<td>4.6</td>
<td>7.41</td>
<td>0.36</td>
<td>15900</td>
<td>1178.60</td>
<td>56.83</td>
<td>0.111</td>
<td>0.0034</td>
<td>26.2</td>
</tr>
<tr>
<td>2</td>
<td>1981</td>
<td>7.77</td>
<td>5.9</td>
<td>7.31</td>
<td>0.46</td>
<td>15000</td>
<td>1096.74</td>
<td>68.76</td>
<td>0.104</td>
<td>0.0065</td>
<td>25.1</td>
</tr>
<tr>
<td>3</td>
<td>1980</td>
<td>8.76</td>
<td>4.6</td>
<td>8.36</td>
<td>0.40</td>
<td>14000</td>
<td>1169.99</td>
<td>56.41</td>
<td>0.111</td>
<td>0.0033</td>
<td>23.5</td>
</tr>
<tr>
<td>4</td>
<td>1979</td>
<td>9.20</td>
<td>2.2</td>
<td>9.00</td>
<td>0.20</td>
<td>13100</td>
<td>1178.69</td>
<td>26.51</td>
<td>0.111</td>
<td>0.0025</td>
<td>20.3</td>
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<tr>
<td>5</td>
<td>1978</td>
<td>8.50</td>
<td>0.4</td>
<td>8.47</td>
<td>0.03</td>
<td>12200</td>
<td>1032.85</td>
<td>4.15</td>
<td>0.098</td>
<td>0.0004</td>
<td>19.9</td>
</tr>
<tr>
<td>6</td>
<td>1977</td>
<td>7.73</td>
<td>0.1</td>
<td>6.72</td>
<td>0.01</td>
<td>11300</td>
<td>759.73</td>
<td>0.76</td>
<td>0.072</td>
<td>0.00007</td>
<td>18.3</td>
</tr>
<tr>
<td>7</td>
<td>1976</td>
<td>5.51</td>
<td>0.1</td>
<td>5.50</td>
<td>0.01</td>
<td>10300</td>
<td>566.96</td>
<td>0.57</td>
<td>0.054</td>
<td>0.00005</td>
<td>17.5</td>
</tr>
<tr>
<td>8</td>
<td>1975</td>
<td>5.37</td>
<td>0.1</td>
<td>5.36</td>
<td>0.01</td>
<td>9400</td>
<td>504.28</td>
<td>0.50</td>
<td>0.048</td>
<td>0.00005</td>
<td>15.8</td>
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<tr>
<td>9</td>
<td>1974</td>
<td>6.45</td>
<td>0.1</td>
<td>6.44</td>
<td>0.01</td>
<td>8500</td>
<td>547.70</td>
<td>0.55</td>
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<tr>
<td>10</td>
<td>1973</td>
<td>5.78</td>
<td>-</td>
<td>5.78</td>
<td>-</td>
<td>7600</td>
<td>439.28</td>
<td>-</td>
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<td>13.6</td>
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<tr>
<td>11</td>
<td>1972</td>
<td>4.90</td>
<td>-</td>
<td>4.90</td>
<td>-</td>
<td>6700</td>
<td>328.30</td>
<td>-</td>
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<td>12</td>
<td>1971</td>
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<td>-</td>
<td>3.88</td>
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<td>6700</td>
<td>259.96</td>
<td>-</td>
<td>0.025</td>
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<td>11.6</td>
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<tr>
<td>213</td>
<td>1970(-)</td>
<td>19.38</td>
<td>-</td>
<td>19.38</td>
<td>-</td>
<td>6700</td>
<td>1298.46</td>
<td>-</td>
<td>0.123</td>
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<td>13.6</td>
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</table>

\[
\text{sum} = (a)(y) + (b)(y) = 10376.58
\]

Average annual mileage/vehicle

### Fraction VMT

<table>
<thead>
<tr>
<th>Description</th>
<th>Fraction VMT</th>
<th>Weighted Average (gal/mi)</th>
<th>Weighted Average Mi/Gal (mpg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-duty gasoline catalyst (unleaded)</td>
<td>0.7080</td>
<td>0.0474</td>
<td>21.66</td>
</tr>
<tr>
<td>Light-duty gasoline non-catalyst (leaded)</td>
<td>0.2717</td>
<td>0.0733</td>
<td>13.71</td>
</tr>
<tr>
<td>Light-duty diesel automobiles</td>
<td>0.0203</td>
<td>0.0405</td>
<td>24.93</td>
</tr>
</tbody>
</table>
Notes for Table A.5

(a) Percent distribution of fee-paid registrations by age of vehicle, 1982, from California Department of Finance (1982, Table J-5).

(b) Values for 1980 and previous years are from Diesel Impacts Study Committee (1982, pp. 1 and 90). Values for 1981 and 1982 are from Automotive News, as cited by Holman and Lauderdale (1983, p. 7).

(c) U.S. Environmental Protection Agency (1982, Table 3.1.2-5).


(e) Fuel economy for 1982 diesel automobiles is 27.0 mpg from Cadle (1983). It is assumed that the fuel economy improvements for newer diesel automobiles are proportional to that observed for newer gasoline automobiles.
### Table A.6
Vehicle Miles Travelled and Fuel Usage for Each Vehicle Type in 1982

<table>
<thead>
<tr>
<th>Vehicle Class</th>
<th>Vehicle Type</th>
<th>Fraction of Daily VMT Within Class</th>
<th>Class Fraction</th>
<th>Fraction of Daily Total VMT</th>
<th>Weighted Avg. (gallon/mile)</th>
<th>50X50-mile grid Thous. VMT/day</th>
<th>Fuel Use (10^9 Btu/day)</th>
<th>4-County SCAB Thous. VMT/day</th>
<th>Fuel Use (10^9 Btu/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autos</td>
<td>Catalyst</td>
<td>0.7080 (a)</td>
<td></td>
<td></td>
<td></td>
<td>86996</td>
<td>515.2</td>
<td>101641</td>
<td>601.9</td>
</tr>
<tr>
<td></td>
<td>Non-catalyst</td>
<td>0.2717</td>
<td></td>
<td></td>
<td></td>
<td>33385</td>
<td>305.6</td>
<td>39005</td>
<td>357.1</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>0.0203</td>
<td></td>
<td></td>
<td></td>
<td>2494</td>
<td>14.0</td>
<td>2914</td>
<td>16.3</td>
</tr>
<tr>
<td>Light Trucks</td>
<td>Catalyst</td>
<td>0.7080 (a)</td>
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<td></td>
<td></td>
<td>11882</td>
<td>96.0</td>
<td>13882</td>
<td>112.2</td>
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<tr>
<td></td>
<td>Non-catalyst</td>
<td>0.2717</td>
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<td></td>
<td>4560</td>
<td>57.0</td>
<td>5528</td>
<td>66.6</td>
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<td></td>
<td>Diesel</td>
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<td>341</td>
<td>2.6</td>
<td>398</td>
<td>3.0</td>
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<tr>
<td>Medium Trucks</td>
<td>Catalyst</td>
<td>0.5951 (b)</td>
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<td></td>
<td></td>
<td>4994</td>
<td>58.9</td>
<td>5835</td>
<td>68.8</td>
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<tr>
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<td>Non-catalyst</td>
<td>0.4049</td>
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<td>3398</td>
<td>40.1</td>
<td>3970</td>
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<tr>
<td>Heavy Trucks</td>
<td>Gas (Leaded)</td>
<td>0.0193</td>
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<td>3050</td>
<td>66.9</td>
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<td>78.1</td>
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<tr>
<td></td>
<td>Diesel</td>
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<td>5857</td>
<td>147.4</td>
<td>6843</td>
<td>172.2</td>
</tr>
<tr>
<td>Motorcycles</td>
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<td>3.8</td>
<td>1756</td>
<td>4.4</td>
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</table>
Notes for Table A.6

(a) See Table A.5.

(b) Air Resources Board of California (1983) data from EMFAC 1982 vehicle emissions model for the South Coast Air Basin.

(c) Light duty fuel economy calculation; see Table A.5.

(d) Assuming improvement in newer light truck fuel economy proportional to that observed for newer automobiles.

(e) U.S. Environmental Protection Agency (1982, Table 3.1.4-7).

(f) Medium and heavy-duty truck fuel economy from EPA test data as reported by the Air Resources Board of California (1980, Table II-10).

(g) Motorcycle fuel economy from Motor Vehicles Facts and Figures '76 as reported by Air Resources Board of California (1980, Table II-10).

(h) Freeway traffic data from Caltrans (California Department of Transportation 1983) give 67,661.6 thousand vehicle miles travelled per day on the 50X50-mile grid. This is added to the surface traffic total of 90,800.0 thousand vehicle miles per day from Cass, Hahn, and Noll (1982) (updated to 1982) to give 158,461.6 thousand vehicle miles travelled per day in 1982.

(i) The heating value of gasoline is $5248 \times 10^3$ Btu/bbl (or 124,952 Btu/gal). The heating value of diesel is $5812 \times 10^3$ Btu/bbl (or 138,381 Btu/gal) from Cass (1977, p. 598).

(j) Total vehicle miles travelled by all vehicles in the South Coast Air Basin (four counties) is 185,136 thousand VMT/day from Air Resources Board of California (1983) EMFAC.
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<th>1976 SCAB</th>
<th>10^6 Tires</th>
<th>10^6 Counted Vehicles Miles/Year</th>
<th>Weighted Avg. No. Tires/ Counted Vehicles</th>
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<th>1982 Tire Attrition (kg/day)</th>
<th>1982 VWT (Thous. VWT/day)</th>
<th>1982 Tire Attrition (kg/day)</th>
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</table>

|                  |                                      |           |            |                                 |                                            |                         |                            |                             |                            |
| **ALL VEHICLE TOTAL** |                                      |           |            |                                 |                                            |                         |                            |                             |                            |

|                  |                                      |           |            |                                 |                                            |                         |                            |                             |                            |

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Table A.7
Tire Attrition 1982

|                |                                      |           |            |                                 |                                            |                         |                            |                             |                            |

|                  |                                      |           |            |                                 |                                            |                         |                            |                             |                            |

296.8 (g) 55050 (f) 346.8

4604.1 5379.2
Notes for Table A.7

(a) Data for 1976 from Halberg (1980).

(b) Tire miles are computed by multiplying annual mileage per vehicle, number of tires and vehicles in the South Coast Air Basin (SCAB). This calculation is performed using 1976 data to get the average number of tires per counted vehicle and the relative number of trailer tire miles to counted vehicle tire miles.

(c) One vehicle count is made for each vehicle (not including trailers) in the SCAB by multiplying annual mileage and number of vehicle.

(d) Suspended aerosol emission rate of 0.0063 gm/tire/mile based on average of results by Pierson and Brachaczek (1974, pp. 1295 and 1296).

(e) See Table A.6 for 1982 grid and SCAB total vehicle miles travelled (VMT).

(f) Vehicle tire miles for trailers was scaled by 1.252 to reflect the increase from 1976 AQMD counted VMT to 1982 VMT (i.e., 53,957 \times 10^6 \text{ VMT/yr} or 147,827 \times 10^3 \text{ VMT/day} \times 1.252 = 185,1136 \times 10^3 \text{ VMT/day}, and 16,044 \times 10^6 \text{ tire miles/yr or 43,956 \times 10^9 \text{ tire miles/day} \times 1.252 = 55,050 \times 10^9 \text{ tire miles/day}). This value represents thousand tire miles per day.

(g) It is assumed that tire miles for trailers in the 50X50-mile grid are of the same proportion to the SCAB as vehicle miles (85.6%); see Table A.6.
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<th>Light Duty Vehicles</th>
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<th>1976 Estimated Annual Mileage</th>
<th>Adjusted 1982 Annual Mileage</th>
<th>Vehicles in SCAB</th>
<th>% VMT Using Front Disc Brakes</th>
<th>Emission Factors (lbs/10^9 VMT) (d)</th>
<th>1982 Particulate Emissions SCAB With Front Disc (kg/day)</th>
<th>Without Disc (kg/day)</th>
<th>Total (kg/day)</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
<td>(d)</td>
<td>(e)</td>
<td>(f)</td>
<td>(g)</td>
<td>(h)</td>
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<tr>
<td>Comm'1 2-axle (5000# curb wt)</td>
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<td>12065</td>
<td>4641484</td>
<td>80%</td>
<td>14.6 + 43.4</td>
<td>43.4 X 2</td>
<td>3229.1</td>
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<td>750176</td>
<td>80%</td>
<td>14.6 + 43.4</td>
<td>43.4 X 2</td>
<td>521.9</td>
<td>195.3</td>
<td>717.2</td>
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</tr>
<tr>
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<td>79683</td>
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<td>413</td>
<td>125 X 3</td>
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<td>Heavy Duty Vehicles</td>
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<td>Comm'1 2-axle &gt;10,000# curb wt</td>
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<td>20883</td>
<td>100%</td>
<td>233 X 2</td>
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<td>83 + 233 X 2</td>
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<td>83 + 233 X 3</td>
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<td>233 X 2</td>
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<td>6445.7</td>
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</table>
Notes for Table A.8

(a) Data for 1976 from Halberg (1980).

(b) 1976 AQMD data multiplied by 1.252 to coincide with 1982 VMT data (not including trailers) in the South Coast Air Basin; see Table A.7, note (f).

(c) Taback et al. (1979, p. 2-88). All past-1970 GM passenger cars equipped with front disc brakes.

(d) Taback et al. (1979, pp. 283-288).

(e) The emissions in the 50×50-mile grid are proportional to the SCAB emissions in the same ratio as vehicle miles travelled; see Table A.6.
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<th>Total Particulate Emission Factor (g/kg wood)</th>
<th>% Residences Burning Wood</th>
<th>Residence-Yr. Wood Burners</th>
<th>Avg. Cords/Residence-Yr. Wood Burners</th>
<th>Fraction of Wood Type</th>
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<th>kg Mass/Cord</th>
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<td>1469.7</td>
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<td>Orange County</td>
<td>3380.5</td>
<td>9.99</td>
<td></td>
<td></td>
<td></td>
<td>0.336</td>
<td>68762</td>
<td>1796.2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>6773.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softwood</td>
<td>3393.4</td>
<td>6.20</td>
<td></td>
<td></td>
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<td>0.664</td>
<td>135888</td>
<td>1469.7</td>
</tr>
<tr>
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<td>3380.5</td>
<td>9.99</td>
<td></td>
<td></td>
<td></td>
<td>0.336</td>
<td>68762</td>
<td>1796.2</td>
</tr>
<tr>
<td>Total</td>
<td>6773.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50x50-mile grid (f)</td>
<td>6556.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Bernardino County</td>
<td>2642.3</td>
<td>6.20</td>
<td>50.0%</td>
<td>262009</td>
<td>1.083</td>
<td>0.373</td>
<td>105841</td>
<td>1469.7</td>
</tr>
<tr>
<td>Riverside County</td>
<td>8746.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.404</td>
<td>177915</td>
<td>1796.2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>11388.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softwood</td>
<td>2642.3</td>
<td>6.20</td>
<td></td>
<td></td>
<td></td>
<td>0.373</td>
<td>105841</td>
<td>1469.7</td>
</tr>
<tr>
<td>Hardwood</td>
<td>8746.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.404</td>
<td>177915</td>
<td>1796.2</td>
</tr>
<tr>
<td>Total</td>
<td>11388.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total 4-County SCAB</td>
<td>18161.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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Table A.9.1
Fireplace Emissions 1982
<table>
<thead>
<tr>
<th></th>
<th>Total Particulate Emissions (kg/day)</th>
<th>Mass Fraction (&lt; 2.1 μm)</th>
<th>Fine Particulate (&lt; 2.1 μm)</th>
<th>% Total Carbon in &lt; 2.1 μm Fraction</th>
<th>Total Fine Carbon (kg/day)</th>
<th>Partition of Carbon</th>
<th>Fine Organic Carbon (kg/day)</th>
<th>Fine Elemental Carbon (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Los Angeles and Orange Counties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softwood</td>
<td>3392.4</td>
<td>42%</td>
<td>1424.8</td>
<td>66.1%</td>
<td>941.8</td>
<td>68.3%</td>
<td>31.7%</td>
<td>643.3</td>
</tr>
<tr>
<td>Hardwood</td>
<td>3380.5</td>
<td>42%</td>
<td>1419.8</td>
<td>51.0%</td>
<td>724.1</td>
<td>92.3%</td>
<td>7.7%</td>
<td>668.3</td>
</tr>
<tr>
<td>Total</td>
<td>6772.9</td>
<td></td>
<td>2844.6</td>
<td>66.1%</td>
<td>1665.9</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>50x50-mile grid (f)</td>
<td>6556.1</td>
<td></td>
<td>2753.6</td>
<td>66.1%</td>
<td>1612.6</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>San Bernardino and Riverside Counties</strong></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softwood</td>
<td>2643.3</td>
<td>42%</td>
<td>1109.8</td>
<td>66.1%</td>
<td>793.6</td>
<td>68.3%</td>
<td>31.7%</td>
<td>501.0</td>
</tr>
<tr>
<td>Hardwood</td>
<td>8746.6</td>
<td>42%</td>
<td>3673.6</td>
<td>51.0%</td>
<td>1873.5</td>
<td>92.3%</td>
<td>7.7%</td>
<td>1729.3</td>
</tr>
<tr>
<td>Total</td>
<td>11388.9</td>
<td></td>
<td>4783.3</td>
<td>66.1%</td>
<td>2607.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total 4-County SCAB</strong></td>
<td>18161.8</td>
<td></td>
<td>7627.9</td>
<td>66.1%</td>
<td>4273.0</td>
<td></td>
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</tr>
</tbody>
</table>
Notes for Table A.9

(a) Total dwellings by county in South Coast Air Basin, 1980, from Southern California Association of Governments (1982, p. 70) using population statistics and data on persons per dwelling unit.

(b) As part of this study, a survey was conducted throughout the South Coast Air Basin to determine the average level of wood-burning in residential fireplaces. The results of this survey produced data on the fraction of residences in each county burning wood, how much wood, what type of wood, and seasonal variation of usage. These data are presented in this table (seasonal variation: 70.8% winter, 10.1% spring, 2.3% summer, 16.8% autumn; 83 responses).

(c) Based on cord weights of red oak (hardwood) and yellow pine (softwood) from Baumeister, Avallone, and Baumeister (1978, pp. 6-124 and 7-13).

(d) Muhlbaier and Williams (1982, Table 2, p. 190).


(f) Emissions in the 50×50-mile grid are assumed to be in proportion to the on-grid fraction of the Los Angeles and Orange Counties population. The fraction of the two-counties population residing in the grid is 0.968 (Southern California Association of Governments 1982).
<table>
<thead>
<tr>
<th>Source Type Used in Emission Inventory (a)</th>
<th>California Air Resources Board Category of Emission Source (CES, SCC) Numbers (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 Off Highway Diesel</td>
<td>AAA47480, AAA54379, AAA54437, AAA54452, AAA54478, AAA54494, AAA54536, AAA54593</td>
</tr>
<tr>
<td>20 Off Highway Gasoline</td>
<td>AAA47449, AAA47464, AAA54387, AAA54411</td>
</tr>
<tr>
<td>35 Industrial IC Gasoline</td>
<td>AAA66746, 20200301</td>
</tr>
<tr>
<td>36 Industrial IC Distillate</td>
<td>AAA54353, 20200102, 20200902</td>
</tr>
<tr>
<td>42 Petrochemical FCCU</td>
<td>30600201</td>
</tr>
<tr>
<td>43 Petrochemical Other</td>
<td>30600401, 30600501, 30600805, 30600999, 30601301, 30699998, 30699999, 40300199, 40399999</td>
</tr>
<tr>
<td>44 Organic Solvent Coating</td>
<td>AAA18697, AAA19034, AAA19109, AAA19315, AAA20107, AAA24794, AAA24877, AAA24935, AAA25056, AAA25213, AAA27920, AAA27920, AAA27995, AAA28464, AAA31583, AAA31963, AAA37861, AAA42358, AAA42416, 40200101, 40200110, 40200199, 40200219, 40200301, 40200399, 40200401, 40200410, 40200499, 40200501, 40200599, 40200601, 40200603, 40200701, 40200799, 40200801, 40200803, 40201001, 40201002, 4028801, 40299999</td>
</tr>
<tr>
<td>45 Organic Solvent Printing</td>
<td>40500101, 40500201, 40500301, 40500401</td>
</tr>
<tr>
<td>46 Organic Solvent Degreasing</td>
<td>40100103, 40100299</td>
</tr>
<tr>
<td>47 Organic Solvent Other</td>
<td>49099999</td>
</tr>
</tbody>
</table>

(a) Emissions for these source types have been compiled in Tables A.1 through A.4. The number corresponds to the source type number in Table D.38 (second column).

(b) The California Air Resources Board uses CES numbers for area sources (first three digits: AAA) and SCC numbers for point sources (Ranzieri 1983).
<table>
<thead>
<tr>
<th>Source Type Used in Emission Inventory</th>
<th>California Air Resources Board Category of Emission Source (CES, SCC) Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 Chemical Organic</td>
<td>30100199, 30100901, 30100902, 30100999, 30101501, 30101599, 30101801, 30101802, 30101899, 30101903, 30102699, 30103204, 30199999</td>
</tr>
<tr>
<td>49 Metal Primary</td>
<td>30300199, 30300302, 30300303, 30300304, 30300399, 30300801, 30300819, 30300821, 30300901, 30300913, 30300914, 30300999, 30301003, 30303005, 30388801, 30400301, 30400350, 30400699, 30400701, 30400702, 30400704, 30400705, 30400706, 30400799</td>
</tr>
<tr>
<td>50 Metal Secondary</td>
<td>30400101, 30400102, 30400103, 30400109, 30400199, 30400203, 30400205, 30400208, 30400209, 30400212, 30400217, 30400219, 30400221, 30400223, 30400224, 30400402, 30400403, 30400407, 30400408, 30400499, 30400501, 30400599, 30400801, 30400803, 30400808, 30400828, 30400899, 30488801, 30499999</td>
</tr>
<tr>
<td>51 Mineral</td>
<td>30500201, 30500205, 30500299, 30500302, 30500311, 30500605, 3050066, 30500609, 30500610, 30500613, 30500616, 30500617, 30500619, 30500699, 30500799, 30500801, 30500803, 30500899, 30501101, 30501199, 30501201, 30501204, 30501205, 30501299, 30501401, 30501402, 30501404, 30501406, 30501410, 30501411, 30501503, 30501599, 30501701, 30501703, 30502006, 30502501, 30502599, 30503203, 30503299, 30588801, 30588802, 30599999</td>
</tr>
<tr>
<td>52 Waste Burning</td>
<td>10201201, 50200505, 50300101, 50300102, 50300108</td>
</tr>
<tr>
<td>53 Wood and Paper Products</td>
<td>30700401, 30700402, 30799999</td>
</tr>
<tr>
<td>54 Asphalt Roofing</td>
<td>30500104, 30500105, 30500199</td>
</tr>
<tr>
<td>55 Rubber and Plastics</td>
<td>30800699</td>
</tr>
<tr>
<td>56 Coke Calciner</td>
<td>30601401</td>
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</table>
Table A.10 (continued)

<table>
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<tr>
<th>Source Type Used in Emission Inventory</th>
<th>California Air Resources Board Category of Emission Source (CES, SCC) Numbers</th>
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</thead>
<tbody>
<tr>
<td>57 Food and Agriculture</td>
<td>30200901, 30200999, 30201301, 30203299, 30299998, 30299999</td>
</tr>
<tr>
<td>58 Textile</td>
<td>33000199, 33000399</td>
</tr>
<tr>
<td>59 Miscellaneous Industrial</td>
<td>AAA10108, 39999999</td>
</tr>
<tr>
<td>60 Livestock Dust</td>
<td>AAA47340</td>
</tr>
<tr>
<td>61 Paved Road Dust</td>
<td>AAA47456</td>
</tr>
<tr>
<td>64 Structural Fires</td>
<td>AAA47324</td>
</tr>
<tr>
<td>67 Agricultural Burning</td>
<td>AAA47258</td>
</tr>
<tr>
<td>68 Charcoal Broilers</td>
<td>AAA60418</td>
</tr>
<tr>
<td>69 Roofing Tar Pots</td>
<td>AAA66738</td>
</tr>
<tr>
<td>70 Chemical Inorganic</td>
<td>30101701, 30102308, 30103601, 30103701, 30113003</td>
</tr>
<tr>
<td>71 Metal Fabrication</td>
<td>30903099, 30999999</td>
</tr>
<tr>
<td>72 Road/Building Construction</td>
<td>AAA47357, AAA47365, AAA47373, AAA47381, AAA54551, AAA60400</td>
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<tr>
<td>73 Agricultural Tilling</td>
<td>AAA47332</td>
</tr>
<tr>
<td>74 Unpaved Road Dust</td>
<td>AAA47399, AAA47407, AAA47415, AAA47431</td>
</tr>
<tr>
<td>- Wild Fires (c)</td>
<td>AAA47308, AAA47316</td>
</tr>
<tr>
<td>- Tire Burning (c)</td>
<td>AAA57307</td>
</tr>
<tr>
<td>- LPG for Carburetion (c)</td>
<td>AAA58727</td>
</tr>
</tbody>
</table>

(c) Source class is not input to the air quality model.
REFERENCES FOR APPENDIX A


Air Resources Board of California. 1983. *Predicted California vehicle emissions—South Coast Air Basin—1982* (Computer-generated listing by that name of data used in EMFAC6 emissions model by the California Air Resources Board.) El Monte.


Flagan, R. C., California Institute of Technology. Personal communication, 1980, suggested this approximation.


Halberg, E., South Coast Air Quality Management District. Personal communication of vehicle distribution data received October 1980.


Manfredi, M., and N. Mansour. 1975. Test conducted at Department of Water and Power City of Los Angeles (Scattergood Station) 12700 Vista Del Mar, Playa Del Rey, California on September 26, 1975—Report on the emissions from steam generator no. 3 under natural gas firing. Southern California Air Pollution Control District, Source Test Section Report No. C-2354. El Monte.

Mansour, N., Southern California Edison Co., Rosemead, California. Personal communication, n.d. Samples taken during source tests on Los Angeles Department of Water and Power Scattergood Unit 3 while burning natural gas showed mostly iron, silica, sodium, and calcium. Samples were not noticeably darkened.


APPENDIX B

1982 FUEL USE DATA
### Table B.1

1980 Population by Region

<table>
<thead>
<tr>
<th>1980 Population</th>
<th>Fraction of California</th>
<th>Fraction of 6-County</th>
<th>Fraction of 4-County SCAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50X50-mile grid (b)</td>
<td>8,734,856</td>
<td>36.9%</td>
<td>77.5%</td>
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<tr>
<td>4-County SCAB (c)</td>
<td>10,508,922</td>
<td>44.4%</td>
<td>93.3%</td>
</tr>
<tr>
<td>6-County Basin (d)</td>
<td>11,266,521</td>
<td>47.6%</td>
<td>100%</td>
</tr>
<tr>
<td>California State Total</td>
<td>23,667,902</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

**Notes for Table B.1**

(a) From the Southern California Association of Governments (1982).

(b) For definition of the grid; see Figure 4.1.

(c) Contains Los Angeles, Orange, Riverside, and San Bernardino Counties.

(d) Contains Los Angeles, Orange, Riverside, San Bernardino, Ventura, and Santa Barbara Counties.
<table>
<thead>
<tr>
<th>Power Plant</th>
<th>Grid Location Coordinates</th>
<th>Natural Gas Boilers (Equivalent bbls/yr)</th>
<th>Turbines (Equivalent bbls/yr)</th>
<th>Residual Fuel Oil (Equivalent bbls/yr)</th>
<th>Distillate Gas (Equivalent bbls/yr)</th>
<th>Digester Gas (Equivalent bbls/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCE El Segundo</td>
<td>LA 7 12</td>
<td>5,373,103.50</td>
<td>0</td>
<td>190,911.0</td>
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<td>0</td>
</tr>
<tr>
<td>DWP LA Scattergood</td>
<td>LA 7 13</td>
<td>1,028,281.19</td>
<td>0</td>
<td>348,730.0</td>
<td>0</td>
<td>18,254.30</td>
</tr>
<tr>
<td>SCE Redondo</td>
<td>LA 8 10</td>
<td>5,641,818.50</td>
<td>0</td>
<td>11,682.0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>DWP LA Valley</td>
<td>LA 8 24</td>
<td>116,017.51</td>
<td>0</td>
<td>45,675.0</td>
<td>0</td>
<td>14,529.00</td>
</tr>
<tr>
<td>Burbank Magnolia</td>
<td>LA 10 22</td>
<td>631,502.06</td>
<td>59,292.0</td>
<td>7340.0</td>
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<td>0</td>
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<tr>
<td>Glendale Airway</td>
<td>LA 11 21</td>
<td>283,391.50</td>
<td>216,602.0</td>
<td>715.0</td>
<td>77.0</td>
<td>0</td>
</tr>
<tr>
<td>SCE Northridge</td>
<td>LA 3 25</td>
<td>0</td>
<td>169,072.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DWP LA Harbor</td>
<td>LA 11 7</td>
<td>137,130.41</td>
<td>11,491.0</td>
<td>21,026.0</td>
<td>1439.0</td>
<td>0</td>
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<tr>
<td>LB Gas Dept. (1)</td>
<td>LA 14 8</td>
<td>0</td>
<td>801.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SCE Long Beach</td>
<td>LA 12 7</td>
<td>12,894.50</td>
<td>1,687,470.0</td>
<td>0</td>
<td>15,080.0</td>
<td>0</td>
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<tr>
<td>LB Gas Dept. (2)</td>
<td>LA 16 9</td>
<td>0</td>
<td>960.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Pasadena Glenarm</td>
<td>LA 15 20</td>
<td>599,898.81</td>
<td>7,835.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SCE Mt. Vernon</td>
<td>LA 25 18</td>
<td>0</td>
<td>44,781.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SCE Alamitos</td>
<td>LA 16 7</td>
<td>10,852,545.00</td>
<td>13,072.0</td>
<td>2,339,868.0</td>
<td>5,721.0</td>
<td>0</td>
</tr>
<tr>
<td>DWP Haynes</td>
<td>LA 16 7</td>
<td>3,212,852.00</td>
<td>0</td>
<td>3,064,680.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SCE H. Beach</td>
<td>Orange 19 3</td>
<td>5,269,042.00</td>
<td>7,161.0</td>
<td>468,774.0</td>
<td>542.0</td>
<td>0</td>
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<tr>
<td>SCE Entwined</td>
<td>SBdo off grid</td>
<td>4,054,134.75</td>
<td>4,515.0</td>
<td>173,554.0</td>
<td>1988.0</td>
<td>0</td>
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<tr>
<td>SCE Highgrove</td>
<td>SBdo off grid</td>
<td>78,694.70</td>
<td>0</td>
<td>18,986.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SCE San Bernardino</td>
<td>SBdo off grid</td>
<td>573,207.56</td>
<td>0</td>
<td>200,654.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Oxnard Beach</td>
<td>Ventura off grid</td>
<td>28,166,950.0 (MCF/yr)</td>
<td>0</td>
<td>545,468.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mandalay</td>
<td>Ventura off grid</td>
<td>9,782,188.00 (MCF/yr)</td>
<td>0</td>
<td>304,818.0</td>
<td>557.1</td>
<td>0</td>
</tr>
</tbody>
</table>

| Total Grid (b)    | 16 utilities              | 572.32                                  | 38.29                        | 610.61                                 | 112.08                             | 0.385                            | 0.566                           |
| Total 4-CO. SCAB (c) | 19 utilities              | 653.55                                  | 38.37                        | 691.92                                 | 118.86                             | 0.429                            | 0.566                           |
| Total 6-CO. Basin (d) | 21 utilities              | 762.76                                  | 38.37                        | 802.13                                 | 133.34                             | 0.522                            | 0.566                           |
Notes for Table B.2

(a) Data from South Coast Air Quality Management District (1983) electric utility fuel use reports for 1982. Ventura County data from the Air Pollution Control District (1983).

(b) Each equivalent barrel of fuel has a heating value of $6.3 \times 10^6$ Btu/equiv.bbl (or $1.06 \times 10^9$ Btu/MCF).

(c) Includes Los Angeles, Orange, Riverside, and San Bernardino Counties.

(d) Includes Los Angeles, Orange, Riverside, San Bernardino, Ventura, and Santa Barbara Counties.
<table>
<thead>
<tr>
<th>Refinery</th>
<th>Grid Location Coordinates</th>
<th>Residual Fuel Oil (Equivalent bbls/yr)</th>
<th>Natural Gas (Equivalent bbls/yr)</th>
<th>Refinery Gas (Equivalent bbls/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newhall Refining</td>
<td>LA off grid</td>
<td>5,251.0</td>
<td>93,113.061</td>
<td>28,455.829</td>
</tr>
<tr>
<td>Standard Oil of California</td>
<td>LA 7 12</td>
<td>231,189.0</td>
<td>1,444,488.990</td>
<td>4,141,342.437</td>
</tr>
<tr>
<td>Mobile Oil</td>
<td>LA 9 10</td>
<td>0.0</td>
<td>196,274.673</td>
<td>3,410,700.430</td>
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<tr>
<td>Union Oil</td>
<td>LA 11 8</td>
<td>0.0</td>
<td>778,004.489</td>
<td>2,015,775.272</td>
</tr>
<tr>
<td>Fletcher Oil &amp; Refining</td>
<td>LA 11 9</td>
<td>0.0</td>
<td>37,290.828</td>
<td>347,632.531</td>
</tr>
<tr>
<td>Golden Eagle Refinery</td>
<td>LA 11 10</td>
<td>0.0</td>
<td>48,574.657</td>
<td>47,864.169</td>
</tr>
<tr>
<td>Shell Oil, Wilmington</td>
<td>LA 12 10</td>
<td>0.0</td>
<td>314,923.842</td>
<td>1,138,756.653</td>
</tr>
<tr>
<td>Shell Oil, Dominguez</td>
<td>LA 12 10</td>
<td>0.0</td>
<td>574,024.331</td>
<td>880,800.292</td>
</tr>
<tr>
<td>Champlin Petroleum</td>
<td>LA 12 8</td>
<td>0.0</td>
<td>12,498.178</td>
<td>957,762.669</td>
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<tr>
<td>Texaco Inc.</td>
<td>LA 12 8</td>
<td>0.0</td>
<td>307,701.665</td>
<td>1,824,471.343</td>
</tr>
<tr>
<td>Atlantic Richfield</td>
<td>LA 12 9</td>
<td>43,515.0</td>
<td>856,525.160</td>
<td>3,019,616.466</td>
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<tr>
<td>Macmillan Ring-free Oil</td>
<td>LA 14 8</td>
<td>0.0</td>
<td>51,849.670</td>
<td>663,955</td>
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<tr>
<td>Marlex Oil &amp; Refining I</td>
<td>LA 14 9</td>
<td>0.0</td>
<td>53,075.009</td>
<td>1,999,441</td>
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<tr>
<td>Edgington Oil</td>
<td>LA 14 11</td>
<td>1894.0</td>
<td>224,006.833</td>
<td>16,220.333</td>
</tr>
<tr>
<td>Douglas Oil</td>
<td>LA 15 12</td>
<td>5940.0</td>
<td>139,437.336</td>
<td>233,262.134</td>
</tr>
<tr>
<td>Powerline Oil</td>
<td>LA 17 13</td>
<td>21,350.0</td>
<td>305,340.180</td>
<td>668,341.003</td>
</tr>
<tr>
<td>Gulf Oil</td>
<td>LA 18 12</td>
<td>118.0</td>
<td>390,836.013</td>
<td>629,792.801</td>
</tr>
</tbody>
</table>

(10⁹ Btu/day) (10⁹ Btu/day) (10⁹ Btu/day)

**TOTAL GRID (b)** 16 refineries 5.25 98.98 333.62

**TOTAL (c)** 17 refineries 5.34 100.59 334.12
Notes for Table B.3

(a) Data from South Coast Air Quality Management District (1983) electric utility fuel use reports for 1982.

(b) Each equivalent barrel of fuel has a heating value of $6.3 \times 10^6$ Btu/equiv.bbl.

(c) Newhall Refining is in Los Angeles County but outside of the 50X50-mile grid.
### Table B.4

**Residential and High Priority Commercial Natural Gas Sales, 1982**

<table>
<thead>
<tr>
<th></th>
<th>Los Angeles</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>TOTAL GRID</th>
<th>TOTAL 6-CO SCAR</th>
<th>TOTAL 6-CO BASIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Orange</td>
<td>So. Cal. Gas Co.</td>
<td>Long Beach Gas Co.</td>
<td>San Bernardino</td>
<td>Riverside</td>
<td>Santa Barbara</td>
<td>Ventura</td>
<td>(10^9 Btu/day)</td>
<td>(10^9 Btu/day)</td>
</tr>
<tr>
<td>Residential Natural Gas Use (MCF/yr)</td>
<td>45,823,497.4</td>
<td>160,440,064.5</td>
<td>8,082,238.0</td>
<td>(b)</td>
<td>19,303,560.5</td>
<td>7,503,997.8</td>
<td>5,322,729.0</td>
<td>12,075,307.6</td>
<td>700.10</td>
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<tr>
<td>High Priority Commercial Natural Gas Use (MCF/yr)</td>
<td>9,504,176.3</td>
<td>86,489,017.8</td>
<td>1,819,956.0</td>
<td>(b)</td>
<td>1,866,711.3</td>
<td>1,833,433.2</td>
<td>1,862,494.7</td>
<td>2,331,487.1</td>
<td>154.66</td>
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<tr>
<td>Total Residential/ High Priority Commercial Natural Gas Use (MCF/yr)</td>
<td>55,327,673.7</td>
<td>166,929,082.3</td>
<td>9,832,194.0</td>
<td>(b)</td>
<td>20,169,271.8</td>
<td>9,360,431.0</td>
<td>7,185,323.7</td>
<td>14,406,794.7</td>
<td>834.76</td>
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<tr>
<td>Residential Natural Gas Use (MCF/yr)</td>
<td>42,661,676.1</td>
<td>149,369,700.0</td>
<td>7,650,083.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>579.32</td>
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<tr>
<td>Weighted Average</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

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Notes for Table B.4

(a) Data from Southern California Gas Company (1983) reports of natural gas sales by county and FPC priority number for 1982. Los Angeles County is supplied by the Southern California Gas Company and also by the City of Long Beach Gas Department.

(b) Data from the City of Long Beach Gas Department monthly natural gas deliveries for 1982 (Kortz 1983). This represents 92.1% of the priority P1 natural gas delivered in Long Beach, which is the same fraction of P1 sold to residential/high-priority commercial users in Los Angeles County during 1982 as reported by the Southern California Gas Company (1983). The remaining 7.9% is assumed to be industrial P1. This 9,822,194 MCF is assumed to be divided into residential and high priority commercial using the proportions found in Los Angeles for P1 fuel sales by the Southern California Gas Company.

(c) FPC priority number P1 only. (Residential users are all classified P1.)

(d) The 50X50-mile grid comprises 93.1% of the population in Los Angeles and Orange Counties (Cass 1977). It is assumed that residential natural gas use is distributed spatially proportional to population distribution.

(e) The 50X50-mile grid comprises 96.8% of the employment in Los Angeles and Orange Counties (Cass 1977). It is assumed that commercial natural gas use is distributed spatially proportional to employment distribution.

(f) The natural gas sales for the calendar year 1982 reported by the Southern California Gas Company do not agree with the total of the monthly gas sales for the same period presented in the same report. Both the annual total and the sum of the monthly values are presented here.

(g) Includes Los Angeles, Orange, Riverside, and San Bernardino Counties.

(h) Includes Los Angeles, Orange, Riverside, San Bernardino, Ventura, and Santa Barbara Counties.
<table>
<thead>
<tr>
<th>County</th>
<th>Industrial Natural Gas Use (MMCF/yr)</th>
<th>Low Priority Commercial Natural Gas Use (MMCF/yr)</th>
<th>Total Industrial Low Priority Commercial Natural Gas Use (MMCF/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange (a)</td>
<td>(a)</td>
<td>(d)</td>
<td>39,608,940.6</td>
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<tr>
<td>So. Cal. Gas Co. (a)</td>
<td>249,619,080.6</td>
<td>39,064,738.3</td>
<td>288,683,818.9</td>
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<tr>
<td>Long Beach Gas Co. (b)</td>
<td>18,106,099.4 (b)</td>
<td>2,833,557.6 (b)</td>
<td>20,939,657.0 (b)</td>
</tr>
<tr>
<td>San Bernardino (a)</td>
<td>24,505,501.7</td>
<td>2,220,592.8</td>
<td>26,726,094.5</td>
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<tr>
<td>Riverside (a)</td>
<td>2,262,233.1</td>
<td>889,539.9</td>
<td>3,151,773.0</td>
</tr>
<tr>
<td>Santa Barbara (a)</td>
<td>1,907,290.6</td>
<td>717,569.6</td>
<td>2,624,860.2</td>
</tr>
<tr>
<td>Ventura (a)</td>
<td>39,816,393.3</td>
<td>995,194.5</td>
<td>40,81,587.8</td>
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</table>

<table>
<thead>
<tr>
<th>Weighted Average Monthly Total Grid Industrial / Commercial (10^9 Btu/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Industrial/Low Priority Commercial (a)</td>
</tr>
<tr>
<td>2-County (f)</td>
</tr>
<tr>
<td>4-County (g)</td>
</tr>
<tr>
<td>6-County (h)</td>
</tr>
<tr>
<td>Utilities (i)</td>
</tr>
<tr>
<td>2-County</td>
</tr>
<tr>
<td>4-County</td>
</tr>
<tr>
<td>6-County</td>
</tr>
<tr>
<td>Refineries (j)</td>
</tr>
<tr>
<td>2-County</td>
</tr>
<tr>
<td>4-County</td>
</tr>
<tr>
<td>6-County</td>
</tr>
<tr>
<td>Total Non-refinery Non-utility Industrial/Low Priority Commercial (k)</td>
</tr>
<tr>
<td>2-County</td>
</tr>
<tr>
<td>50X50-mile grid (l)</td>
</tr>
<tr>
<td>4-County SCAB</td>
</tr>
<tr>
<td>6-County Basin</td>
</tr>
</tbody>
</table>
Notes for Table B.5

(a) Data from Southern California Gas Company (1983) reports of natural gas sales by county and FPC priority number for 1982. Los Angeles County is supplied by the Southern California Gas Company and also by the City of Long Beach Gas Department.

(b) Data from the City of Long Beach Gas Department monthly natural gas deliveries for 1982 (Kortz 1983). This represents 7.9% of the priority P1 natural gas and all of the lower priority natural gas delivered; see note (b), Table B.4. The 20,939,657 MCF is assumed to be divided into industrial and low priority commercial using the proportions found in Los Angeles County for fuel sales by the Southern California Gas Company.

(c) All FPC priorities. This includes gas supplied to utilities and refineries which is subtracted below.

(d) All FPC priorities lower than P1.

(e) Includes gas supplied to utilities and refineries.

(f) Includes Orange and Los Angeles Counties.

(g) Includes Los Angeles, Orange, Riverside, and San Bernardino Counties.

(h) Includes Los Angeles, Orange, Riverside, San Bernardino, Ventura, and Santa Barbara Counties.

(i) From Table B.2.

(j) From Table B.3. All 17 refineries are in Los Angeles County.

(k) Non-refinery, non-utility industrial and low priority commercial natural gas usage is obtained by subtracting the natural gas used by utilities and refineries from the total industrial and low priority commercial natural gas use.

(l) The natural gas use by non-refinery, non-utility industrial and low priority commercial establishments in the 50X50-mile grid is assumed to be 96.8% of the natural gas use in Los Angeles and Orange Counties (2-county). This is the fraction of the 2-county employment in the grid (Cass 1977).

(m) The natural gas sales for the calendar year 1982 reported by the Southern California Gas Company do not agree with the total of the monthly gas sales for the same period presented in the same report. Both the annual total and the sum of the monthly values are presented here.
Table B.6  
Deliveries of Fuels in 1982

<table>
<thead>
<tr>
<th></th>
<th>California (1000 bbls/yr)</th>
<th>6-County Basin (1000 bbls/yr)</th>
<th>6-County Basin (10^9 Btu/day)</th>
<th>4-County SCAB (10^9 Btu/day)</th>
<th>50x50-mile Grid (10^9 Btu/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distillate Fuel Oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential/Commercial</td>
<td>4482</td>
<td>1380.5 (e)</td>
<td>22.03 (k)</td>
<td>20.55 (o)</td>
<td>17.08 (o)</td>
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<tr>
<td>Industrial (b)</td>
<td>4794</td>
<td>2301.1 (d)</td>
<td>36.72 (k)</td>
<td>27.92 (p)</td>
<td>26.54 (p)</td>
</tr>
<tr>
<td>Railroad</td>
<td>7138</td>
<td>1557.0 (e)</td>
<td>24.85 (k)</td>
<td>22.42 (e)</td>
<td>14.13 (e)</td>
</tr>
<tr>
<td>Residual Fuel Oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential/Commercial</td>
<td>5697</td>
<td>1754.7 (f)</td>
<td>30.22 (l)</td>
<td>28.19 (o)</td>
<td>23.43 (o)</td>
</tr>
<tr>
<td>Industrial (b)</td>
<td>973</td>
<td>467.0 (g)</td>
<td>8.04 (l)</td>
<td>7.65 (q)</td>
<td>7.27 (q)</td>
</tr>
<tr>
<td>Liquefied Petroleum Gas (LPG)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal Combustion Engines</td>
<td>1697.5</td>
<td>814.8 (h)</td>
<td>8.48 (m)</td>
<td>8.07 (q)</td>
<td>7.67 (q)</td>
</tr>
<tr>
<td>Residential/Commercial</td>
<td>5220.0</td>
<td>1607.8 (i)</td>
<td>16.74 (m)</td>
<td>15.61 (n)</td>
<td>12.98 (n)</td>
</tr>
<tr>
<td>Industrial (b)</td>
<td>907.5</td>
<td>435.6 (j)</td>
<td>4.54 (m)</td>
<td>4.31 (q)</td>
<td>4.10 (q)</td>
</tr>
<tr>
<td>Digester Gas--Industrial</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Coke Oven Gas--Industrial</td>
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<tr>
<td>Coal--Residential/Commercial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

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Notes for Table B.6

(a) Deliveries of fuels in 1982 for the state of California from the Energy Information Administration (1983). Liquefied petroleum gas (LPG) was reported by the state of California in $10^7$ gal/yr, so those values are divided by 42 (gal/bbl).

(b) Non-refinery, non-utility industrial fuel.

(c) Southern California portion of residential and commercial oil use in California is 0.4 from Stanford Research Institute (1973). The 6-county basin fuel use is assumed to be a fraction of the Southern California fuel use based on population density. From the 1980 census of population in California counties (U.S. Bureau of the Census 1982), 77% of Southern California population is in the six counties; therefore, \(4482 \times 0.4 \times 0.77 = 4482 \times 0.308 = 1380.5 \times 10^3\) bbls/yr.

(d) 64% of the state of California's industrial oil use is in Southern California from Stanford Research Institute (1973), and 75% of the non-refinery industrial heating demand in Southern California is in the 6-county basin from Cass (1977); therefore, \(4794 \times 0.64 \times 0.75 = 4794 \times 0.48 = 2301.1 \times 10^3\) bbls/yr. This contains some fuel used for internal combustion engines; see note (o), below.

(e) Railroad fuel is assumed to be used geographically in proportion to track mileage. The track mileage in railroad yards was counted for each track to account for the heavy traffic in those areas. From Cass (1977, p. 628), track miles were summed for the 6-county basin and were found to be 1842.3 miles, which is 21.8% of the 8446.6 miles of railroad track in California. The 4-county SCAB track mileage was obtained by subtracting the 180.0 miles in the counties of Santa Barbara and Ventura, leaving 1662.3 miles in the 4-county SCAB (19.7% of the state). The track miles existing on the 50X50-mile grid totalled 1047.9 miles (12.4% of the state).

(f) 30.8% of the California residential and commercial oil is consumed in the 6-county basin (see note [c], above); therefore, \(5697 \times 0.308 = 1754.7 \times 10^3\) bbls/yr.

(g) 48% of the California industrial oil use is in the 6-county basin (see note [d], above); therefore \(973 \times 0.48 = 467.0 \times 10^3\) bbls/yr.

(h) The Energy Information Administration (1983) gives \(71,294 \times 10^3\) gal/yr for LPG use by internal combustion engines in California during 1982. Assuming usage is proportional to population, this
given $71.294 \times 10^3$ gal + 42 gal/bbl ($= 1697.5$ bbls/yr) $\times 48% = 814.8 \times 10^3$ bbls/yr; see note (d).

(i) The Energy Information Administration (1983) gives $219,239 \times 10^3$ gal/yr for LPG use by residential and commercial customers in California for 1982. The fraction of LPG used by customers in the 6-county basin is estimated to be 30.8% (see note [c], above); therefore, $219,239 \times 10^3$ gal/yr + 42 gal/bbl ($= 5220.0$ bbls/yr) $\times 30.8% = 1607.8$ bbls/yr.

(j) LPG use in the state of California for chemical and industrial uses totalled $214,216 \times 10^3$ gal in 1982 from the Energy Information Administration (1983). Also, 17.8% of chemical/industrial LPG use was for industrial customers (including a small amount of refinery fuel) in the United States during 1982. Assuming this proportion holds for California LPG use, then $214,216 \times 10^3$ gal/yr $\times 17.8% + 42$ gal/bbl $= 907.5$ bbls/yr $\times 10^3$ bbls/yr. It is assumed that 48% of the California LPG use is in the 6-county basin (see note [d], above); therefore, $907.5 \times 48% = 435.6 \times 10^3$ bbls/yr.

(k) Assumed distillate fuel oil heating value of $5825 \times 10^3$ Btu/bbl from Cass (1977, p. 598).

(l) Assumed residual oil heating value of $6287 \times 10^3$ Btu/bbl from Cass (1977, p. 598).

(m) Assumed LPG heating value of $3800 \times 10^3$ Btu/bbl from Cass (1977, p. 598).


(o) Assuming the fuel use in the 6-county basin is distributed geographically in proportion to population, then 93.3% of the 6-county basin fuel use is in the 4-county SCAB and 77.5% of the 6-county basin fuel use is in the 50X50-mile grid.

(p) The fraction of fuel used in the 4-county SCAB is assumed to be equal to the ratio of industrial natural gas usage in the four counties to industrial usage in the six counties, which is 95.1% from Table B.5. This gives $34.92 \times 10^9$ Btu/yr for the 4-county industrial distillate oil used. This includes distillate oil used by internal combustion engines, which is estimated to be $7.00 \times 10^7$ Btu/day in the 4-county SCAB and $5.43 \times 10^9$ Btu/day in the 50X50-mile grid, from the Air Resources Board of California 1982 inventory of area and point source emissions (Ranzieri 1983); see note (n), Table A.2. Therefore, the total for industrial distillate not including IC fuel in the 4-county SCAB is $34.92 - 7.00 = 27.92 \times 10^9$ Btu/day. It is further assumed
that the fraction of the 4-county SCAB distillate oil used within
the 50X50-mile grid is equal to the ratio of industrial natural
gas usage in the grid versus the four counties, which is 95.1%;
see Table B.5. Therefore, the grid total is 27.92 \times 95.1\% =
26.54 \times 10^7 \text{ Btu/day}.

(q) Assuming the fuel use for industrial customers is proportional to
the natural gas used in the 6-county, 4-county, and
50X50-mile grid gives 95.1\% of the 6-county basin industrial fuel
is in the 4-county SCAB and 90.4\% of the 6-county basin
industrial fuel is in the 50X50-mile grid.

(r) All the coke oven gas use is in the 4-county SCAB but outside the
50X50-mile grid.
REFERENCES FOR APPENDIX B

Air Pollution Control District, Ventura County. 1983. Forwarded electric utility fuel use data reports.


Kortz, R. G., City of Long Beach Gas Department. Personal communication, August 1983: provided 1982 monthly natural gas deliveries by FPC priority number.


Appendix C

1982 Emissions Estimates in the 4 County South Coast Air Basin

The following tables contain estimates of particle emissions in the 4 county South Coast Air Basin during 1982. The methodology used to construct Tables C.1 through C.4 is the same as that used in Tables A.1 through A.4, respectively. Therefore explanatory notes are omitted from tables in Appendix C. The interested reader will find explanations of the calculations in the notes following the corresponding table in Appendix A.
<table>
<thead>
<tr>
<th>M O B I L E  S O U R C E S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway Vehicles</td>
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<tr>
<td>Catalyst Autos</td>
</tr>
<tr>
<td>Non-catalyst Autos</td>
</tr>
<tr>
<td>Diesel Autos</td>
</tr>
<tr>
<td>Diesel Light Trucks</td>
</tr>
<tr>
<td>Non-catalyst Light Trucks</td>
</tr>
<tr>
<td>Diesel Light Trucks</td>
</tr>
<tr>
<td>Diesel Medium Trucks</td>
</tr>
<tr>
<td>Non-catalyst Medium Trucks</td>
</tr>
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<td>Gasoline Heavy Trucks</td>
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<td>Diesel Heavy Trucks</td>
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<td>Residual Oil-fired Ships</td>
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Total Mobile Sources:

<table>
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<th>Emissions Estimates for Mobile Sources</th>
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</thead>
<tbody>
<tr>
<td>in a County South Coast Air Basin</td>
</tr>
</tbody>
</table>

(a) See Table A.1 for calculation procedure.
## Table C.2

**Emissions Estimates for Stationary Combustion Sources in 4 County South Coast Air Basin**

(a)

<table>
<thead>
<tr>
<th>STATIONARY SOURCES</th>
<th>Estimated 1982 Fuel Use (10^9 Btu/day)</th>
<th>Total particulate emissions (kg/10^9 Btu)</th>
<th>Total particulate mass fraction &lt; 2.1 μm</th>
<th>Fine particulate mass fraction &lt; 2.1 μm</th>
<th>%Total Carbon in Fine particulate mass fraction &lt; 2.1 μm</th>
<th>Partition of Carbon</th>
<th>Fine Organic Carbon (kg/day)</th>
<th>Fine Elemental Carbon (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electric Utilities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas (boilers)</td>
<td>653.6</td>
<td>1.08</td>
<td>705.9</td>
<td>92%</td>
<td>649.4</td>
<td>7%</td>
<td>45.5</td>
<td>100%</td>
</tr>
<tr>
<td>Natural Gas (turbines)</td>
<td>38.4</td>
<td>5.99</td>
<td>230.0</td>
<td>92%</td>
<td>211.6</td>
<td>7%</td>
<td>14.8</td>
<td>100%</td>
</tr>
<tr>
<td>Residual Oil</td>
<td>118.9</td>
<td>9.09</td>
<td>1080.8</td>
<td>95%</td>
<td>1026.8</td>
<td>20%</td>
<td>205.4</td>
<td>80%</td>
</tr>
<tr>
<td>Distillate Oil (turbines)</td>
<td>0.43</td>
<td>16.35</td>
<td>7.0</td>
<td>96.4%</td>
<td>6.8</td>
<td>15%</td>
<td>1.0</td>
<td>42%</td>
</tr>
<tr>
<td>Digester Gas</td>
<td>0.57</td>
<td>1.08</td>
<td>0.6</td>
<td>92%</td>
<td>0.6</td>
<td>7%</td>
<td>0.04</td>
<td>100%</td>
</tr>
</tbody>
</table>

| **Refinery Fuel** | | | | | | | | |
| Natural Gas | 100.6 | 9.07 | 912.4 | 92% | 889.4 | 7% | 58.8 | 100% | small | 58.8 | 0 |
| Refinery Gas | 334.1 | 9.07 | 3000.3 | 92% | 2787.9 | 7% | 195.2 | 100% | small | 195.2 | 0 |
| Residual Oil | 5.34 | 21.64 | 115.6 | 72% | 83.2 | 11.3% | 9.4 | 80% | 20% | 7.5 | 1.9 |

| **Non-refinery Industrial/Low Priority Commercial Fuel** | | | | | | | | |
| Natural Gas | 308.5 | 7.56 | 2332.3 | 92% | 2145.7 | 7% | 150.2 | 100% | small | 150.2 | 0 |
| LPG | 4.31 | 7.56 | 32.6 | 92% | 30.0 | 7% | 2.1 | 100% | small | 2.1 | 0 |
| Residual Oil | 7.65 | 21.64 | 165.3 | 72% | 119.2 | 11.3% | 13.5 | 80% | 20% | 10.8 | 2.7 |
| Distillate Oil | 27.9 | 23.55 | 657.0 | 96.4% | 633.4 | 15% | 95.0 | 42% | 50% | 39.9 | 55.1 |
| Coke Oven Gas | 5.99 | 20.41 | 122.3 | 99% | 121.0 | 21% | 25.4 | 77% | 23% | 19.6 | 5.8 |
| Gasoline (IC engines) | 37.3 | 7.56 | 285.3 | 92% | 260.8 | 7% | 18.3 | 100% | small | 18.3 | 0 |
| Distillate Oil (IC engines) | 5.16 | 23.49 | 121.2 | 99% | 120.0 | 20% | 24.0 | 90% | 10% | 21.6 | 2.4 |

| **Residential/High Priority Commercial Fuel** | | | | | | | | |
| Natural Gas | 854.8 | 8.06 | 6889.7 | 92% | 6338.5 | 12% | 760.6 | 67% | 33% | 509.6 | 251.0 |
| LPG | 15.6 | 8.06 | 125.7 | 92% | 115.7 | 12% | 13.9 | 67% | 33% | 9.3 | 4.6 |
| Residual Oil | 28.2 | 21.64 | 610.2 | 72% | 439.4 | 11.3% | 49.6 | 80% | 20% | 39.7 | 9.9 |
| Distillate Oil | 20.6 | 21.64 | 445.8 | 96.4% | 429.7 | 15% | 64.0 | 42% | 38% | 27.1 | 37.4 |
| Coal | 0.51 | 378.0 | 192.8 | 62% | 119.5 | 96% | 114.7 | 78% | 22% | 88.5 | 25.2 |

**TOTAL FUEL COMBUSTION**

| | 1890.5 | 1424.2 | 466.3 |

(a) See Table A.2 for calculation procedure.
<table>
<thead>
<tr>
<th>STATIONARY SOURCES</th>
<th>Total Particulate</th>
<th>Mass Fraction</th>
<th>Fine Suspended</th>
<th>% Total Carbon in Fine Total</th>
<th>Partition of Carbon</th>
<th>Fine Organic Carbon</th>
<th>Fine Elemental Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emissions (kg/day)</td>
<td>&lt; 2.1 µm</td>
<td>(kg/day)</td>
<td>&lt; 2.1 µm</td>
<td>(kg/day)</td>
<td>% OC</td>
<td>% EC</td>
</tr>
<tr>
<td><strong>Industrial Process Point Sources</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Petroleum Industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refining (FCCU)</td>
<td>1591.2</td>
<td>54%</td>
<td>859.2</td>
<td>3.8%</td>
<td>32.7</td>
<td>75%</td>
<td>25%</td>
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<tr>
<td>Other</td>
<td>342.4</td>
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<td>342.4</td>
<td>58%</td>
<td>284.2</td>
<td>100%</td>
<td>0%</td>
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<td>Organic Solvent Use</td>
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<td></td>
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<td>Surface Coating</td>
<td>3131.6</td>
<td>91.5%</td>
<td>2865.4</td>
<td>55%</td>
<td>1576.0</td>
<td>100%</td>
<td>0%</td>
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<tr>
<td>Printing</td>
<td>32.0</td>
<td>91.5%</td>
<td>29.3</td>
<td>55%</td>
<td>16.1</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Degreasing</td>
<td>25.6</td>
<td>100%</td>
<td>29.6</td>
<td>53%</td>
<td>24.6</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Other</td>
<td>154.1</td>
<td>100%</td>
<td>154.1</td>
<td>53%</td>
<td>127.9</td>
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<td>Chemical Organic</td>
<td>2435.3</td>
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<td>33%</td>
<td>759.4</td>
<td>94%</td>
<td>6%</td>
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<td>Inorganic</td>
<td>151.2</td>
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<tr>
<td>Metallurgical</td>
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<tr>
<td>Primary</td>
<td>6211.1</td>
<td>98.2%</td>
<td>6099.3</td>
<td>59.2%</td>
<td>3610.8</td>
<td>100%</td>
<td>0%</td>
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<tr>
<td>Secondary</td>
<td>1506.8</td>
<td>88.5%</td>
<td>1687.2</td>
<td>13%</td>
<td>219.4</td>
<td>100%</td>
<td>0%</td>
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<td>Fabrication</td>
<td>556.4</td>
<td>77%</td>
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<td>Mineral</td>
<td>14257.1</td>
<td>55.1%</td>
<td>7855.7</td>
<td>10.2%</td>
<td>801.3</td>
<td>74.4%</td>
<td>25.6%</td>
</tr>
<tr>
<td>Waste Burning</td>
<td>297.9</td>
<td>84.5%</td>
<td>251.7</td>
<td>10%</td>
<td>75.5</td>
<td>74%</td>
<td>25%</td>
</tr>
<tr>
<td>Wood Processing</td>
<td>372.4</td>
<td>56%</td>
<td>208.5</td>
<td>41.2%</td>
<td>85.9</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Food and Agriculture</td>
<td>2442.3</td>
<td>1%</td>
<td>24.4</td>
<td>2%</td>
<td>2.0</td>
<td>96%</td>
<td>4%</td>
</tr>
<tr>
<td>Asphalt Roofing</td>
<td>377.1</td>
<td>93%</td>
<td>350.7</td>
<td>24%</td>
<td>24.4</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Textile</td>
<td>237.8</td>
<td>3%</td>
<td>2.4</td>
<td>5%</td>
<td>0</td>
<td>-</td>
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<tr>
<td>Rubber and Plastics</td>
<td>77.2</td>
<td>100%</td>
<td>77.2</td>
<td>58%</td>
<td>64.1</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Coke Calciner</td>
<td>266.4</td>
<td>100%</td>
<td>266.4</td>
<td>89.8%</td>
<td>239.2</td>
<td>92.8%</td>
<td>7.2%</td>
</tr>
<tr>
<td>Miscellaneous Industrial</td>
<td>2098.7</td>
<td>69.5%</td>
<td>1458.6</td>
<td>32.7%</td>
<td>477.0</td>
<td>92.8%</td>
<td>7.2%</td>
</tr>
<tr>
<td><strong>TOTAL PROCESS POINT SOURCES</strong></td>
<td></td>
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</table>

(a) See Table A.3 for calculation procedure.
<table>
<thead>
<tr>
<th>Fugitive Sources</th>
<th>Total Emissions (kg/day)</th>
<th>Mass Fraction (%)</th>
<th>Fine Total Emissions (kg/day)</th>
<th>Fine Mass Fraction (%)</th>
<th>Fine Total Carbon in Particulate (kg/day)</th>
<th>Fine Carbon Partition of Carbon</th>
<th>Fine Organic Carbon (kg/day)</th>
<th>Fine Elemental Carbon (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road and Building Construction</td>
<td>90341.0</td>
<td>32%</td>
<td>28909.1</td>
<td>0%</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Agricultural Tilling</td>
<td>68200.9</td>
<td>30.5%</td>
<td>20801.3</td>
<td>0%</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Livestock Feedlots</td>
<td>38073.6</td>
<td>54%</td>
<td>20559.7</td>
<td>2%</td>
<td>411.2</td>
<td>100%</td>
<td>0%</td>
<td>411.2</td>
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<tr>
<td>Unpaved Road Dust</td>
<td>33009.3</td>
<td>24%</td>
<td>7922.2</td>
<td>0%</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Paved Road Dust</td>
<td>158300.6</td>
<td>27%</td>
<td>42742.8</td>
<td>15.1%</td>
<td>6454.2</td>
<td>96.7%</td>
<td>3.3%</td>
<td>6241.2</td>
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<td>Tire Attrition</td>
<td>5379.2</td>
<td>25%</td>
<td>1344.8</td>
<td>87%</td>
<td>1170.0</td>
<td>67%</td>
<td>33%</td>
<td>783.9</td>
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<tr>
<td>Brake Lining Attrition</td>
<td>7530.8</td>
<td>100%</td>
<td>7530.8</td>
<td>26%</td>
<td>2108.6</td>
<td>82%</td>
<td>18%</td>
<td>1728.1</td>
</tr>
<tr>
<td>Forest Fires (seasonal)</td>
<td>13564.8</td>
<td>86%</td>
<td>11665.7</td>
<td>63%</td>
<td>7349.4</td>
<td>94%</td>
<td>6%</td>
<td>6984.8</td>
</tr>
<tr>
<td>Structural Fires</td>
<td>396.0</td>
<td>86.3%</td>
<td>342.3</td>
<td>30%</td>
<td>102.8</td>
<td>68%</td>
<td>32%</td>
<td>69.9</td>
</tr>
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<td>Fireplaces</td>
<td>18161.8</td>
<td>42%</td>
<td>7627.9</td>
<td>4273.0</td>
<td>1541.9</td>
<td>731.1</td>
<td>-</td>
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</tr>
<tr>
<td>Cigarettes</td>
<td>2008.6</td>
<td>100%</td>
<td>2008.6</td>
<td>82.5%</td>
<td>1657.1</td>
<td>97%</td>
<td>3%</td>
<td>1607.4</td>
</tr>
<tr>
<td>Charcoal Broilers</td>
<td>6342.0</td>
<td>100%</td>
<td>6342.0</td>
<td>82.3%</td>
<td>5219.5</td>
<td>98.5%</td>
<td>1.5%</td>
<td>5141.2</td>
</tr>
<tr>
<td>Agricultural Burning</td>
<td>28.8</td>
<td>94%</td>
<td>27.1</td>
<td>98%</td>
<td>14.1</td>
<td>91%</td>
<td>9%</td>
<td>12.8</td>
</tr>
<tr>
<td>Sea Salt</td>
<td>65406.9</td>
<td>9%</td>
<td>5232.6</td>
<td>0%</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Roofing Tar Pots</td>
<td>1028.7</td>
<td>100%</td>
<td>1028.7</td>
<td>81.7%</td>
<td>840.4</td>
<td>99.9%</td>
<td>0.1%</td>
<td>839.6</td>
</tr>
</tbody>
</table>

**TOTAL FUGITIVE SOURCES**

|                | 29600.3 | 27286.6 | 2313.8 |

(a) See Table A.4 for calculation procedure.
APPENDIX D

ESTIMATES OF THE COSTS AND EMISSION REDUCTIONS
OF FINE PARTICLE CONTROL MEASURES

The costs and fine carbon particle emission reductions for the control measures used in this study are summarized in Chapter 5, Table 5.1. The source types affected by each control measure are identified by numbers which appear below the titles of the control measures. These numbers correspond to the source type identification numbers listed in the right-hand column of Table D.38.
Cost Calculation D.1

Unleaded Gasoline Use by Non-catalyst Autos and Light Trucks

Sources Affected: 3, 4

Cost: $82.924 \times 10^6$/yr

1. Difference in retail price between unleaded and leaded gas, national average 1982: $6.7$/gal or $536.20/10^9$ Btu from Energy Information Administration (1982).
2. SCAB 1982 fuel use: $423.7 \times 10^9$ Btu/day (from Table C.1).

Total Cost = ($536.20/10^9$ Btu) ($423.7 \times 10^9$ Btu/day) 
\times (365 \text{ days/yr}) = $82.924 \times 10^6$/yr

Purpose:

This is not a control measure for aerosol carbon emission reduction. The cost of unleaded fuel is needed in order to evaluate Control Measure D.2 which involves replacement of non-catalyst autos and light trucks by catalyst equipped vehicles.
Control Measure D.2

Catalysts on Non-catalyst Autos and Light Trucks

Sources Affected: 3,4

Cost: \(236.352 \times 10^6\$/yr\)

1. Unleaded fuel must be used. Cost: \(82.926 \times 10^6\$/yr\) (see Cost Calculation D.1).
2. Catalyst cost: $155 per system for 1978 Federal System (this system would be adequate to achieve carbon particle emission reduction cited) from Cross (1982). Convert to 1982 dollars by multiplying by 0.512/0.344 (Dept. of Labor 1985), which gives a cost of $230.70/system.
3. Assume 5 year payback period at 10% interest which yields a capital recovery factor of 0.26380. This gives an annual cost of $60.86/vehicle-yr for the catalyst system.
4. Number of light-duty autos and trucks in SCAB, 1982, is estimated to be 6,243,184 from the California Air Resources Board (1983a). From Table A.5, 40.38% of the automobile fleet was non-catalyst in 1982 giving approximately 2,521,000 light-duty non-catalyst vehicles.

Total Cost = \((60.86/\text{vehicle-yr}) \times 2,521,000 \text{ vehicles}\) 
+ 82.924 \times 10^6\$/yr = 236.352 \times 10^6\$/yr

Fine TC Reduction: 3.7387 T/day

1. Fine total carbon emission factors:
   - Noncat: 9.72 kg/10^9 Btu (see Table C.1).
   - Catalyst: 0.91 kg/10^9 Btu (see Table C.1).
2. Fine total carbon emissions from sources: 4.1230 T/day (SCAB, Table C.1).

\[\text{Reduction} = (4.1230 \ T/day) \left(1 - \frac{0.91}{9.72}\right) = 3.7387 \ T/day\]

TC fraction reduction = 0.9068
EC fraction reduction = \(1 - 0.45\) \(1 - 0.9068)/(0.213) = 0.8031\) (see Table A.1 for EC/TC ratios)
Control Measure D.3

#1 Diesel Fuel Use by Light-duty Diesel Vehicles

Sources Affected: 6,7

Cost: $4.317 \times 10^6 \$/yr

1. Diesel price difference: $8.5/\text{gal}$ (Difference of arithmetic averages for #1 and #2 diesel fuel from 1982 Lundberg Survey from Turner 1985). $(\$0.085/\text{gal}) (\frac{42 \text{ gal}}{\text{bbl}}) (\frac{1 \text{ bbl}}{5825 \times 10^3 \text{ Btu}}) = \$612.88/10^9 \text{ Btu}.$

2. SCAB 1982 fuel use: $19.3 \times 10^9 \text{ Btu/day}$ (from Table C.1).

Total Cost = $(\$612.88/10^9 \text{ Btu}) (19.3 \times 10^9 \text{ Btu/day}) (365 \text{ days/yr})$

$= 4.317 \times 10^6 \$/yr$

Fine TC Reduction: 0.2475 T/day

1. Particulate emissions are reduced 20% by switching from #2 diesel to #1 diesel (from Burley and Rosebrock 1979, SAE 790923, fig. 6).

2. Fine total carbon emissions from sources: 1.2375 T/day (SCAB, Table C.1).

Reduction = $(0.20)(1.2375) = 0.2475 \text{ T/day}$

TC fraction reduction = 0.20
EC fraction reduction = 0.20

Conflicts: D.4, D.5
Control Measure D.4

Particle Traps on Light-duty Diesel Vehicles

Sources Affected: 6, 7

Cost: $8.148 \times 10^6$/yr

1. California Air Resources Board (1983b) cites a number of sources including manufacturers and independent consultants concerning estimates of the consumer cost of a fuel additive ceramic monolith trap-oxidizer system for light-duty diesel vehicles. Estimates of the initial cost ranged from $140 to $450, although the CARB believes the lower end of the range to be most realistic. Their findings are supported by cost estimates of Weaver et al. (1983), who estimated an initial cost of $180 to $342. Assume an initial cost of $280/vehicle (approximate middle of both ranges stated).

2. Assume 5 year payback period at 10% interest which results in a capital recovery factor of 0.26380. This gives an equivalent annual charge for the capital cost of $73.86/vehicle-yr.

3. Number of light-duty diesel vehicles in SCAB, 1982 estimated as 92,400 from California Air Resources Board (1983a; 6,243,184 light-duty vehicles) and Table A.5 (diesels make up 1.48% of light-duty fleet).

4. Weaver et al. (1983) estimated the loss in fuel economy due to the trap to be about 2%. Total fuel use by light-duty diesels in 1982 was $19.3 \times 10^9$ Btu/day (SCAB, Table C.1) or $50.91 \times 10^6$ gal/yr. Dividing by 92,400 vehicles gives 550.9 gal/vehicle-yr. At $1.30/gal, this gives additional cost of $14.32/vehicle-yr. The total cost is then $88.18/vehicle-yr.

Total Cost = \left( \frac{88.18}{\text{vehicle-year}} \right) (92,400 \text{ vehicles})

= 8.148 \times 10^6$/yr
Control Measure D.4 (continued)

Fine TC Reduction: 0.9900 T/day

1. Collection efficiencies ranging from 50% to greater than 90% have been reported for the cellular ceramic filters (CARB 1982; Weaver 1983; Urban et al. 1983; Ludecke and Dimick 1983; Miller et al. 1983; Montierth 1984; Ullman et al. 1984; Howitt and Montieth 1981; Wade et al. 1983; Wiedemann et al. 1983, 1984; Ludecke and Bly 1984; General Motors 1983). A mean value of 80% would probably be attained for large scale use.

2. Fine total carbon emissions from sources: 1.2375 T/day (SCAB, Table C.1).

Reduction = (0.80) (1.2375) = 0.9900 T/day

TC fraction reduction = 0.80
EC fraction reduction = 0.80

Conflicts: D.3, D.5
Control Measure D.5

Particle Traps & #1 Diesel Fuel Use for Lt-duty Diesel Vehicles

Sources Affected: 6, 7

Cost: $12.465 \times 10^6 / \text{yr}$

1. Cost of #1 diesel fuel: $4.317 \times 10^6 / \text{yr}$ (see Control D.3).
2. Particle trap system cost: $8.148 \times 10^6 / \text{yr}$ (see Control D.4).

Total Cost = $4.317 + 8.148 = 12.465 \times 10^6 / \text{yr}$

Fine TC Reduction: 1.0395 T/day

1. 20% reduction due to #1 diesel fuel use (see Control D.3).
2. Additionally, 80% of the remaining 80% is removed by trap (see Control D.4).
3. Fine total carbon emissions from sources: 1.2375 T/day (SCAB, Table C.1).

Reduction = (1.2375 T/day) [0.20 + 0.80 (0.80)] = 1.0395 T/day

TC fraction reduction = 0.84
EC fraction reduction = 0.84

Conflicts: D.3, D.4
Cost Calculation D.6

Unleaded Gasoline Use by Non-catalyst Medium & Heavy Vehicles

Sources Affected: 9,10

Cost: \( 24.445 \times 10^6 \$/yr \)

1. Difference in retail price between unleaded and leaded gas: \( 536.20 \times 10^9 \text{ Btu} \) (see Control D.1).
2. SCAB 1982 fuel use: \( 124.9 \times 10^9 \text{ Btu/day} \) (from Table C.1).

Total Cost = \( (536.20 \times 10^9 \text{ Btu}) (124.9 \times 10^9 \text{ Btu/day}) (365 \text{ day/yr}) \)
            \( = 24.445 \times 10^6 \$/yr \)

Purpose:

This is not a control measure for aerosol carbon emission reduction. The cost of unleaded fuel is needed in order to evaluate Control Measure D.7 which involves replacement of non-catalyst medium and heavy vehicles by catalyst equipped vehicles.
Control Measure D.7

Catalysts on Non-Catalyst Medium & Heavy Gas Vehicles

Sources Affected: 9, 10

Cost: \(66.453 \times 10^6\$/yr\)

1. Unleaded fuel must be used. Cost: \(24.445 \times 10^6\$/yr\) (see Cost Calculation D.6).
2. Catalyst cost: \$353/system (average of estimates by EPA, GM, and Chrysler for 1979 system) from Cross (1982). Convert to 1982 dollars by multiplying by 0.461/0.344 (Dept. of Labor 1985) which gives a cost of \$473.06/system.
3. Assume 5 year payback period at 10% interest which results in a capital recovery factor of 0.26380. Then the annual cost is \$124.79/vehicle-yr for the catalyst system.

Total Cost = \$(124.79/vehicle-yr) (336,631 vehicles)
+ \(24.445 \times 10^6\$/yr = 66.453 \times 10^6\$/yr\)

Fine TC Reduction: 1.1026 T/day

1. Fine total carbon emission factors:
   Noncat: 9.72 kg/10^9 Btu (see Table C.1).
   Catalyst: 0.91 kg/10^9 Btu (see Table C.1).
   (Note: Small differences between these emission factors and those found by dividing TC emissions by fuel use in Table C.1 are due to roundoff. These emission factors per unit fuel burned are assumed to be the same as for light-duty vehicles; see Control D.2.)
2. Fine total carbon emissions from sources: 1.2159 T/day (SCAB, Table C.1).

Reduction = (1.2159 T/day) \((1 - 0.91/9.72) = 1.1026 T/day\)

TC fraction reduction = 0.9068
EC fraction reduction = 0.8031 (see Control D.2)
Control Measure D.8

#1 Diesel Fuel Use by Heavy-duty Diesel Vehicles

Sources Affected: 11

Cost: $38.523 \times 10^6 \$/yr

1. Diesel price difference: $612.9/10^9 \text{ Btu}$ (see Control D.3).
2. SCAB 1982 fuel use: $172.2 \times 10^9 \text{ Btu/day}$ (from Table C.1).

\[
\text{Total Cost} = (612.9/10^9 \text{ Btu}) (172.2 \times 10^9 \text{ Btu/day}) (365 \text{ day/yr}) \\
= 38.523 \times 10^6 \$/yr
\]

Fine TC Reduction: 1.4808 T/day

1. 20% reduction (see Control D.3).
2. Fine total carbon emissions from sources: 7.4041 T/day (SCAB, Table C.1).

\[
\text{Reduction} = (0.20) (7.4041 \text{ T/day}) = 1.4808 \text{ T/day}
\]

TC fraction reduction = 0.20
EC fraction reduction = 0.20

Conflicts: D.9, D.10
Control Measure D.9

Particle Traps on Heavy-duty Diesel Vehicles

Sources Affected: 11

Cost: $36.240 \times 10^6 \$/yr

1. Weaver et al. (1984) estimates a lifecycle cost (assuming average vehicle life of 8 years) for a Monolith/Additive particle trap system of $2471.58/vehicle if the trap is cleaned periodically (including the cost of periodic cleaning) or $3906.74/vehicle if the trap must be replaced instead of cleaned (including replacement costs). These costs include estimates for maintenance and loss in fuel consumption. Using the average of these two costs gives a lifecycle cost of $3189.16/vehicle.

2. Amortizing this cost over 8 years at 10% interest results in a capital recovery factor of 0.18744, which gives an annual cost of $597.78/vehicle-yr.

3. Number of heavy-duty diesels in SCAB, 1982 is 60,624 from California Air Resources Board (1983a).

Total Cost = ($597.78/vehicle-yr) (60,624 vehicles)
= $36.240 \times 10^6 \$/yr

Fine TC Reduction: 6.6637 T/day

1. This trap system can be designed to be over 90% effective from Weaver et al. (1984).

2. Fine total carbon emissions from sources = 7.4041 T/day
(SCAB, Table C.1).

Reduction = (0.90) (7.4041 T/day) = 6.6637 T/day

TC fraction reduction = 0.90
EC fraction reduction = 0.90

Conflicts: D.8, D.10
Control Measure D.10

Particle Traps & #1 Diesel Fuel for Heavy-duty Diesel Vehicles

Sources Affected: 11

Cost: $74,763 \times 10^6$/yr

1. Cost of #1 diesel fuel: $38,523 \times 10^6$/yr (see Control D.8).
2. Particle trap system cost: $36,240 \times 10^6$/yr (see Control D.9).

Total Cost = $38,523 + 36,240 = 74,763 \times 10^6$/yr

Fine TC Reduction: 6.8118 T/day

1. 20% reduction due to #1 diesel fuel use (see Control D.3).
2. Additionally, 90% of the remaining 80% is removed by trap (see Control D.9).
3. Fine total carbon emissions from sources: 7.4041 T/day (SCAB, Table C.1).  
   Reduction = (7.4041 T/day) \times [0.20 + 0.90 (0.80)] = 6.8118 T/day

TC fraction reduction = 0.92  
EC fraction reduction = 0.92

Conflicts: D.8, D.9
Control Measure D.11

Air Taxi Modification (Towing)

Sources Affected: 12

Cost: $0 (overall savings expected)

This control measure is proposed as part of the 1982 Air Quality Management Plan for the South Coast Air Basin. The South Coast Air Quality Management District (1982) has determined that the fuel savings involved should exceed the cost of the change in operations.

Fine TC Reduction: 0.1354 T/day

1. Of the 417.1 kg/day TC emitted from jet aircraft in the SCAB (see Table C.1), emissions at the surface account for 227.8 kg/day (idle and takeoff cycles — using USEPA calculation procedure, see Table A.1; note [c]; TC (kg/day) from idle: 193.32; takeoff: 34.44; climbout: 87.49; approach: 101.84). Idle operations, therefore, account for 84.9% of emissions from surface operations.

2. Most of the particulate emissions during idle can be avoided by towing the aircraft into and out of the terminal (even considering tow truck fuel use). A conservative estimate is a 70% reduction. See South Coast Air Quality Management District (1982) for a description of this control measure.

Reduction = (0.849) (0.70) (0.2278 T/day) = 0.1354 T/day

TC fraction reduction = 0.5943
EC fraction reduction = 0.5943
Control Measure D.12

0.5% S Residual Oil for Shipping — Berthing Operations

Sources Affected: 16

Cost: \(2.253 \times 10^6\$/yr\)

1. Low sulfur fuel oil (0.5% S) is to be used for berthing operations only. Fuel costs will increase approximately $2 per barrel (from Nazemi et al. 1981) or $318.12/10^9 Btu.

2. Of the \(14.8 \times 10^9\) Btu/day residual oil use in the SCAB for shipping operations in 1982 (see Table C.1), \(9.5 \times 10^9\) Btu/day was used during berthing operations (see Table A.1; note [d]).

3. Additionally, Nazemi et al. (1981) estimate an extra labor cost required for fueling operations of \(1.15 \times 10^6\$/yr.

Total Cost = \((9.5 \times 10^9 \text{ Btu/day}) \times (\$318.12/10^9 \text{ Btu}) \times (365 \text{ days/yr})\)
+ \(1.15 \times 10^6\$/yr = 2.253 \times 10^6\$/yr

Fine TC Reduction: 0.0442 T/day

1. Assume particulate emissions are reduced by 67% for switching from 1.5% S to 0.5% S fuel oil (based on observations by Taback et al. [1979]—particle emissions are proportional to sulfur content).

2. Only 64% of the emissions from residual oil combustion (9.5/14.8; see above) are operated on with this control measure (berthing operations only).

2. Fine total carbon emissions from sources: 0.1030 T/day (SCAB, Table C.1).

Reduction = \((0.67) \times (0.64) \times (0.1030 \text{ T/day}) = 0.0442 \text{ T/day}\)

TC fraction reduction = 0.4288
EC fraction reduction = 0.4288
Control Measure D.13

#1 Diesel Fuel Use by Railroads

Sources Affected: 18

Cost: $5.011 \times 10^6$ $\$/yr

1. Diesel price difference: $612.9/10^9$ Btu (see Control D.3).
2. SCAB 1982 fuel use: $22.4 \times 10^9$ Btu/day (from Table C.1).

Total Cost = ($612.9/10^9$ Btu) $\times$ ($22.4 \times 10^9$ Btu/day) $\times$ 365 day/yr
= $5.011 \times 10^6$ $\$/yr

Fine TC Reduction: 0.2858 T/day

1. Assumed 20% reduction (see Control D.3).
2. Fine total carbon emissions from sources: 1.4289 T/day (SCAB, Table C.1).

Reduction = (0.20) (1.4289 T/day) = 0.2858 T/day

TC fraction reduction = 0.20
EC fraction reduction = 0.20
Control Measure D.14

#1 Diesel Fuel Use in Off-road Diesel Engines

Sources Affected: 19

Cost: \(8.725 \times 10^6\) $/yr

1. Diesel price difference: \(612.9 \times 10^9\) Btu (see Control D.3).
2. SCAB 1982 fuel use: \(39.0 \times 10^9\) Btu/day (from Table C.1).

Total Cost = \(612.9 \times 10^9\) Btu \(\cdot\) \(39.0 \times 10^9\) Btu/day \(\cdot\) \(365\) day/yr
   \[= 8.725 \times 10^6\] $/yr

Fine TC Reduction: 0.4771 T/day

1. Assumed 20% reduction (see Control D.3).
2. Fine total carbon emissions from sources: 2.3854 T/day (SCAB, Table C.1).

Reduction = \(0.20\) \(\cdot\) \(2.3854\) T/day = 0.4771 T/day

TC fraction reduction = 0.20
EC fraction reduction = 0.20

Conflicts: D.15, D.16
Control Measure D.15

Particle Traps on Off-road Diesel Engines

Sources Affected: 19

Cost: $19,535 \times 10^6$/yr

1. Number of off-road diesel vehicles in SCAB, 1982, estimated to be 75,194, of which 44,827 are light-duty and 30,367 are heavy-duty vehicles, from California Air Resources Board (1984) and data of Ranzieri (1983).

2. Light-duty engine particle trap system cost: $73.86/vehicle-yr (see Control D.4; not including additional fuel cost due to loss in fuel economy).

3. Heavy-duty engine particle trap system cost: Capital cost (data from Weaver et al. 1984): $1,121.04; using 5 year payback period at 10% interest gives capital recovery factor of 0.26380, so annual capital cost is $295.73/yr; Maintenance cost: $5/yr (approximation based on ratio of fuel usage for individual off-road engines and heavy diesel trucks and maintenance cost for heavy diesel trucks from Weaver et al. [1984]); Replacement cost (one per 5 year lifetime): $776 (from Weaver et al. 1984); amortized over 5 years gives $145.46/yr. Total cost (not including additional fuel cost due to reduction in fuel economy): $446.19/vehicle-yr.

4. Total fuel use by off-road diesel engines in 1982 was 39.0 $\times 10^6$ Btu/day (SCAB, Table C.1) or 102.9 $\times 10^6$ gal/yr. Assuming a loss in fuel economy of 2% and $1.30/gal, this gives additional fuel cost of $2.675 \times 10^6$/yr.

Total Cost = (\$73.86/vehicle-yr) (44,827 vehicles) 
+ (\$446.19/vehicle-yr) (30,367 vehicles) 
+ 2.675 \times 10^6$/yr = $19,535 \times 10^6$/yr
Control Measure D.15 (continued)

Fine TC Reduction: 2.0827 T/day

1. From Ranzieri (1983), light-duty off-road vehicles (CARB categories AAA54536 and AAA54379; see Table A.10; source type 19) accounted for 26.9% of the emissions in this source class.

2. Particulate fraction reductions: 80% (light-duty; see Control D.4) and 90% (heavy-duty; see Control D.9).

3. Fine total carbon emissions from sources: 2.3854 T/day (SCAB, Table C.1).

Reduction = [(0.269)(0.80) + (0.731)(0.90)] (2.3854 T/day) = 2.0827 T/day

TC fraction reduction = 0.8731
EC fraction reduction = 0.8731

Conflicts: D.14, D.16
Control Measure D.16

Particle Traps & #1 Diesel Fuel Use for Off-road Diesel Engines

Sources Affected: 19

Cost: $28,260 \times 10^6$/yr

1. Cost of #1 diesel fuel: $8,725 \times 10^6$/yr (see Control D.14).
2. Particle trap system cost: $19,535 \times 10^6$/yr (see Control D.15).

Total Cost = $8,725 + 19,535 = 28,260 \times 10^6$/yr

Fine TC Reduction: 2.1432 T/day

1. Light-duty vehicles are 26.9% of this source class (by emissions; see Control D.15).
2. Particulate fraction reductions: 84% (light-duty; see Control D.5) and 92% (heavy-duty; see Control D.10).
3. Fine total carbon emissions from sources: 2.3854 T/day (SCAB, Table C.1).

Reduction = [(0.269)(0.84) + (0.731)(0.92)] (2.3854 T/day) = 2.1432 T/day

TC fraction reduction = 0.8985
EC fraction reduction = 0.8985

Conflicts: D.15, D.16
Cost Calculation D.17

Unleaded Gasoline Use by Off-road Gasoline Engines

Sources Affected: 20

Cost: $1.840 \times 10^6$/yr

1. Difference in retail price between unleaded and leaded gas: $536.20/10^9$ Btu (see Control D.1).

2. SCAB 1982 fuel use estimated as $12.3 \times 10^9$ Btu/day (from Table C.1, using approximate particulate emission factor of $35.0$ kg/$10^9$ Btu from light-duty non-catalyst vehicles).

3. This measure is operable on off-road recreational vehicles and forklifts (source categories AAA47464, AAA54387, and AAA54411; see Table A.10; source 20) but not on residential utility equipment (category AAA47449). The fraction of this source class falling into categories AAA47464, AAA54387, and AAA54411 is 76.6% (by emissions, from Ranzieri [1983]), so controllable fuel use is assumed to be $(0.766) (12.3 \times 10^9$ Btu/day) = $9.4 \times 10^9$ Btu/day.

Total Cost = ($536.20/10^9$ Btu) ($9.4 \times 10^9$ Btu/day) (365 day/yr)

= $1.840 \times 10^6$/yr

Purpose:

This is not a control measure for aerosol carbon emission reduction. The cost of unleaded fuel is needed in order to evaluate Control Measure D.18 which involves replacement of non-catalyst off-road vehicles by catalyst equipped vehicles.
Control Measure D.18

Catalysts on Off-road Gasoline Engines

Sources Affected: 20

Cost: $15.615 \times 10^6$/yr

1. Unleaded fuel must be used. Cost: $1.840 \times 10^6$/yr (see Cost Calculation D.17).
2. Assume catalysts used are similar to those used for light-duty vehicles. Annual cost is $60.86/vehicle-yr (see Control D.2).
3. Number of vehicles in source categories AAA47464, AAA54387, and AAA54411 (see Cost Calculation D.17) is estimated to be 226,346 from California Air Resources Board (1984) data.

Total Cost = $1.840 + 13.775 = 15.615 \times 10^6$/yr

Fine TC Reduction: 0.0831 T/day

1. Assume similar emissions reduction as light-duty catalyst use: 90.68% (see Control D.2).
2. Fine total carbon emissions from sources: 0.1196 T/day (SCAB, Table C.1).
3. Controllable sources account for 76.6% of this source class (see Cost Calculation D.17).

Reduction = (0.9068) (0.766) (0.1196 T/day) = 0.0831 T/day

TC fraction reduction = (0.9068) (0.766) = 0.6946
EC fraction reduction = (0.8031) (0.766) = 0.6152 (see Control D.2)
Control Measure D.19

Use of 0.10%S Residual Oil by Utilities

Sources Affected: 23

Cost: $30.442 \times 10^6$/yr

1. Difference in price between 0.25%S and 0.10%S residual oil is estimated to be $4.41/bbl or $701.45/10^9$ Btu from Energy Information Administration (Monthly Petroleum Price Report, Dec. 1982 and Annual Energy Review, 1982) and data from Robert Elrod (1985) of Southern California Edison Co.

2. SCAB 1982 fuel use: $118.9 \times 10^9$ Btu/day (from Table C.2).

Total Cost = ($701.45/10^9$ Btu) $(118.9 \times 10^9$ Btu/day) $(365$ day/yr) 
= $30.442 \times 10^6$$/yr

Fine TC Reduction: 0.1232 T/day

1. Assume particulate emissions are in proportion to sulfur content, based on observations by Taback et al. (1979). This gives a reduction of 60%.

2. Fine total carbon emissions from sources: 0.2054 T/day (SCAB, Table C.2).

Reduction = (0.60) (0.2054 T/day) = 0.1232 T/day

TC fraction reduction = 0.60
EC fraction reduction = 0.60

Conflicts: D.34
Control Measure D.20

Use of 0.10\%S Residual Oil by Refineries

Sources Affected: 28

Cost: $1.367 \times 10^6$\$/yr

1. Difference in price between 0.25\%S and 0.10\%S residual oil is estimated to be $701.45/10^9$ Btu (see Control D.19).
2. SCAB 1982 fuel use: $5.34 \times 10^9$ Btu/day (from Table C.2).

Total Cost = ($701.45/10^9$ Btu) ($5.34 \times 10^9$ Btu/day) (365 day/yr)
= $1.367 \times 10^6$\$/yr

Fine TC Reduction: 0.0056 T/day

1. Assume particulate emissions are in proportion to sulfur content, based on observations by Taback et al. (1979). This gives a reduction of 60%.
2. Fine total carbon emissions from sources: 0.0094 T/day (SCAB, Table C.2).

Reduction = (0.60) (0.0094 T/day) = 0.0056 T/day

TC fraction reduction = 0.60
EC fraction reduction = 0.60

Conflicts: D.35
Control Measure D.21

Use of 0.25%S Residual Oil in Industrial Boilers

Sources Affected: 31

Cost: \(0.445 \times 10^6\) $/yr

1. Difference in price between 0.50%S and 0.25%S residual oil is estimated to be \(1.89/\text{bbl}\) or \(300.62/10^9\text{ Btu}\) from Energy Information Administration (Monthly Petroleum Price Report, Dec. 1982 and Annual Energy Review, 1982) and data from Robert Elrod (1985) of Southern California Edison Co. Assume that this price difference is representative of the price difference between fuel oil in the range [0.25%S to 0.50%S] vs. oil meeting [\(\leq 0.25\%\text{S}\)] specifications.

2. Approximately 53% of residual oil used in industrial boilers is in the range 0.25% \(\leq \%\text{S} \leq 0.50\%\), from industrial fuel use survey (South Coast Air Quality Management District 1983).

3. SCAB 1982 fuel use: \(7.65 \times 10^9\text{ Btu/day}\) (from Table C.2).

Total Cost = \((0.53 \times 300.62/10^9\text{ Btu}) \times 7.65 \times 10^9\text{ Btu/day}\) \(\times 365\text{ day/yr}\) = \(0.445 \times 10^6\) $/yr

Fine TC Reduction: 0.0047 T/day

1. Assume particulate emissions are in proportion to sulfur content, based on observations by Taback et al. (1979). This gives a reduction of 50% in emissions for 50% reduction in fuel sulfur content.

2. Control is only operative on 53% of residual oil use (see note [2], above).

3. Fine total carbon emissions from sources: 0.0135 T/day (SCAB, Table C.2). Controllable carbon emissions:

\[
\frac{(0.0135 \text{ T/day}) \times 0.5}{0.47 + 0.53/0.5} = 0.0094 \text{ T/day.}
\]

Reduction = \((0.50) (0.0094 \text{ T/day}) = 0.0047 \text{ T/day}

TC fraction reduction = 0.3464
EC fraction reduction = 0.3464

Conflicts: D.22, D.36
Control Measure D.22

Use of 0.10%S Residual Oil in Industrial Boilers

Sources Affected: 31

Cost: $2.404 \times 10^6 \$/yr

1. Cost for getting all industries down to 0.25%S: $0.445 \times 10^6 \$/yr (see Control D.21).
2. Difference in price between 0.25%S and 0.10%S residual oil is $701.45/10^9 \text{ Btu} (\text{see Control D.19}) (assumed to represent price increase for reducing maximum allowable sulfur content from 0.25%S to 0.10%S).
3. SCAB 1982 fuel use: $7.65 \times 10^9 \text{ Btu/day} (\text{from Table C.2}).

Total Cost = ($701.45/10^9 \text{ Btu}) (7.65 \times 10^9 \text{ Btu/day}) (365 \text{ day/yr})
+ $0.445 \times 10^6 \$/yr = $2.404 \times 10^6 \$/yr

Fine TC Reduction: 0.0100 T/day

1. Assume particulate emissions are in proportion to sulfur content, based on observations by Taback et al. (1979). This gives an emissions reduction of 60% (for sulfur content reduction from 0.25%S to 0.10%S).
2. Reduction achieved from getting all industries down to 0.25%S: 0.0047 T/day (see Control D.21).
3. Fine total carbon emissions from sources: 0.0135 T/day (SCAB, Table C.2).

Reduction = 0.0047 T/day + (0.60) [(0.0135 - 0.0047) T/day]
= 0.0100 T/day

TC fraction reduction = 0.7386
EC fraction reduction = 0.7386

Conflicts: D.21, D.36
Cost Calculation D.23

Unleaded Gasoline Use in Large Industrial IC Engines

Sources Affected: 35

Cost: $0.060 \times 10^6 \$/yr

1. Difference in retail price between unleaded and leaded gas: $536.20/10^9$ Btu (see Control D.1).
2. SCAB 1982 fuel use: $5.16 \times 10^9$ Btu/day (from Table C.2).
3. This measure is operable on industrial IC engines (pt. source category 20200301; see Table A.10; source 35). The industrial IC engine source class in emission inventory of Table C.2 includes many types of small gasoline engines that are too small to merit consideration. Large engines which might be considered for control account for only 5.94% of the emissions stated in Table C.2 (from Ranziere 1983). The fuel use that could be controlled is assumed to be $(0.0594) (5.16 \times 10^9$ Btu/day) = $0.307 \times 10^9$ Btu/day.

Total Cost = ($536.20/10^9$ Btu) (0.307 $\times 10^9$ Btu/day) (365 day/yr)
= $0.060 \times 10^6 \$/yr

Purpose:

This is not a control measure for aerosol carbon emission reduction. The cost of unleaded fuel is needed in order to evaluate Control Measure D.24 which involves replacement of non-catalyst industrial IC engines by catalyst equipped engines.
Control Measure D.24

Catalysts on Gasoline Large Industrial IC Engines

Sources Affected: 35

Cost: $0.113 \times 10^6$/yr

1. Unleaded fuel must be used. Cost: $0.060 \times 10^6$/yr (see Cost Calculation D.23).

2. The number of industrial gasoline IC engines is not known exactly. Assume same average heat input per engine as diesel industrial IC engines. From Control D.26, there were 9671 diesel units in the SCAB, 1982, consuming fuel at a rate of $7.00 \times 10^9$ Btu/day, so number of gasoline industrial IC engines in pt. source category 20200301 (see Cost Calculation D.23) is estimated to be $(0.307/7.00)$ (9671 units) = 424 units.

3. Assuming catalysts used are similar to those used for medium/heavy vehicles. Annual cost of catalyst is $124.79/\text{unit-yr}$ (see Control D.7).

Total Cost = ($124.79/\text{unit-yr}$) (424 units) + $0.060 \times 10^6$/yr
= $0.113 \times 10^6$/yr

Fine TC Reduction: 0.0013 T/day

1. Assume similar emissions reduction as medium/heavy-duty catalyst use: 90.68% (see Control D.7).

2. Fine total carbon emissions from sources: 0.0240 T/day (SCAB, Table C.2).

3. Controllable sources account for 5.94% of this source class (see Cost Calculation D.23).

Reduction = (0.9068) (0.0594) (0.0240 T/day) = 0.0013 T/day

TC fraction reduction = (0.9068) (0.0594) = 0.0539
EC fraction reduction = (0.8031) (0.0594) = 0.0477 (see Control D.2)
(Reduction is relative to entire source category of industrial gasoline IC engines shown in Table C.2.)
Control Measure D.25

#1 Diesel Fuel Use in Diesel Industrial IC Engines

Sources Affected: 36

Cost: \(1.566 \times 10^6\$/yr\)

1. Diesel price difference: \(\$612.9/10^9\) Btu (see Control D.3).
2. SCAB 1982 fuel use: \(7.00 \times 10^9\) Btu/day (from Table C.2).

Total Cost = \(\$612.9/10^9\) Btu \((7.00 \times 10^9\) Btu/day \((365\) day/yr\))

= \(1.566 \times 10^6\$/yr\)

Fine TC Reduction: 0.0057 T/day

1. Assumed 20% reduction (see Control D.3).
2. Fine total carbon emissions from sources: 0.0286 T/day (SCAB, Table C.2).

Reduction = \((0.20)\) \((0.0286\) T/day\) = 0.0057 T/day

TC fraction reduction = 0.20
EC fraction reduction = 0.20

Conflicts: D.26, D.27
Control Measure D.26

Particle Traps on Diesel Industrial IC Engines

Sources Affected: 36

Cost: \(4.796 \times 10^6\) $/ yr

1. Number of diesel IC engines in this source category in the SCAB, 1982, estimated to be 9671 units (data on number of units in 1979 from California Air Resources Board [1984], emission factors from Grisinger [1982], and 1982 emissions inventory from Ranzieri [1983]).

2. Assume traps used are similar to those used for heavy-duty diesel engines. From Control D.15, the annual cost (including capital cost, maintenance, and replacement costs) is estimated to be $446.19/unit-yr.

3. SCAB 1982 fuel use for industrial IC engines: \(7.00 \times 10^6\) Btu/day (from Table C.2) or \(18.5 \times 10^6\) gal/yr. Assuming a loss in fuel economy due to the particle trap of 2%, and $1.30/gal, this gives additional fuel cost of \(0.481 \times 10^6\) $/yr.

Total Cost = ($446.19/unit-yr) (9671 units) + \(0.481 \times 10^6\) $/yr
= \(4.796 \times 10^6\) $/yr

Fine TC Reduction: 0.0257 T/day

1. Assume 90% efficient control (similar to heavy-duty trucks—see Control D.9).

2. Fine total carbon emissions from sources: 0.0286 T/day (SCAB, Table C.2).

Reduction = (0.90) (0.0286 T/day) = 0.0257 T/day

TC fraction reduction = 0.90
EC fraction reduction = 0.90

Conflicts: D.25, D.27
Control Measure D.27

Particle Traps & #1 Fuel in Diesel Industrial IC Engines

Sources Affected: 36

Cost: $6.362 \times 10^6 / \text{yr}

1. Cost of #1 diesel fuel: $1.566 \times 10^6 / \text{yr}$ (see Control D.25).
2. Particle trap system cost: $4.796 \times 10^6 / \text{yr}$ (see Control D.26).

Total Cost = $1.566 + 4.796 = 6.362 \times 10^6 / \text{yr}$

Fine TC Reduction: 0.0263 T/day

1. 20% reduction due to #1 diesel fuel use (see Control D.3).
2. Additionally, 90% of the remaining 80% is removed by trap (see Control D.9).
3. Fine total carbon emissions from sources: 0.0286 T/day (SCAB, Table C.2).

Reduction = (0.0286 T/day) \left[ 0.20 + 0.90 \left( 0.80 \right) \right] = 0.0263 T/day

TC fraction reduction = 0.92
EC fraction reduction = 0.92

Conflicts: D.25, D.26
Control Measure D.28

Use of 0.25%S Residual Oil by Residential/Commercial

Sources Affected: 39

Cost: $3.094 \times 10^6$/yr

1. Difference in price between 0.50%S and 0.25%S residual oil is $300.62/10^9$ Btu (see Control D.21).
2. SCAB 1982 fuel use: $28.2 \times 10^8$ Btu/day (from Table C.2).

Total Cost = ($300.62/10^9$ Btu) ($28.2 \times 10^8$ Btu/day) (365 day/yr)
= $3.094 \times 10^6$/yr

Fine TC Reduction: 0.0248 T/day

1. Assume particulate emissions are in proportion to sulfur content, based on observations by Taback et al. (1979). This gives a reduction of 50%.
2. Fine total carbon emissions from sources: 0.0496 T/day (SCAB, Table C.2).

Reduction = (0.50) (0.0496 T/day) = 0.0248 T/day

TC fraction reduction = 0.50
EC fraction reduction = 0.50

Conflicts: D.37
Control Measure D.29

Paved Road Flushing

Sources Affected: 61

Cost: $430.689 \times 10^6$/yr

2. Equivalent street mileage in 4-county SCAB: 42,276 miles (road mileage data from Higgins [1982] and Black [1982]; It was assumed that freeways have as many lanes as 5 surface streets, thus freeway mileage was multiplied by 5 before being added to surface streets to arrive at this total).
3. Assume streets are flushed every third day.
4. Deflate 1983 price by 0.341/0.344 to get 1982 dollars from Consumer Price Index (Department of Labor 1985).

Total Cost = ($84.47$/mile) (42,276 miles) \left(\frac{1}{3} \text{ days} \right) (365 \text{ day/yr}) 
\times (0.341/0.344) = 430.689 \times 10^6$/yr

Fine TC Reduction: Not computed

1. 68.1\% control efficiency for fine particulate emissions from Cuscino et al. (1982).
2. Road dust contribution to ambient air quality was determined by receptor modeling approach (see Chapter 4, Section 4.2.1). Fraction reduction for control is applied directly to ambient road dust concentration contribution estimate at each monitoring site to determine effect of control measure. (Applying this control measure to the original estimate of road dust emissions from Ranzieri [1983] gives a fine TC reduction of (0.681) (6.4542 T/day) = 4.3953 T/day; see Table C.4.)

TC fraction reduction = 0.681
EC fraction reduction = 0.681
(Fraction is applied directly to air quality contribution.)

Conflicts: D.30
Control Measure D.30

Paved Road Flushing and Broom Sweep

Sources Affected: 61

Cost: \(556.628 \times 10^6\$ /\text{yr}\)

1. 1983 flusher truck cost: \$84.47/\text{street mile from Yamanishi (1983)}.
2. 1983 broomsweeping cost: \$12.35 per curb-mile or \$24.70/\text{street mile from Yamanishi (1983)}.
3. Equivalent street mileage in 4-county SCAB: 42,276 miles (see Control D.29).
4. Assume streets are flushed and broomswept every three days.
5. Deflate 1983 price by 0.341/0.344 to get 1982 dollars from Consumer Price Index (Department of Labor 1985).

Total Cost = \[\left[\frac{(84.47 + 24.70)}{\text{mile}}\right] \times 42,276 \text{ miles} \times \frac{1}{3 \text{ days}} \times (365 \text{ day/yr}) \times \frac{0.341}{0.344} = 556.628 \times 10^6\$ /\text{yr}\]

Fine TC Reduction: Not computed

1. 71.8% control efficiency for fine particulate emissions from Cuscino et al. (1982).
2. Road dust contribution to ambient air quality was determined by receptor modeling approach (see Chapter 4, Section 4.2.1). Fraction reduction for control is applied directly to ambient road dust concentration contribution estimate at each monitoring site to determine effect of control measure. (Applying this control measure to the original estimate of road dust emissions from Ranzieri [1983] gives a fine TC reduction of (0.718) \((6.4542 \text{ T/day}) = 4.6341 \text{ T/day}; \text{see Table C.4.})

TC fraction reduction = 0.718

EC fraction reduction = 0.718

(Fraction is applied directly to air quality contribution.)

Conflicts: D.29
Control Measure D.31

Radial Tire Use on Light-duty Vehicles

Sources Affected: 62

Cost: $0

Radial tires have higher cost but wear proportionately longer than bias-ply tires.

Fine TC Reduction: 0.1167 T/day

1. Approximately 70% of tires on road in 1982 were radials (domestic passenger cars) from Standard & Poor’s Corporation (1981).
2. 50% longer life from Firestone Study in Standard & Poor’s Corporation (1981) implies 1/3 reduction in emissions rate.
3. Tire attrition from light-duty vehicles accounts for 77.26% of the tire wear in the SCAB (see Table A.7).
4. Fine total carbon emissions from sources: 1.170 T/day (SCAB, Table C.4).
5. Current bias-ply total fine carbon emissions from light-duty vehicles:

   \[ (0.7726) \times (0.30 \times 1.5) \times (0.30 \times 1.5) + 0.70) = 0.3537 \text{ T/day}. \]

   Reduction = (0.33) \times (0.3537 \text{ T/day}) = 0.1167 \text{ T/day}

TC fraction reduction = 0.0998
EC fraction reduction = 0.0998
Control Measure D.32

Use of Gas Logs in Fireplaces

Sources Affected: 65

Cost: \(23.897 \times 10^6\$/yr\)

1. Approximate cost of new gas log unit: \$200 (typical middle range price of gas log set, with installation; quoted at Floyd S. Lee, Pasadena, 1985). Assume ten-year payback period at 10% interest, giving a capital recovery factor of 0.16275.

2. Number of residences burning wood in SCAB is 977,568 (see Table A.9).

Gas log fireplace cost = \((0.16275/\text{yr}) \times 977,568 \text{ residences}\) \times (\$200/\text{residence}) = 31.820 \times 10^6\$/yr

3. Assume natural gas use replaces logs at same energy level, i.e., same number of Btu/year.

   Hardwood: 246,677 cords/yr (see Table A.9) \times 30.4 \times 10^6 Btu/cord (Baumeister et al. 1978, p. 7-19)
   = 7499.0 \times 10^9 \text{ Btu/yr}.

   Softwood: 241,729 cords/yr (see Table A.9) \times 26.0 \times 10^6 Btu/cord (Baumeister et al. 1978, p. 7-19)
   = 6285.0 \times 10^9 \text{ Btu/yr}.

   Natural gas cost = 13,783.93 \times 10^6 \text{ Btu/yr} \times \$3500/10^9 \text{ Btu}
   = 48,244 \times 10^6\$/yr
   (Natural gas price estimated from author's home utility bill.)

4. Assume half the wood burned is purchased as firewood.

   Approximate 1985 cost of cord of firewood is \$230/cord (quote from Glatts Lumber, Pasadena, August 1985).

   Firewood cost savings = (488,406 cords/yr) (0.50) (\$230/cord)
   = 56,167 \times 10^6\$/yr

Total Cost = 31.820 + (48.244 - 56.167) = 23.897 \times 10^6\$/yr
Control Measure D.32 (continued)

Fine TC Reduction: 4.2394 T/day

1. Fine total carbon emissions factors:
   Residential natural gas: 0.8898 kg/10^9 Btu (see Table A.2).
   Fireplace: 113.15 kg/10^9 Btu (see Table A.4).

2. Fine total carbon emissions from sources: 4.2730 T/day
   (SCAB, Table C.4).

Reduction = (4.2730 T/day) (1 - 0.8898/113.15) = 4.2394 T/day

TC fraction reduction = 0.9921
EC fraction reduction = 1 - (0.33) (1 - 0.9921)/(0.1711) = 0.9847
Control Measure D.33

Charcoal Broiler Control

Sources Affected: 68

Cost: $4.370 \times 10^6$/yr

1. Approximate cost of mist eliminator system for typical charbroiler facility (i.e., "The Conqueror" manufactured by Hardee's Food Systems) is between $4500 and $5500 (includes installation) from Stahl (1985). Assume $5000 per facility. Assume five-year payback period at 10% interest which gives a capital recovery factor of 0.26380. Then annual capital cost is $1319.00/yr.

2. Maintenance cost is approximately $1000–1500/year from Stahl (ibid.). Assume $1250/year.

3. The number of charcoal broilers in the South Coast Air Basin, 1982, is calculated to be 1701 from California Air Resources Board data (Ranzieri 1983) on total particulate emissions of 6342.0 kg/day (see Table C.4) divided by the CARB emission factor of 3000 lb/facility (Grisinger 1982).

Total Cost = (1701 facilities) ($1319/yr + $1250/yr)/facility

= $4.370 \times 10^6$/yr

Fine TC Reduction: 4.8541 T/day

1. Mist eliminator (i.e., "The Conqueror" manufactured by Hardee's Food Systems) removes 93% of particulate by weight (from Bornstein 1978 and Stahl 1985).

2. Fine total carbon emissions from sources: 5.2195 T/day (SCAB, Table C.4).

Reduction = (0.93) (5.2195) = 4.8541 T/day

TC fraction reduction = 0.93
EC fraction reduction = 0.93
Control Measure D.34

Substitute Natural Gas for Residual Oil in Utility Boilers

Sources Affected: 23

Cost: $0 (savings to utilities if natural gas is available)

1. Natural gas price is approximately $5000/10^9$ Btu from Robert Elrod (1985) of Southern California Edison Co.
2. Residual oil price (0.25%) is estimated to be $33.39/bbl = $5310.96/10^9$ Btu from Energy Information Administration (1982) data and data from Robert Elrod (1985).
3. SCAB 1982 residual fuel oil use: $118.9 \times 10^9$ Btu/day (from Table C.2).

Savings = [(5310.96 - 5000.00)$/10^9$ Btu] (118.9 $\times 10^9$ Btu/day) $\times$ (365 day/yr) = $13.495 \times 10^6$/yr

Fine TC Reduction: 0.1971 T/day

1. Fine total carbon emission factors for utility boiler fuels: Natural gas: 0.0696 kg/10^9 Btu (see Table A.2). Residual oil: 1.7271 kg/10^9 Btu (see Table A.2).
2. Fine total carbon emissions from sources: 0.2054 T/day (SCAB, Table C.2).

Reduction = (0.2054 T/day) (1 - 0.0696/1.7271) = 0.1971 T/day

TC fraction reduction = 0.9597
EC fraction reduction = 1.0000 (see Table A.2, note [rr])

Conflicts: D.19

Natural gas resource: $118.9 \times 10^9$ Btu/day
Control Measure D.35

Substitute Natural Gas for Residual Oil in Refineries

Sources Affected: 28

Cost: $0 small savings (see Control D.34)

Fine TC Reduction: 0.0063 T/day

1. Fine total carbon emission factors for refinery boiler fuels:
   Natural gas: 0.5841 kg/10^9 Btu (see Table A.2).
   Residual oil: 1.7606 kg/10^9 Btu (see Table A.2).

2. Fine total carbon emissions from sources: 0.0094 T/day
   (SCAB, Table C.2).

Reduction = (0.0094 T/day) (1 - 0.5841/1.7606) = 0.0063 T/day

TC fraction reduction = 0.6682
EC fraction reduction = 1.0000 (see Table A.2, note [uu])

Conflicts: D.20

Natural gas resource: 5.34 × 10^9 Btu/day
Control Measure D.36

Substitute Natural Gas for Residual Oil in Industrial Boilers

Sources Affected: 31

Cost: $0 small savings (see Control D.34)

Fine TC Reduction: 0.0098 T/day

1. Fine total carbon emission factors for industrial boiler fuels:
   Natural gas: 0.4869 kg/10^9 Btu (see Table A.2).
   Residual oil: 1.7606 kg/10^9 Btu (see Table A.2).

2. Fine total carbon emissions from sources: 0.0135 T/day (SCAB, Table C.2).

   Reduction = (0.0135 T/day) (1 - 0.4869/1.7606) = 0.0098 T/day

   TC fraction reduction = 0.7235
   EC fraction reduction = 1.0000 (see Table A.2, note [rr])

Conflicts: D.21, D.22

Natural gas resource: 7.65 × 10^9 Btu/day
Control Measure D.37

Substitute Natural Gas for Residual Oil in Residential/Commercial Sources Affected: 39

Cost: $0 small savings (see Control D.34)

Fine TC Reduction: 0.0245 T/day

1. Fine total carbon emission factors for residential/commercial boiler fuels:
   Natural gas: 0.8898 kg/10^9 Btu (see Table A.2).
   Residual oil: 1.7606 kg/10^9 Btu (see Table A.2).

2. Fine total carbon emissions from sources: 0.0496 T/day
   (SCAB, Table C.2).

Reduction = (0.0496 T/day) (1 - 0.8898/1.7606) = 0.0245 T/day

TC fraction reduction = 0.4946
EC fraction reduction = 1 - (0.33) (1 - 0.4946)/(0.20) = 0.1577
(see Table A.2 for EC/TC ratios)

Conflicts: D.28

Natural gas resource: 28.2 x 10^9 Btu/day
### Table D.38
Source class list correspondence

<table>
<thead>
<tr>
<th>source classes input to the air quality model (a)</th>
<th>source types used in emission and control inventories (b)</th>
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</thead>
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<tr>
<td>Mobile Sources</td>
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<td>1 CATALYST AUTOS</td>
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(a) These are the 47 source classes input to the air quality model (see Chapter 4). Source types within each source class have similar emission characteristics.

(b) These are the 74 source types identified in the emission inventory (Tables A.1 through A.4) and the control strategy inventory (Tables D.1 through D.37).
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<tr>
<th>Source Classes Input to the Air Quality Model</th>
<th>Source Types Used in Emission and Control Inventories</th>
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<td>22 Utilities Turbine NG</td>
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<td>Source Classes Input to the Air Quality Model</td>
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(c) For the correspondence between source types used in this study and California Air Resources Board category of emission source (CES, SCC) numbers, see Table A.10.
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<td>47 UNPAVED ROAD</td>
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APPENDIX E

FINE PARTICLE CONCENTRATIONS AT ELEVEN LOCATIONS IN THE SOUTH COAST AIR BASIN DURING 1982

Appendix E contains the results of the air quality monitoring program conducted in the Los Angeles area during 1982 (see Chapter 2). The locations monitored were Azusa, Burbank, Long Beach, Lennox, Pasadena, West Los Angeles, Los Angeles (central), Upland, Rubidoux, Anaheim, and San Nicolas Island. A 24-hour sample was collected at each location on every sixth day in conjunction with the NASN sampling schedule. Tabulated in this appendix are the daily average concentrations (and error bounds) for the following fine (d < 2.1 μm) aerosol species: Total mass, organic carbon, elemental carbon, NO₃⁻, SO₄²⁻, NH₄⁺, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, As, Sc, Br, Rb, Sr, Y, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Ba, La, Hg, and Pb. Also included are the daily fine particle fractions of total mass, SO₄²⁻, NO₃⁻, and Pb which were obtained by dividing the fine aerosol concentrations by the corresponding species concentration found in the total suspended particulate matter data reported by the South Coast Air Quality Management District, El Monte, California (all locations except Burbank, Upland, and San Nicolas Island). Monthly and annual averages of these values are also tabulated. Throughout this appendix, missing data are indicated by the value -10.0 or -9.9.

Appendix E and Appendix F are contained in a separate volume. The data are available by contacting the Environmental Quality Laboratory, Caltech, Pasadena, California 91125.
APPENDIX F

SOURCE CLASS CONTRIBUTIONS TO 1982
ANNUAL AVERAGE CARBON PARTICLE AIR QUALITY

Appendix F contains the contributions to fine total carbon and fine elemental carbon concentrations at seven receptor sites from each of 74 source classes, as computed by the air quality model (see Chapter 4). Estimates of emissions are also presented for each source class (see Appendix A and Appendix C).

Appendix E and Appendix F are contained in a separate volume. The data are available by contacting the Environmental Quality Laboratory, Caltech, Pasadena, California 91125.