APPENDIX B

DOCUMENTATION OF 7-PAH AND 16-PAH NATIONAL EMISSION ESTIMATES

B.1 RESIDENTIAL WOOD COMBUSTION

Basis for Input Data

1. 7-PAH and 16-PAH emission factors were developed for conventional woodstoves, catalytic/noncatalytic woodstoves, and fireplaces. Emission factors for conventional woodstoves were developed from the individual PAH emission factors provided in AP-42 (U.S. EPA, 1995a). AP-42 also provided individual PAH emission factors for catalytic and for noncatalytic woodstoves. 7-PAH and 16-PAH factors were developed for the two types, and then averaged together to obtain factors representing catalytic/noncatalytic woodstoves.

   The 7-PAH and 16-PAH emission factors for fireplaces were developed form individual PAH emissions data from two emissions tests. 7-PAH and 16-PAH factors were developed for a fireplace burning seasoned oak wood (Hall and DeAngelis, 1980) and for a fireplace burning green pine wood (Hall and DeAngelis, 1980). The 7-PAH and 16-PAH factors from the two tests were averaged together to obtain factors representing wood combustion in fireplaces.

2. The 7-PAH and 16-PAH emission factors for conventional woodstoves are 0.044 and 0.718 lb/ton, respectively.

   The 7-PAH and 16-PAH emission factors for catalytic/noncatalytic woodstoves are 0.048 and 0.627 lb/ton, respectively.

   The 7-PAH and 16-PAH emission factors for fireplaces are 0.007 and 0.037 lb/ton, respectively.

The national 7-PAH emissions estimates includes benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

The national 16-PAH emissions estimates include benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, acenaphthene, acenaphthylene, anthracene, benzo(ghi)perylene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene.

3. 29.1 million cords (33.8 million tons) of wood combusted in residential wood combustion in 1990 (U.S. DOE, 1993a; (U.S. DOE, 1993b). The average nationwide percentage of wood consumption is 28 percent for fireplaces and 72 percent for woodstoves (U.S. DOE, 1993b). Of the 72 percent combusted in woodstoves, no more than five percent is combusted in catalytic and noncatalytic stoves (Menotti, 1996). For calculational purposes, it is assumed the remaining 95 percent (of the 72 percent) is combusted in conventional woodstoves.

Calculation

1. 7-PAH Annual emissions for conventional woodstoves =
33.8 million tons * 72% * 95% * 0.044 lb/ton = 1,017,245 lb

7-PAH Annual emissions for catalytic and noncatalytic woodstoves =
33.8 million tons * 72% * 5% * 0.0475 lb/ton = 57,798 lb

7-PAH Annual emissions for fireplaces =
33.8 million tons * 28% * 0.0072 lb/ton = 68,141 lb

7-PAH Annual emissions for residential wood combustion =
1,017,245 lb + 57,798 lb + 68,141 lb = 1,143,184 lb = 572 tons
7-PAH emission factor for residential wood combustion =
1,143,184 lb/33,800,000 tons = 0.034 lb/ton

2. 16-PAH Annual emissions for conventional woodstoves =
33.8 million tons * 72% * 95% * 0.718 lb/ton = 16,599,586 lb

16-PAH Annual emissions for catalytic and noncatalytic woodstoves =
33.8 million tons * 72% * 5% * 0.6265 lb/ton = 762,325 lb

16-PAH Annual emissions for fireplaces =
33.8 million tons * 28% * 0.0367 lb/ton = 347,329 lb

16-PAH Annual emissions for residential wood combustion =
16,599,586 lb + 762,325 lb + 347,329 lb = 17,709,240 lb = 8,855 tons

16-PAH emission factor for residential wood combustion =
17,709,204 lb/33,800,000 tons = 0.524 lb/ton

B.2 RESIDENTIAL NATURAL GAS COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 0.0373 lb/1E+12 Btu (1.6E-08 g/MJ) and the 16-PAH emission factor was 2.37 lb/1E+12 Btu (1.02E-06 g/MJ). These factors were developed from the individual PAH emission factors for a natural gas-fired hot air furnace, wall space heater, and shell boiler as reported in the POM L&E document (U.S. EPA, 1997). It was assumed that 1 cubic foot of natural gas produces 1,000 Btu.

2. The 7-PAH emission factor includes Benzo(a)pyrene.

   The 16-PAH emission factor includes Benzo(a)pyrene, Benzo(ghi)perylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1990, residential natural gas consumption in the United States was 4.3E+15 Btu (EIA, 1992).

Calculation

7-PAH Annual Emissions = 0.0373 lb/1E+12 Btu * 4.3E+15 Btu = 160.4 lb
= 0.0802 tons

16-PAH Annual Emissions = 2.37 lb/1E+12 Btu * 4.3E+15 Btu = 1.02E+04 lb
= 5.1 tons

B.3 RESIDENTIAL DISTILLATE OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.63E-04 lb/1000 gallons (6.75E-08 Mg/kL) and the 16-PAH emission factor was 6.97E-03 lb/1000 gallons (8.35E-07 Mg/kL). These factors were developed from the individual PAH emission factors for distillate (No. 2) oil-fired furnaces as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes Benz(a)anthracene and Benzo(a)pyrene. The 16-PAH emission factor includes Benz(a)anthracene, Benzo(a)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1990, 6.04E+09 gallons of distillate fuel were consumed for residential heating use in the United States (EIA, 1992).

Calculation

7-PAH Annual Emissions =

5.63E-04 lb/1000 gal * 6.04E+09 gallons = 3,400 lb

= 1.70 tons

16-PAH Annual Emissions =

6.97E-03 lb/1000 gal * 6.04E+09 gallons = 4.21E+04 lb

= 21.0 tons

B.4 RESIDENTIAL COAL COMBUSTION

Basis for Input Data

1. The emission factors for 7-PAH were 0.0335 lb/ton (0.0168 kg/Mg) for bituminous and lignite coal and 1.41E-04 lb/ton (7.05E-05 kg/Mg) for anthracite coal. The emission factors for 16-PAH were 0.108 lb/ton (0.054 kg/Mg) for bituminous and lignite coal and 6.18E-04 lb/ton (3.09E-04 kg/Mg) for anthracite coal. These factors were developed from the individual PAH emission factors for residential coal stoves, and residential coal boilers and furnaces as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factors include: Acenaphthene, Acenapthylene, Anthracene, Fluoranthene, Fluorene, Phenanthrene, and Pyrene.

3. In 1990, 1.9 million tons of bituminous and lignite coal and 732,000 tons of anthracite coal were consumed in the United States (EIA, 1992).

Calculation

7-PAH bituminous and lignite coal =

0.0335 lb/ton * 1.9 million tons = 6.37E+04 lb

= 31.8 tons

7-PAH anthracite coal =

1.41E-04 lb/ton * 732,000 tons = 103 lb

= 0.0516 tons

16-PAH bituminous and lignite coal =

0.108 lb/ton * 1.9 million ton = 2.05E+05 lb

= 102.6 tons

16-PAH anthracite coal =

6.18E-04 lb/ton * 732,000 tons = 452 lb

= 0.226 tons

B.5 UTILITY COAL COMBUSTION
UTILITY OIL COMBUSTION
UTILITY NATURAL GAS COMBUSTION

Basis for Estimate

1. 7-PAH and 16-PAH national emissions estimates for 1990 were obtained directly from a U.S. Environmental Protection Agency study report on HAP emissions from electric utility steam generating units (U.S. EPA, 1996a).

Utility Coal Combustion

1. The 7-PAH national emissions estimate is 0.21 tons/yr. These data include the following PAH: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

2. The 16-PAH national emissions estimate is 7.55 tons/year. These data include the following PAH: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

Utility Residual Oil Combustion

1. The 7-PAH national emissions estimate is 0.05 tons/yr. These data include the following PAH: Benz(a)anthracene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

2. The 16-PAH national emissions estimate is 0.57 tons/year. These data include the following PAH: Benz(a)anthracene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

Utility Natural Gas Combustion

1. There were no 7-PAH compounds listed in the U.S. EPA study report, therefore, national emissions were not estimated.

2. The 16-PAH national emissions estimate is 0.69 tons/year. These data include the following PAH: Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

B.6 INDUSTRIAL WOOD/WOOD RESIDUE COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.90E-05 lb/ton (2.95E-05 kg/Mg) and the 16-PAH emission factor was 3.36E-03 lb/ton (1.68E-03 kg/Mg). These factors were developed from the individual PAH emission factors for industrial wood waste boilers as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 4.09E+07 million tons of oven-dried wood were burned for industrial use in the United States (EIA, 1991; American Forest and Paper Association, 1996). See Appendix A, Section A.15 for more details on the derivation of this volume.

Calculation

7-PAH Annual Emissions = 5.90E-05 lb/ton * 4.09E+07 tons = 2.41E+03 lb
= 1.21 tons

16-PAH Annual Emissions = 3.36E-03 lb/ton * 4.09E+07 tons = 1.38E+05 lb
= 68.8 tons

B.7 INDUSTRIAL NATURAL GAS COMBUSTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 5.56E-06 lb/MMCF (8.91E-08 g/kL). This factor was developed from the individual PAH emission factors for natural gas-fired boilers as reported in the POM L&E document (U.S. EPA, 1997).

2. The 16-PAH emission factor includes: Acenapthylene, Fluoranthene, Naphthalene, Phenanthrene and Pyrene.

3. In 1990, 7,732 billion cubic feet of natural gas were consumed for industrial use in the United States (EIA, 1992).

Calculation

16-PAH Annual Emissions =

5.56E-06 lb/MMCF * 7,732 billion cubic feet = 43.0 lb

= 0.0215 tons

B.8 INDUSTRIAL COAL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.36E-05 lb/ton (2.68E-05 kg/Mg) and the 16-PAH emission factor was 2.72E-03 lb/ton (1.36E-03 kg/Mg). These factors was developed from the individual PAH emission factors for pulverized bituminous wet and dry-bottom and bituminous stoker industrial coal-fired boilers. An average factor was calculated using the factors from these two types of boilers (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi) Perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 115 million tons of bituminous and lignite coal and 390,000 tons of anthracite coal for a total of 115.39 million tons of coal consumed in the United States (EIA, 1992).

Calculation

7-PAH Annual Emission = 5.36E-05 lb/ton * 115.39 million tons = 6,180 lb
= 3.09 tons

16-PAH Annual Emission = 2.72E-03 lb/ton * 115.39 million tons = 3.14E+05 lb
= 157 tons

B.9 INDUSTRIAL RESIDUAL OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 1.60E-07 lb/MMBtu (6.88E-08 g/MJ) and the 16-PAH emission factor was 2.15E-04 lb/MMBtu (9.25E-05 g/MJ). These factors were developed from the individual PAH emission factors for a No. 6 oil-fired industrial boiler as reported in the POM L&E document (U.S. EPA, 1997). It was assumed that 1 gallon of residual oil produces 150,000 Btu.

2. The 7-PAH emission factor includes: Chrysene and Benzo(b)fluoranthene.

   The 16-PAH emission factor includes: Chrysene, Benzo(b)Fluoranthene, Acenapthylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, industrial residual oil consumption in the United States was 4.16E+08 MMBtu (EIA, 1992).

Calculation

7-PAH Annual Emissions = 1.60E-07 lb/MMBtu * 4.16E+08 MMBtu = 66.6 lb
= 0.0333 tons

16-PAH Annual Emissions = 2.15E-04 lb/MMBtu * 4.16E+08 MMBtu = 8.94E+04 lb
= 44.7 tons

B.10 INDUSTRIAL WASTE OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 4.53E-03 lb/1,000 gallons (5.43E-04 kg/kL) and the 16-PAH emission factor was 0.0265 lb/1,000 gallons (1.44E-03 kg/kL). These factors were developed from the individual PAH emission factors for waste oil combustion in space heaters as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor for bituminous coal includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1993, 590 million gallons of industrial waste oil was consumed in the United States (U.S. EPA, 1993a).

Calculation

7-PAH Annual Emission =

4.53E-03 lb/1,000 gallon * 590 million gallons = 2,670 lb

= 1.34 tons

16-PAH Annual Emissions =

0.0265 lb/1,000 gallons * 590 million gallons = 1.56E+04 lb

= 7.82 tons

B.11 INDUSTRIAL DISTILLATE OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.96E-09 lb/MMBtu (2.56E-09 g/MJ) and the 16-PAH emission factor was 5.00E-05 lb/MMBtu (2.15E-05 g/MJ). These factors were developed from the individual PAH emission factors for a No. 2 oil-fired boiler with no control device as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benzo(a)pyrene.

   The 16-PAH emission factor includes: Benzo(a)pyrene, Fluoranthene, Naphthalene, and Pyrene.

3. In 1990, industrial distillate oil consumption in the United States was 2.46E+08 MMBtu (EIA, 1992).

Calculation

7-PAH Annual Emission =

5.96E-09 lb/MMBtu * 2.46E+08 MMBtu = 1.47 lb

= 7.33E-04 tons

16-PAH Annual Emissions =

5.00E-05 lb/MMBtu * 2.46E+08 MMBtu = 1.23E+04 lb

= 6.15 tons

B.12 COMMERCIAL WOOD/WOOD RESIDUE COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 7.43E-05 lb/MMBtu (3.19E-05 g/MJ) and the 16-PAH emission factor was 2.63E-03 lb/MMBtu (1.13E-03 g/MJ). These factors were developed from the individual PAH emission factors for wood waste-fired commercial/institutional boilers as reported in the POM L&E document (U.S. EPA, 1997). It was assumed that 1 lb of dry wood produces 8,000 Btu.

2. The 7-PAH emission factor includes Benzo(a)pyrene, Chrysene, Benz(a)anthracene, Benzo(b+k)fluoranthene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes Benzo(a)anthracene, Benzo(a)pyrene, Chrysene, Benzo(b+k)fluoranthene, Indeno(1,2,3-cd)pyrene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, Pyrene, Acenapthylene, and Anthracene.

3. In 1990, commercial wood/wood residue consumption in the United States was 2.72E+07 MMBtu (EIA, 1991).

Calculation

7-PAH Annual Emissions = 7.43E-05 lb/MMBtu * 2.72E+07 MMBtu = 2,020 lb
= 1.01 tons

16-PAH Annual Emissions = 2.63E-03 lb/MMBtu * 2.72E+07 MMBtu = 7.15E+04 lb
= 35.8 tons

B.13 COMMERCIAL NATURAL GAS COMBUSTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data (U.S. EPA, 1997).

   The emission factor for 16-PAH was 2.54E-05 lb/MMCF (4.07E-07 g/kL). This factor was developed from the individual PAH emission factors for natural gas fired commercial boilers reported in the POM L&E document (U.S. EPA, 1997).

2. The 16-PAH emission factor includes Fluoranthene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 2,677 billion cubic feet of natural gas were consumed for commercial use in the United States (EIA, 1992).

Calculation

16-PAH Annual Emissions = 2.54E-05 lb/MMCF * 2,677 billion cubic feet = 68.0 lb

= 0.034 tons

B.14 COMMERCIAL COAL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 0.0200 lb/ton (0.0100 kg/Mg) for bituminous and lignite coal; there was no 7-PAH emission factor developed for anthracite coal combustion. The 16-PAH emission factors were 0.0771 lb/ton (0.0386 kg/Mg) for bituminous and lignite coal and 0.137 lb/ton (0.0684 kg/Mg) for anthracite coal. These factors were developed from the individual PAH emission factors for commercial coal bituminous stoker boilers as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, and Dibenz(a,h)anthracene.

   The 16-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenz(a,h)anthracene, Benzo(ghi)perylene, Fluoranthene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 3.6 million tons of bituminous and lignite and 493,000 tons of anthracite commercial coal were consumed in the United States (EIA, 1992).

Calculation

7-PAH Annual Emissions =

0.0200 lb/ton * 3.6 million tons of bituminous and lignite coal = 7.2E+04 lb

= 36 tons

16-PAH Annual Emissions =

0.0771 lb/ton * 3.6 million tons of bituminous and lignite coal = 2.78E+05 lb

= 139 tons

16-PAH Annual Emissions =

0.137 lb/ton * 493,000 tons of anthracite coal = 6.74E+04 lb

= 33.7 tons

B.15 COMMERCIAL DISTILLATE OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.96E-09 lb/MMBtu (2.56E-09 g/MJ) and the 16-PAH emission factor was 5.00E-05 lb/MMBtu (2.15E-05 g/MJ). These factors were developed from the individual PAH emission factors for a No. 2 oil-fired boiler with no control device as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benzo(a)pyrene.

   The 16-PAH emission factor for bituminous coal includes: Benzo(a)pyrene, Fluoranthene, Naphthalene, and Pyrene.

3. In 1990, commercial distillate oil consumption in the United States was 5.27E+08 MMBtu (EIA, 1992).

Calculation

7-PAH Annual Emission =

5.96E-09 lb/MMBtu * 5.27E+08 MMBtu = 3.14 lb

= 1.57E-03 ton

16-PAH Annual Emissions =

5.00E-05 lb/MMBtu * 5.27E+08 MMBtu = 2.6E+04 lb

= 13.2 tons

B.16 COMMERCIAL RESIDUAL OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 1.60E-07 lb/MMBtu (6.88E-08 g/MJ) and the 16-PAH emission factor was 2.14E-04 lb/MMBtu (9.20E-05 g/MJ). These factors were developed from the individual PAH emission factors for a No. 6 oil-fired industrial boiler with no control device as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benzo(b)fluoranthene and Chrysene.

   The 16-PAH emission factor includes: Benzo(b)fluoranthene, Chrysene, Acenapthylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, commercial residual oil consumption in the United States was 3.75E+08 MMBtu (EIA, 1992).

Calculation

7-PAH Annual Emission =

1.60E-07 lb/MMBtu * 3.75E+08 MMBtu = 60.0 lb

= 0.0300 tons

16-PAH Annual Emissions =

2.14E-04 lb/MMBtu * 3.75E+08 MMBtu = 8.025E+04 lb

= 40.1 tons

B.17 DIESEL-FIRED STATIONARY INTERNAL COMBUSTION ENGINES - RECIPROCATING

Basis for Input Data

1. The emission factor for the 7-PAH group was 3.36E-06 lb/MMBtu (1.44E-06 g/MJ) and the 16-PAH emission factor was 1.89E-04 lb/MMBtu (8.13E-05 g/MJ). These factors were developed from the individual PAH emission factors for industrial, commercial, and institutional engines and industrial large bore engines as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, distillate oil (diesel fuel) consumption in stationary reciprocating IC engines in the United States was 5.31E+07 MMBtu (EIA, 1992).

Calculation

$$7\text{-PAH Annual Emissions} = 3.36E{-}06 \text{ lb/MMBtu} * 5.313E{+}07 \text{ MMBtu} = 178 \text{ lbs} = 0.0893 \text{ tons}$$

$$16\text{-PAH Annual Emissions} = 1.89E{-}04 \text{ lb/MMBtu} * 5.313E{+}07 \text{ MMBtu} = 1.00E{+}04 \text{ lbs} = 5.02 \text{ tons}$$

B.18 NATURAL GAS-FIRED STATIONARY INTERNAL COMBUSTION ENGINES - RECIPROCATING

Basis for Input Data

1. The emission factor for the 7-PAH group was 2.75E-03 lb/MMCF (0.044 kg/MMm^3) and the 16-PAH emission factor was 0.127 lb/MMCF (2.03 kg/MMm^3). These factors were developed from the individual PAH emission factors for two-cycle lean burn and four-cycle rich burn internal combustion engines with no control devices as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 750 billion cubic feet of natural gas were consumed in stationary reciprocating IC engines in the United States (EIA, 1992).

Calculation

$$7\text{-PAH Annual Emissions} = 2.75\text{E}{-}03 \text{ lb/MMCF} * 750 \text{ billion cubic feet} = 2{,}060 \text{ lbs} = 1.03 \text{ tons}$$

$$16\text{-PAH Annual Emissions} = 1.27\text{E}{-}01 \text{ lb/MMCF} * 750 \text{ billion cubic feet} = 9.53\text{E}{+}04 \text{ lbs} = 47.6 \text{ tons}$$

B.19 DIESEL-FIRED INTERNAL COMBUSTION ENGINES - GAS TURBINES

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 1.03E-07 lb/MMBtu (4.43E-08 g/MJ). This factor was developed from the individual PAH emission factors for electric generation diesel-fired gas turbines as reported in the POM L&E document (U.S. EPA, 1997).

2. The 16-PAH emission factor includes: Anthracene, Fluorene, and Phenanthrene.

3. In 1990, distillate oil (diesel fuel) consumption in gas turbines in the United States was 3.01E+08 MMBtu (EIA, 1992).

Calculation

$$16\text{-PAH Annual Emissions} = 1.03E-07 \text{ lb/MMBtu} * 3.01E+08 \text{ MMBtu} = 31.0 \text{ lbs}$$

$$= 0.0155 \text{ tons}$$

B.20 NATURAL GAS-FIRED STATIONARY INTERNAL COMBUSTION ENGINES - GAS TURBINES

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 4.90E-05 lb/MMBtu (2.11E-05 g/MJ). This factor was developed from the individual PAH emission factors for electric generation natural gas-fired gas turbines as reported in the POM L&E document (U.S. EPA, 1997).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1990, natural gas consumption in gas turbines in the United States was 5.62E+08 MMBtu (EIA, 1992).

Calculation

$$16\text{-PAH Annual Emissions} = 4.90E-05 \text{ lb/MMBtu} * 5.62E+08 \text{ MMBtu} = 2.75E+04 \text{ lb}$$

$$= 13.8 \text{ ton}$$

B.21 MUNICIPAL WASTE COMBUSTION

Basis for Input Data

1. There was no 7-PAH emission factor developed for this source because the emissions test data used to develop emission factors show that none of the 7-PAH were detected in any test run at any facility (U.S. EPA, 1997; Zannes, 1996).

2. The 16-PAH emission factor is 6.07E-06 lb/ton and includes only naphthalene. The emissions test data used to develop the emission factors show that none of the other 16-PAH were detected in any test run at any facility (U.S. EPA, 1997; Zannes, 1996).

3. In 1991, 3.24E+07 tons of municipal waste were incinerated in the United States (U.S. EPA, 1992a).

Calculation

16-PAH Annual Emissions = 6.06E-06 lb/ton * 3.24E+07 tons = 197 lb

= 0.099 tons

B.22 SEWAGE SLUDGE INCINERATION

Basis for Input Data

1. The emission factor for 7-PAH was 1.82E-05 lb/ton (9.11E-06 kg/Mg) and the 16-PAH emission factor was 3.44E-03 lb/ton (1.72E-03 kg/Mg). These factors was developed from the individual PAH emission factors for a multihearth sewage sludge incinerator with a wet scrubber as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 9.53E+05 tons of sewage sludge were incinerated in the United States (U.S. EPA, 1994a).

Calculation

7-PAH Annual Emission = 1.82E-05 lb/ton * 9.53E+05 ton = 17.4 lb
= 8.67E-03 tons

16-PAH Annual Emission = 3.44E-03 lb/ton * 9.53E+05 ton = 3.28E+03 lb
= 1.64 tons

B.23 MEDICAL WASTE INCINERATION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data (U.S. EPA, 1997).

   The 16-PAH emission factor was 9.22E-04 lb/ton (4.61E-04 kg/Mg). This factor was developed from the individual PAH emission factors for medical waste, multi-chambered and single chambered incinerators as reported in the POM L&E document (U.S EPA, 1997).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1990, 1.73E+06 tons of medical waste were incinerated in the United States (Copeland, 1997).

Calculation

16-PAH Annual Emission = 9.22E-04 lb/ton * 1.73E+06 tons = 1,595 lbs

= 0.798 tons

B.24 HAZARDOUS WASTE INCINERATION

Basis for Input Data

1. The emission factor for the 7-PAH group was 2.91E-05 lb/ton (1.46E-05 kg/Mg) and the 16-PAH emission factor was 2.44E-04 lb/ton (1.22E-04 kg/Mg). These factors were developed from the individual PAH emission factors from a liquid injection incinerator for mixed liquid industrial waste as they are reported in the POM L&E document (U.S EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Phenanthrene, and Pyrene.

3. In 1992, approximately 249 million metric tons of hazardous waste were generated. It is estimated that of the total amount of hazardous waste incinerated, 1.3 million tons were burned in dedicated hazardous waste facilities. (Dempsey and Oppelt, 1993).

Calculation

7-PAH Annual Emission = 1.3E+06 metric tons * 1.1 ton/metric ton * 2.91E-05 lb/ton

= 42 lbs

= 0.021 tons

16-PAH Annual Emissions = 1.3E+06 metric tons * 1.1 ton/metric ton * 2.44E-04 lb/ton

= 349 lb

= 0.17 tons

B.25 DRUM AND BARREL RECLAMATION

Basis for Input Data

1. The emission factor for the 7-PAH group was 5.53E-07 lb/1,000 barrels (2.5E-10 Mg/1,000 barrels) and the 16-PAH emission factor was 3.56E-05 lb/1,000 barrels (1.61E-08 Mg/1,000 barrels). These factors were developed from the individual PAH emission factors for 55-gallon drum recycling furnace as reported in the POM L&E document (U.S EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(b)fluoranthene, and Chrysene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(b)fluoranthene, Chrysene, Acenaphthene, Acenapthylene, Anthracene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1994, 4.60E+06 55-gallon drums were reclaimed in the United States (U.S. EPA, 1994a).

Calculation

$$7\text{-PAH Annual Emissions} = 5.53E-07 \text{ lb/1,000 barrels} * 4.60E+06 \text{ barrels} = 2.54E-03 \text{ lbs}$$

$$= 1.27E-06 \text{ tons}$$

$$16\text{-PAH Annual Emissions} = 3.56E-05 \text{ lb/1,000 barrels} * 4.60E+06 \text{ barrels} = 0.164 \text{ lbs}$$

$$= 8.19E-05 \text{ tons}$$

B.26 SCRAP TIRE INCINERATION

Basis for Input Data

1. The emission factor for the 7-PAH group was 1.68E-03 lb/million tires (0.762 g/million tires) and the 16-PAH emission factor was 0.40 lb/million tires (181 g/million tires). These factors were developed from the individual PAH factors from scrap tire incinerators (U.S EPA, 1997).

2. The 7-PAH emission factor includes Benzo(b)fluoranthene

   The 16-PAH emission factor includes Benzo(b)fluoranthene, Acenaphthene, Anthracene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 25.9 million scrap tires were burned in the United States (U.S. EPA, 1991b).

Calculation

7-PAH Annual Emission = 1.68E-03 lb/million tires * 25.9 million tires = 0.0435 lbs
= 2.17E-05 tons

16-PAH Annual Emission = 0.40 lb/million tires * 25.9 million tires = 10.4 lbs
= 5.18E-03 tons

B.27 LANDFILL FLARES

Basis for Input Data

1. The emission factor for the 7-PAH group was 3.08E-08 lb/MMBtu (1.32E-11 g/kJ) and the 16-PAH emission factor was 1.30E-05 lb/MMBtu (5.56E-09 g/kJ). These factors were developed from the individual PAH emission factors from a solid waste landfill waste gas flare with an afterburner control device as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1994, landfill waste gas consumed in flares in the United States was 6.85E+07 MMBtu (Berenyi, 1994).

Calculations

$$7\text{-PAH Annual Emissions} = 3.08E{-}08 \text{ lb/MMBtu} * 6.85E{+}07 \text{ MMBtu} = 2.11 \text{ lbs}$$
$$= 1.05E{-}03 \text{ tons}$$

$$16\text{-PAH Annual Emissions} = 1.30E{-}05 \text{ lb/MMBtu} * 6.85E{+}07 \text{ MMBtu} = 890 \text{ lbs}$$
$$= 0.445 \text{ tons}$$

B.28 PRIMARY ALUMINUM PRODUCTION

Basis for Input Data

1. Overall 7-PAH and 16-PAH emission factors were developed from the background information used to develop MACT standards that is presented in the Technical Support Document (U.S. EPA, 1996b). Overall emission factors were developed for the individual emission factors for six processes involved in producing primary aluminum: Horizontal stud Soderberg cells; vertical Soderberg cells; pre-bake cells, casting; paste production and, anode bake furnaces (Fruh, 1997). In the reduction process, 66 percent of production is in pre-bake cells, 21 percent of production is in horizontal Soderberg cells, and 13 percent of production is in vertical Soderberg cells. The emission factors for each operation were weighted according to the respective production percent. Half of all primary aluminum produced goes through the casting process. Emission factors for paste plants and anode bake furnaces, which are given in lb/ton of paste, were converted to lb/ton aluminum by multiplying by 0.5 (typical carbon usage is 0.5 lb/lb aluminum) and were multiplied by 0.66 because only pre-bake plants have anode bake furnaces. The estimates for the individual processes for 1990 were derived based on the percent of the capacity that was uncontrolled, the percent controlled by various devices, and the appropriate emission factors for each. The overall factor is the sum of the weighted individual factors. The individual and overall factors are shown below in the calculations. The 1990 emissions estimates will be reduced by 50 percent after the primary aluminum industry MACT is implemented.

2. The 7-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

The 16-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene,Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 4.41E+06 tons of primary aluminum were produced in the United States (Plunkert and Sehnke, 1990).

Calculation

Weighted Emission Factors for Horizontal Stud Soderberg Cells

7-PAH Emission Factor = 0.058 lb/ton * 0.21 = 0.012 lb/ton

16-PAH Emission Factor = 0.59 lb/ton * 0.21 = 0.12 lb/ton

Weighted Emission Factors for Vertical Soderberg Cells

7-PAH Emission Factor = 0.12 lb/ton * 0.13 = 0.016 lb/ton

16-PAH Emission Factor = 0.49 lb/ton * 0.13 = 0.064 lb/ton

Weighted Emission Factors for Vertical Pre-bake Cells

7-PAH Emission Factor = 0.0013 lb/ton * 0.66 = 0.00086 lb/ton

16-PAH Emission Factor = 0.0073 lb/ton * 0.66 = 0.0048 lb/ton

Weighted Emission Factors for Casting Operations

7-PAH Emission Factor = 3.64E-04 lb/ton * 0.50 = 0.000182 lb/ton

16-PAH Emission Factor = 1.30E-02 lb/ton * 0.50 = 0.0069 lb/ton

Weighted Emission Factors for Paste Production

7-PAH Emission Factor = 3.7E-03 lb/ton paste * 0.5 ton paste/ton Al = 0.0019 lb/ton

16-PAH Emission Factor = 0.029 lb/ton paste * 0.5 ton paste/ton Al = 0.015 lb/ton

Weighted Emission Factors for Anode Bake Furnaces

7-PAH Emission Factor = 0.10 lb/ton anode * 0.5 ton anode/ton Al * 0.66 = 0.033 lb/ton

16-PAH Emission Factor = 0.27 lb/ton anode * 0.5 ton anode/ton Al * 0.66 = 0.089 lb/ton

Overall Emission Factors

7-PAH Emission Factor = (0.012) + (0.016) + (0.00086) + (0.000182) + (0.0019) + (0.033) = 0.064 lb/ton

16-PAH Emission Factor = (0.12) + (0.064) + (0.0048) + (0.0069) + (0.015) + (0.089) = 0.30 lb/ton

Total Annual Emissions

7-PAH Annual Emissions = 0.064 * 4.41E+06 ton = 282,240 lbs
= 141 tons

16-PAH Annual Emissions = 0.30 * 4.41E+06 ton = 1,323,000 lbs
= 662 tons

B.29 FERROALLOY MANUFACTURING

Basis for Input Data

1. The 7-PAH and 16-PAH emission factors were developed by EPA from the individual PAH emissions from open EAFs producing silicon metal, ferrosilicon, silicomanganese, ferromanganese, calcium carbide, and ferrochrome. PAH emissions from covered and semi-covered furnaces were not quantified and are assumed to be negligible because all covered and semi-covered furnaces have flares (Chin, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene for open furnaces.

   The 16-PAH emission factor includes Acenaphthene, Acenaphthylene, Benzo(b)fluoranthene, Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Phenanthrene, Naphthalene, and Pyrene for open furnaces.

3. Uncontrolled emission factors were developed based on fuel consumption of wood, coal, and coke (Chin, 1997).

4. The uncontrolled emission factors were converted to controlled emission factors assuming 99 percent control of organics (Chin, 1997).

5. The resulting controlled emission factors are:

7-PAH

0.000824 lbs/ton wood consumed
0.002324 lbs/ton coal consumed
0.000232 lbs/ton coke consumed

16-PAH

0.001752 lbs/ton wood consumed
0.005035 lbs/ton coal consumed
0.000503 lbs/ton coke consumed

6. The controlled emission factors were then multiplied by estimated fuel consumption for each ferroalloy manufacturing facility in the U.S. with an open furnace. Fuel consumption estimates were developed based on annual production levels (Chin, 1997).

Calculation

7-PAH Annual Emissions Open EAFs

0.000824 lb/ton wood consumed * 207,513 tons wood = 170.99 lbs
0.002324 lb/ton coal consumed * 141,836 tons coal = 316.63 lbs.
0.000232 lb/ton coke consumed * 89,390 tons coke = 20.74 lbs.

16 PAH Annual Emissions Open EAFs

0.001752 lb/ton wood consumed * 207,513 tons wood = 363.56 lbs

0.005035 lb/ton coal consumed * 141,836 tons coal = 714.14 lbs

0.000503 lb/ton coke consumed * 89,390 tons coke = 44.96 lbs

Total Annual Emission

7-PAH = 170.99 lbs + 316.63 lbs + 20.74 lbs ÷ 2000 = 0.25 tons

16-PAH = 363.56 lbs + 714.14 lbs + 44.96 lbs ÷ 2000 = 0.56 tons

B.30 IRON FOUNDRIES

Basis for Input Data

1. The emission factor for 7-PAH was 2.07E-05 lb/ton (1.04E-05 kg/Mg) and 16-PAH emission factor was 6.21E-05 lb/ton (3.10E-05 kg/Mg). These factors were developed from the individual PAH emission factors from two testing programs at a gray iron foundry using a cupola (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 6,187,878 million tons of iron castings that were cupola-melted were produced in the United States (Mosher, 1997).

Calculation

7-PAH Annual Emission = 2.07E-05 lb/ton * 6,187,878 million tons = 128 lb
= 0.06 tons

16-PAH Annual Emission = 6.21E-05 lb/ton * 6,187,878 million tons = 384 lb
= 0.19 tons

B.31 SECONDARY LEAD SMELTING

Basis for Input Data

1. The calculation of national emissions for the secondary lead category was based on the most recent emission factor test data for POM species that could be determined and the production levels of lead by furnace type. Much of the information for these estimates was obtained from the EPA staff involved with the development of the MACT standard for this source category. Production data were provided by the MACT staff for three breakdowns of furnace type. These are as follows.

Blast Furnaces:	273,396 Mg/yr production
Blast/Reverb Furnaces:	613,902 Mg/yr production
Reverb and Rotary Furnaces:	305,176 Mg/yr production
TOTAL:	1,192,474 Mg/yr

POM emission factors were not available for each of these furnace types; therefore, assumptions had to be made that resulted in combining some furnace types together in order to calculate emissions. Based on input from the MACT team, the production data for the Blast/Reverb and the Reverb and Rotary were combined together and applied to the emission factors that were available for rotary furnaces. The production breakdowns, by furnace type, that were used to calculate national emissions are as follows.

Blast Furnaces:	273,396 Mg/yr
Blast/Reverb and Rotary Furnaces:	919,078 Mg/yr
TOTAL:	1,192,474 Mg/yr

Based on these data and emission factor information, national 7-PAH estimates were calculated. The national estimate for 16-PAH was provided directly from the EPA

MACT development program for secondary lead smelting. Specific details on how the 16-PAH estimate was derived were not available. The EPA MACT program group would need to be contacted to obtain these data.

2. The emission factors were determined for 7-PAH by furnace grouping. Each grouping is explained below.

Blast Furnaces

a. 7-PAH Factor: The available test data had no results for any of the species identified as being in the 7-PAH group; therefore, there is no 7-PAH factor for blast furnaces. Consequently, there is no national emission estimate for this source as well.

Rotary and Blast/Reverb Furnaces

a. 7-PAH Factor: The available test data from the MACT program only contained data for one specie in the list of 7-PAH. This specie was chrysene. The uncontrolled chrysene emission factor that was developed from the data was:

0.00183 lb/ton (0.000917 kg/Mg), Uncontrolled

The same rationale and approach described above in terms of reflecting controlled MACT levels for national emissions was applied here as well. The MACT team indicated that for these sources a control of approximately 98 percent would be achieved. The uncontrolled chrysene factor was adjusted accordingly as follows.

(0.00183 lb/ton) x (0.02) = 0.000037 lb/ton (0.000018 kg/Mg)

This factor was used to calculate national emissions.

Calculation

1. 7-PAH Emissions:

Blast Furnaces

As discussed above, due to a lack of data, there is no national estimate for blast furnaces for the 7-PAH group.

Rotary and Blast/Reverb

(919,078 Mg/yr production) x (0.000018 kg/Mg) = 0.017 Mg/yr (represents only chrysene)

2. 16-PAH Emissions:

The 16-PAH emissions estimate provided by the EPA MACT program for secondary lead smelting is 69.9 tons of emissions in 1990. The 16-PAH figure included the PAH species of naphthalene, pyrene, and chrysene (Cavendar, 1997). No breakdown by furnace type was provided.

B.32 PETROLEUM REFINERY: ALL PROCESSES

Basis for Input Data

1. The emission factor used for catalytic cracking units for the 7-PAH group was 1.66E-05 lb/barrel (7.53E-06 kg/barrel) and the 16-PAH emission factor was 3.16E-04 lb/barrel (1.43E-04 kg/barrel). These factors were developed from the individual PAH emission factors for two types of catalytic cracking units (U.S. EPA, 1997). Fluid catalytic cracking units make up 90 percent of the cracking units. Moving-bed catalytic cracking units make up the remaining 10 percent. The emission factors were developed using a weighted average based on the percentage each type of cracking unit contributes to the total production.

2. The 7-PAH emission factor includes: Benzo(a)pyrene.

   The 16-PAH emission factor includes: Benzo(a)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1991, 1.98E+09 barrels of oil were charged to catalytic cracking units in the United States (Oil and Gas Journal, 1991).

4. For emissions sources other than catalytic cracking, a naphthalene estimate was provided by the EPA MACT rule development program. The MACT program compiled an emissions estimate for 16-PAH (naphthalene only) for all refinery processes other than catalytic cracking of 783 tons (Durham, 1997).

Calculation

7-PAH Annual Emissions = 1.66E-05 lb/barrel * 1.98E+09 barrels = 3.29E+04 lbs
= 16.4 tons

16-PAH Annual Emissions = 3.16E-04 lb/barrel * 1.98E+09 barrels = 6.26E+05 lbs
= 313 tons

Combining the naphthalene and 16 PAH values provides a total 16-PAH estimate of:

16 PAH: 313 + 783 = 1,096 tons/yr

B.33 ASPHALT ROOFING MANUFACTURING

Basis for Input Data

1. The emission factor for the 7-PAH group was 1.10E-04 lb/ton (5.50E-05 kg/Mg) for felt saturation. There is no 7-PAH emission factor for asphalt blowing because none of the 7-PAH were reported in the available test data. The 16-PAH emission factors were 5.10E-03 lb/ton (2.55E-03 kg/Mg) for asphalt blowing and 3.17E-04 lb/ton (1.58E-04 kg/Mg) for felt saturation. The overall 7-PAH emission factor was 1.10E-04 lb/ton (5.50E-05 kg/Mg) and the overall 16-PAH emission factor was 2.86E-03 lb/ton (1.93E-03 kg/Mg) (U.S. EPA, 1980).

   These factors were developed from the individual PAH emission factors for two processes involved in producing asphalt roofing: asphalt blowing and felt saturation. Half of the weight of asphalt roofing products is blown asphalt. The overall emission factors were calculated by summing the total emissions from asphalt blowing and felt saturation and dividing by the total asphalt roofing produced.

2. The 7-PAH emission factor includes: Benz(a)anthracene, and Chrysene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Chrysene, Anthracene, Fluoranthene, and Phenanthrene.

3. In 1993, 3.05E+07 tons of asphalt roofing was produced in the United States (Asphalt Roofing Manufacturers Association, 1994).

Calculation

Asphalt Blowing

16-PAH Annual Emissions = 5.10E-03 lb/ton * 1.52E+07 tons = 7.75E+04 lb
= 38.8 tons

Felt Saturation

7-PAH Annual Emissions = 1.1E-04 lb/ton * 3.05E+07 tons = 3360 lb
= 1.68 tons

16-PAH Annual Emissions = 3.17E-04 lb/ton * 3.05E+07 tons = 9,670 lb
= 4.83 tons

Total Emissions

7-PAH Total Annual Emission 1.68 tons + 0 tons = 1.68 tons

16-PAH Total Annual Emission 4.83 + 38.8 tons = 43.6 tons

B.34 ASPHALT HOT-MIX PRODUCTION

Basis for Input Data

1. The emission factor for the 7-PAH group was 3.90E-07 lb/ton (1.95E-07 kg/Mg) and the 16-PAH emission factor was 1.82E-04 lb/ton (9.10E-05 kg/Mg). These factors were developed from the individual PAH emission factors for natural gas- or propane-fired dryers, oil-fired dryers, natural gas-fired dryer with fabric filter and oil-fired dryer with fabric filter as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1993, 4.80E+08 tons of hot-mix asphalt were produced in the United States (NAPA, 1993).

Calculation

$$7\text{-PAH Annual Emissions} = 3.90\text{E}{-}07 \text{ lb/ton} * 4.80\text{E}{+}08 \text{ tons} = 187 \text{ lbs} = 0.094 \text{ tons}$$

$$16\text{-PAH Annual Emissions} = 1.82\text{E}{-}04 \text{ lb/ton} * 4.80\text{E}{+}08 \text{ tons} = 8.74\text{E}{+}04 \text{ lbs} = 43.7 \text{ tons}$$

B.35 COKE OVENS: CHARGING, DOOR, AND TOPSIDE LEAKS

Basis for Input Data

1. The emission factor for the 7-PAH group is 3.72E-03 lb/ton (1.86E-03 kg/Mg) and the 16-PAH emission factor is 2.79E-02 lb/ton (1.39E-02 kg/Mg). These factors were developed from the individual PAH emission factors for controlled oven charging, oven door, lid leaks, and offtake leaks as reported in EPA's AP-42 document (U.S. EPA, 1995b).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 3.86E+07 tons of coal were charged to coke ovens in the United States (EIA, 1990).

Calculation

$$7\text{-PAH Annual Emissions} = 3.72E{-}03 \text{ lb/ton} * 3.86E{+}07 \text{ tons} = 143{,}592 \text{ lbs} = 71.8 \text{ tons}$$

$$16\text{-PAH Annual Emissions} = 2.79E{-}02 \text{ lb/ton} * 3.86E{+}07 \text{ tons} = 1{,}076{,}940 \text{ lbs} = 538.5 \text{ tons}$$

B.36 COKE OVENS: PUSHING, QUENCHING, AND BATTERY STACKS

Basis for Input Data

1. The emission factors for the 7-PAH group and the 16-PAH group were derived from data reported in the U.S. Environmental Protection Agency Locating and Estimating Document for POM (U.S. EPA, 1997). The factors used in the 112(c)(6) analysis were developed from the individual PAH emission factors for uncontrolled oven pushing, oven underfiring, and quenching. The individual PAH data were obtained from various source test reports for these sources. Most all of the data dated back to the 1980's and late 1970's.

2. Because of the scarcity of data for these sources types, the available factors were combined together and reported as one factor applicable to the group of sources as a whole. The factors used to estimate emissions for pushing, quenching, and battery stacks are:

    7-PAH: 3.093E-03 lb/ton (1.55E-03kg/Mg) of coal charged
    16-PAH: 0.053 lb/ton (0.026 kg/Mg) of coal charged

    These factors were multiplied by the national activity data for 1990 to obtain national uncontrolled emissions.

3. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Diben(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

    The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene,

Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

4. The uncontrolled emission rate was adjusted for controls in place by using an overall control efficiency derived from available data. The control efficiency figure was derived by averaging data from Trenholm and Beck, 1978 and EPA's AP-42 document. The AP-42 data were obtained from the May, 1995 draft section on coke ovens which EPA felt was the most recent and reliable data available. Control efficiencies for these operations were back calculated from the uncontrolled and controlled emission factors reported in AP-42. Based on the engineering judgements of EPA specialists on coke ovens, a conservative control efficiency value was averaged from the AP-42 data to reflect the fact that the entire category is not well controlled for these sources. The average control efficiency value for these source types that was derived and used for this analysis is 49.5 percent control.

5. In 1990, 3.86E+07 tons of coal were charged to coke ovens in the United States (EIA, 1990).

Calculation

A. 7-PAH National Emissions (Uncontrolled)

= 0.00309 lb/ton * 3.86E+07 tons/yr = 119,274 lb

= 59.6 tons/yr

7-PAH National Emissions (Controlled)

= 59.6 tons/yr * (1-0.495) = 30.1 tons/yr

B. 16-PAH National Emissions (Uncontrolled)

= 0.053 lb/ton * 3.86E+07 tons/yr = 2,045,800 lbs

= 1,022.9 tons/yr

16-PAH National Emissions (Controlled)

= 1,022.9 tons/yr * (1-0.495) = 516.6 tons/yr

B.37 PORTLAND CEMENT MANUFACTURING

Basis for Input Data

1. The emission factors used to estimate annual emissions for hazardous waste (HW) kilns and non-hazardous (NHW) waste kilns were developed from data presented in the POM Locating and Estimating document (U.S. EPA, 1997). These data include emissions of individual PAHs from HW and NHW kilns. The individual emissions were summed to develop 7-PAH and 16-PAH emission factors and all factors for HW kilns were averaged to produce overall averages for HW kilns. The same procedure was used for NHW kilns.

2. The activity data used to estimate annual emissions from NHW kilns were obtained from data and analyses developed as a part of the MACT development programs for Portland Cement Kilns (Heath, 1996a), (Heath, 1996b). These memorandums presented national baseline emission calculations for dioxins/furan from HW and NHW kilns. A value of 63.34 million tons of clinker per year was used to calculate emissions from NHW kilns. A value of 16,500,000 tons of clinker per year was used for HW kilns. This value was derived from multiple information provided by the industry (Hawkins, 1997; CKRC, 1996).

Non-Hazardous Waste Kilns

1. The emission factor for the 7-PAH group was 8.21E-05 lb/ton (4.11E-05 kg/Mg) and the 16-PAH emission factor was 1.51E-03 lb/ton (7.55E-04 kg/Mg). These factors were developed from the individual PAH emission factors for a coal-fired precalciner dry process kiln, a coal-fired wet process kiln, a coal/coke-fired wet process kiln, and a coal/TDF-fired wet process kiln.

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. Calculations

7-PAH annual emissions = 8.21E-05 lb/ton * 63.34E+06 tons = 5,200 lbs = 2.60 tons
16-PAH annual emissions = 1.51E-03 lb/ton * 63.34E+06 tons = 95,643 lbs = 47.9 tons

<u>Hazardous Waste Kilns</u>

1. The emission factor for the 7-PAH group was 2.52E-04 lb/ton (1.26E-04 kg/Mg) and the 16-PAH emission factor was 1.53E-03 lb/ton (7.65E-04 kg/Mg). These factors were developed from the individual PAH emission factors for two coal/coke/hazardous waste-fired wet process kilns, a coal/hazardous waste-fired wet process kiln, a hazardous waste-fired wet process kiln, a gas/hazardous waste-fired wet process kiln, a coal/coke/hazardous waste-fired dry process kiln, and a coal/hazardous waste-fired dry process kiln.

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. Calculations

7-PAH annual emissions = 2.52E-04 lb/ton *16,500,000 tons = 4,158 lbs = 2.08 tons

16-PAH annual emissions = 1.53E-03 lb/ton * 16,500,000 tons = 25,245 lbs = 12.6 tons

B.38 PULP AND PAPER--KRAFT RECOVERY BOILERS

Basis for Input Data

1. Two general types of recovery boilers are used for this process, direct contact evaporators (DCE) and non-direct contact evaporators (NDCE). POM emission factor data were available from industry reports for both types of units; however, activity data were not found on a process-specific basis. Activity data were only found as a total for all boilers. 7-PAH and 16-PAH national emission estimates were calculated by determining an average emission factor across all boiler types and applying this factor to total boiler activity. The emission factor data used in the analysis and the PAH compounds represented in the estimate are shown below (NCASI, 1993).

PAH Specie	7- or 16-PAH	NDCE/ Dry Bottom ESP[a]	NDCE/ Wet Bottom ESP/Scrubber[a]	DCE/ Wet Bottom ESP/Scrubber[a]
Benz(a)anthracene	7-PAH, 16-PAH	1.20E-05	3.50E-06	9.60E-05
Benz(o)pyrene	7-PAH, 16-PAH	2.60E-06	3.50E-06	5.80E-06
Benzo(b)fluoranthene	7-PAH, 16-PAH	6.40E-06	3.50E-06	2.90E-05
Benzo(k)fluoranthene	7-PAH, 16-PAH		3.50E-06	8.00E-06
Chrysene	7-PAH, 16-PAH	6.50E-05	3.50E-06	3.90E-05
Dibenz(a,h)anthracene	7-PAH, 16-PAH	6.00E-06	3.50E-06	6.80E-06
Indeno(1,2,3-cd)pyrene	7-PAH, 16-PAH	6.00E-06	3.50E-06	4.20E-06
Acenaphthene	16-PAH	5.00E-06	3.50E-06	1.60E-05
Acenaphthylene	16-PAH		1.30E-05	2.60E-03
Anthracene	16-PAH		3.50E-06	4.00E-04
Benzo(ghi)perylene	16-PAH	7.90E-06	3.50E-06	1.20E-05
Fluoranthene	16-PAH		1.90E-05	6.90E-04
Fluorene	16-PAH		3.50E-06	2.10E-04
Naphthalene	16-PAH		6.40E-04	3.20E-02
Phenanthrene	16-PAH		9.50E-06	5.60E-03

Pyrene	16-PAH	1.00E-04	1.10E-05	3.30E-04
SUM of 7-PAH EF[b]		8.80E-05	2.45E-05	1.89E-04
SUM of 16-PAH EF[c]		2.01E-04	8.17E-04	4.20E-02
NCDE Average EF				
7-PAH EF	5.63E-05			
16-PAH EF	5.09E-04			
DCE EF				
7-PAH EF	1.89E-04			
16-PAH EF	4.20E-02			
Overall Average EF[d]				
7-PAH EF	1.23E-04			
16-PAH EF	2.13E-02			

[a] All emission factor data are in units of lb emissions/ton air dried pulp.
[b] This row represents the sum of 7-PAH emission factors.
[c] This row represents the sum of 16-PAH emission factors.
[d] Overall average of the NDCE and DCE average emission factors.
NDCE = Non-direct Contact Evaporator
DCE = Direct Contact Evaporator

2. The individual emission factor data for 7- and 16-PAH were totaled to produce a sum of 7-PAH and a sum of 16-PAH emission factor. The two sets NCDE factors were then averaged together to produce an average factor for NCDE units. The NCDE average factor was then averaged together with the DCE factor to produce the overall factor used to calculate a national emissions estimate.

3. The overall average emission factors were applied to an annual activity level for recovery boilers of 6.10E+07 tons of air-dried pulp in the United States (U.S. EPA, 1993b).

Calculation

7-PAH Annual Emission = 1.23E-04 lb/ton pulp * 6.10E+07 tons pulp =
7,474 pounds = 3.74 tons/yr

16-PAH Annual Emission = 2.13E-02 lb/ton pulp * 6.10E+07 tons pulp =
1,297,943 pounds = 649 tons/yr

B.39 PULP AND PAPER--LIME KILNS

Basis for Input Data

1. The emission factor for 7-PAH was 3.30E-06 lb/MMBtu (1.42E-06 g/MJ) and the 16-PAH emission factor was 2.46E-03 lb/MMBtu (1.06E-03 g/MJ). These factors was developed from the individual PAH emission factors for two natural gas-fired lime kilns. Both kilns were controlled with scrubbers as reported in the POM L&E document (U.S. EPA, 1997). It was assumed that there are 550 CaO per ton pulp, 8 MMBtu per ton lime product, and 90 percent lime availability, i.e., 0.9 ton CaO per ton lime product.

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, and Chrysene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Anthracene, Fluoranthene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, the energy consumed in pulp and paper lime kilns in the United States was 1.49E+08 MMBtu (U.S. EPA, 1993b).

Calculation

7-PAH Annual Emission = 3.30E-06 lb/MMBtu * 1.49E+08 MMBtu = 492 lb
= 0.246 tons

16-PAH Annual Emission = 2.46E-03 lb/MMBtu * 1.49E+08 MMBtu = 3.67E+05 lb
= 183 tons

B.40 SULFITE RECOVERY FURNACES

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH's were reported in the available test data.

   The 16-PAH emission factor was 4.30E-03 lb/ADTP (2.15E-03 kg/Mg). This factor was developed from the individual PAH emission factors for ammonia-based sulfite recovery furnace as reported in the POM L&E document (U.S. EPA, 1997).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 2.87E+06 tons of pulp were produced in the United States (U.S. EPA, 1993b).

Calculation

16-PAH Annual Emission = 4.30E-03 lb/ADTP * 2.87E+06 tons = 1.23E+04 lb
= 6.17 tons

B.41 WILDFIRES AND PRESCRIBED BURNING

Basis for Input Data

1. The emission factor for the 7-PAH group was 0.020 lb/ton (0.010 kg/Mg) and the 16-PAH emission factor was 0.053 lb/ton (0.027 kg/Mg). These factors were developed from the individual PAH emission factors for wildfire and prescribed burning of pine needles, agricultural fields temperate and bared forest and sugar cane as they are reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Indeno(1,2,3-cd)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1990, 9.50E+07 tons of biomass were burned in the United States (Peterson and Ward, 1993; U.S. Forest Service, 1993).

Calculations

7-PAH Annual Emissions 0.020 lb/ton * 9.50E+07 tons = 1.93E+06 lbs
= 964 tons

16-PAH Annual Emissions 0.053 lb/ton * 9.50E+07 tons = 5.07E+06 lbs
= 2,540 tons

B.42 OPEN BURNING OF SCRAP TIRES

Basis for Input Data

1. The emission factor for the 7-PAH was 1,400 lb/1,000 tons of tire (0.70 kg/Mg) and the 16-PAH emission factor was 7,850 lb/1,000 tons of tire (3.93 kg/Mg). These factors were developed from the individual PAH emission factors from simulation of open burning of chunk and shredded scrap tires as they are reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. Approximately 7.5 million tires burn each year in landfills and illegal dumps in the United States. This estimate is the average of the range of 5 to 10 million tires, which were estimated to have burned in landfills and illegal dumps based on input from the Center for Fire Safety Studies at the Worcester Polytechnic Institute (Barnett, 1997). Assuming the average weight of a tire to be 20 pounds, the following activity level for scrap tire burning can be computed.

   7,500,000 tires x 20 lbs/tire = 1.5E+08 lbs
   1.5E+08 lbs x 1 ton/2,000 lbs = 75,000 tons of tires

Calculation

7-PAH Annual Emissions = 1,400 lb/1,000 tons * 75,000 tons = 1.05E+05 lbs
= 52.5 tons

16-PAH Annual Emissions = 7,850 lb/1,000 tons * 75,000 tons = 5.89E+05 lbs
= 294 tons

B.43 MOBILE SOURCES--ONROAD VEHICLES

Basis for Input Data

1. The emission factors for 7-PAH and the 16-PAH emission factors are provided in Table A-22a (of Appendix A). These factors were developed from the individual PAH emission factors for specific vehicle types. Fleet-wide emission factors were developed taking into consideration areas with and without inspection and maintenance programs.

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Indeno(1,2,3-cd)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1990, 2,147 billion vehicle miles were traveled in the United States (U.S. Department of Transportation, 1990).

Calculation

7-PAH Annual Emission = 14.52 μg/mile * 2,147 billion miles = 31.16 Mg
= 34.35 tons

16-PAH Annual Emission = 32.085 μg/mile * 2,147 billion miles = 68.88 Mg
= 75.93 tons

B.44 MOBILE SOURCES--AIRCRAFT

Basis for Input Data

The procedures used for all emission estimation calculations for aircraft were specified by EPA's Office of Mobile Sources (OMS).

Commercial Aircraft

For Commercial Aircraft, landing and take-off (LTO) data from Table 7 of Airport Activity Statistics of Certified Route Air Carriers (U.S. DOT, 1994a) were applied to Version 2.1 of the FAA Aircraft Engine Emission Database to estimate total hydrocarbon emissions (see Table below).

Note that the FAA Aircraft Engine Emission Database did not have all aircraft models and in some cases models were included in the database but no engine information was associated with a given model. Such that for the 87 aircraft models that were used in the commercial aircraft fleet in 1990, emission estimates could be calculated for only 40 aircraft models. Relative to LTO cycles, emissions for 76.13 percent of LTOs could be calculated. To compensate for the missing engine data, the hydrocarbon (HC) estimate provided in the spreadsheet below was adjusted by using a ratio of total national 1990 LTOs noted in FAA's Airport Activity Statistics of Certified Route Air Carriers (U.S. DOT, 1994a) and the actual total used in the FAA Aircraft engine Emission database.

26,856 tons of HC x (6,641,681 Total 1990 LTOs/5,056,281 LTOs used in FAA database) = 35,277 tons of HC

B.44 MOBILE SOURCES--AIRCRAFT

Aircraft Model	Aircraft Manufacturer	Engine Model	Number of Engines	Time In Mode (Minutes)					LTOs	HC Emissions (lbs)
				Engine Manufacturer	Idle	Take-off	Climb-out	Approach		
A300-600	AIRBUS	CF6-80C2A5 (RE	200%	GE	26	0.70	2.20	4.00	10,874	142,188
A310-200	AIRBUS	PW4X52 PHASE 3	200%	P&W	26	0.70	2.20	4.00	2,470	20,848
A310-300	AIRBUS	CF6-80A3	200%	GE	26	0.70	2.20	4.00	15,290	111,859
A320-200	AIRBUS	CFM56-5-A1	200%	CFMI	26	0.70	2.20	4.00	11,628	14,615
BAE 146-100	BAE	ALF 502R-5	400%	TEX LYC	26	0.70	2.20	4.00	14,185	43,958
BAE 146-200	BAE	ALF 502R-5	400%	TEX LYC	26	0.70	2.20	4.00	72,534	224,779
BAE 146-300	BAE	ALF 502R-5	400%	TEX LYC	26	0.70	2.20	4.00	31,271	96,907
B727-100	BOEING	JT8D-7,7A & 7B	300%	P&W	26	0.70	2.20	4.00	167,978	922,030
B727-100(CARG)	BOEING	JT8D-7B	300%	P&W	26	0.70	2.20	4.00	57,273	876,837
B727-200	BOEING	JT8D-15 (R.E.C	300%	P&W	26	0.70	2.20	4.00	1,210,878	3,430,497
B727-200(CARG)	BOEING	JT8D-17A	300%	P&W	26	0.70	2.20	4.00	23,455	239,289
B737-100	BOEING	JT8D-17	200%	P&W	26	0.70	2.20	4.00	798,460	9,314,135
B737-200 (CARG)	BOEING	JT8D-17	200%	P&W	26	0.70	2.20	4.00	96,530	1,126,034
B737-300	BOEING	CFM56-3-B1	200%	CFMI	26	0.70	2.20	4.00	771,658	1,421,723
B737-400	BOEING	CFM56-3C-1	200%	CFMI	26	0.70	2.20	4.00	78,429	99,185
B737-500	BOEING	CFM56-3-B1	200%	CFMI	26	0.70	2.20	4.00	18,544	34,166
B747	BOEING	PW4X62 PHASE 3	400%	P&W	26	0.70	2.20	4.00	32,307	339,524
B747-200	BOEING	JT9D-59A	400%	P&W	26	0.70	2.20	4.00	13,071	525,486
B747-400	BOEING	CF6-80C2B1 (DE	400%	GE	26	0.70	2.20	4.00	2,436	63,445
B747F (CARG)	BOEING	JT9D-7F (MOD V	400%	P&W	26	0.70	2.20	4.00	3,963	316,436
B747-SP	BOEING	RB211-524B	400%		26	0.70	2.20	4.00	2,192	434,021
B757-200	BOEING	PW2037	200%	P&W	26	0.70	2.20	4.00	233,763	546,765
B757-200(CARG)	BOEING	RB211-535E4	200%	RR	26	0.70	2.20	4.00	571	773
B767-200	BOEING	JT9D-7R4E1	200%	P&W	26	0.70	2.20	4.00	75,934	149,616
B767-300	BOEING	PW4060	200%	P&W	26	0.70	2.20	4.00	33,859	88,765
F100	FOKKER	TAY MK 650-15	200%	RR	26	0.70	2.20	4.00	34,259	108,258
L-1011-500	LOCKHEED	RB211-524B SER	300%		26	0.70	2.20	4.00	3,712	22,919
L-1011-100	LOCKHEED	RB211-22B (REV	300%	RR	26	0.70	2.20	4.00	71,108	11,594,019
DC10-10	MCDONNELL DOUG	CF6-50C	300%	GE	26	0.70	2.20	4.00	116,813	6,178,905
DC10-30	MCDONNELL DOUG	CF6-50C	300%	GE	26	0.70	2.20	4.00	22,412	1,185,498
DC10-40	MCDONNELL DOUG	JT9D-20	300%	P&W	26	0.70	2.20	4.00	18,938	1,516,582
DC8-61	MCDONNELL DOUG	JT3D-3B	400%	P&W	26	0.70	2.20	4.00	461	99,041

B.44 MOBILE SOURCES--AIRCRAFT (Continued)

Aircraft Model	Aircraft Manufacturer	Engine Model	Number of Engines	Time In Mode (Minutes)					LTOs	HC Emissions (lbs)
				Engine Manufacturer	Idle	Take-off	Climb-out	Approach		
DC8-62	MCDONNELL DOUG	JT3D-3B	400%	P&W	26	0.70	2.20	4.00	1,295	278,217
DC8-62 (CARG)	MCDONNELL DOUG	JT3D-7	400%	P&W	26	0.70	2.20	4.00	1,432	312,675
DC8-63F (CARG)	MCDONNELL DOUG	JT3D-7	400%	P&W	26	0.70	2.20	4.00	1,713	374,031
DC9-10	MCDONNELL DOUG	JT8D-7 (OLD CO	200%	P&W	26	0.70	2.20	4.00	107,937	1,101,662
DC9-15F	MCDONNELL DOUG	JT8D-7B	200%	P&W	26	0.70	2.20	4.00	22,278	227,381
DC9-30	MCDONNELL DOUG	JT8D-17	200%	P&W	26	0.70	2.20	4.00	722,285	8,425,544
DC9-40	MCDONNELL DOUG	JT8D-15 (R.E.C	200%	P&W	26	0.70	2.20	4.00	7,256	13,704
DC9-50	MCDONNELL DOUG	JT8D-17	200%	P&W	26	0.70	2.20	4.00	144,829	1,689,448
Total									5,056,281	53,711,765
							Conversion to Tons			**26,856**

A correction factor from Procedures for Emission Inventory Preparation Volume IV: Mobile Sources (U.S. EPA, 1992b), was applied to the commercial aircraft hydrocarbon emission estimate to obtain a VOC estimate:

35,277 tons of HC x 1.0947 VOC/HC = 38,618 tons of VOC

The VOC estimate was speciated for 7-PAH and 16-PAH using speciation profiles from a memo from Rich Cook U.S. EPA/OMS to Anne Pope EPA/OAQPS (Cook, 1997).

38,618 tons of VOC x 1.049 x 10^{-6} 7-PAH/VOC= 0.04 tons 7-PAH
38,618 tons of VOC x 1.166 x 10^{-4} 16-PAH/VOC= 4.50 tons 16-PAH

Air Taxis

For air taxis, 1990 activity data were taken from the FAA Air Traffic Activity - Fiscal Year 1993 (U.S. DOT, 1994b). In this reference, each FAA activity (i.e. a landing or take-off) is counted. This means that for every LTO there are two FAA activities. These 1990 data were converted to LTOs by dividing the FAA activity data by two.

8,837,671 FAA activity/2 = 4,418,836 LTOs

These LTO data were applied to generic air taxi HC emission factors found in Procedures for Emission Inventory Preparation Volume IV: Mobile Sources (U.S. EPA, 1992b) to estimate HC emissions:

4,418,836 LTOs x 1.234 pounds HC/LTO x 1 ton/2,000 pounds = 2,726.42 tons of HC

A correction factor from Procedures for Emission Inventory Preparation Volume IV: Mobile Sources (U.S. EPA, 1992b), was applied to the air taxi HC emission estimate to obtain a VOC estimate:

2,726.42 tons of HC x 0.9914 VOC/HC = 2,702.97 tons of VOC

The VOC estimate was speciated for 7-PAH and 16-PAH using speciation profiles from a memo from Rich Cook U.S. EPA/OMS to Anne Pope EPA/OAQPS (Cook, 1997).

2,702.97 tons of VOC x 7.234×10^{-6} 7-PAH/VOC= 0.02 tons 7-PAH
2,702.97 tons of VOC x 6.829×10^{-5} 16-PAH/VOC= 0.18 tons 16-PAH

General Aviation

For General Aviation, 1990 activity data were taken from the FAA Air Traffic Activity - Fiscal Year 1993 (U.S. DOT, 1994b). This data were converted to LTOs by dividing the FAA activity data by two.

39,169,795 FAA activity/2 = 19,584,898 LTOs

The LTOs data were applied to a generic general aviation HC emission factors found in Procedures for Emission Inventory Preparation Volume IV: Mobile Sources to estimate HC emissions:

19,584,898 LTOs x 0.394 pounds HC/LTO x 1 ton/2,000 pounds = 3,858.22 tons of HC

A correction factor from Procedures for Emission Inventory Preparation Volume IV: Mobile Sources, were applied to the air taxi hydrocarbon emission estimate to obtain a VOC estimate:

3,858.22 tons of HC x 0.9708 VOC/HC = 3,745.56 tons of VOC

The VOC estimate was speciated for 7-PAH and 16-PAH using speciation profiles from a memo from Rich Cook U.S. EPA/OMS to Anne Pope EPA/OAQPS (Cook, 1997).

3,745.56 tons of VOC x 9.062×10^{-6} 7-PAH/VOC= 0.03 tons 7-PAH
3,745.56 tons of VOC x 2.954×10^{-5} 16-PAH/VOC= 0.11 tons 16-PAH

Military Aircraft

Estimates for military aircraft were not possible due to the lack of information concerning the make up of the military aircraft fleet or alternatively a generic HC emission factor.

Total Aircraft Emissions (tons/year)

Pollutant	Commercial Aircraft	Air Taxis	General Aviation	Total
7-PAH	0.04	0.02	0.03	0.09
16- PAH	4.50	0.18	0.11	4.79

B.45 CARBON BLACK MANUFACTURING

Basis for Input Data

1. The emission factor for the 7-PAH group was 5.25E-04 lb/ton (2.63E-04 kg/Mg) and the 16-PAH emission factor was 5.04E-03 lb/ton (2.52E-03 kg/Mg). These factors were developed from the individual PAH emission factors for oil furnace carbon black manufacturing as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, and Chrysene.

   The 16-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Acenapthylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1993, the industry had a capacity to produce 1.72E+06 tons of carbon black in the United States (SRI International, 1993).

Calculations

$$7\text{-PAH Annual Emissions} = 5.25E{-}04 \text{ lb/ton} * 1.72E{+}06 \text{ tons} = 903 \text{ lbs} = 0.451 \text{ tons}$$

$$16\text{-PAH Annual Emissions} = 5.04E{-}03 \text{ lb/ton} * 1.72E{+}06 \text{ tons} = 8{,}670 \text{ lbs} = 4.33 \text{ tons}$$

B.46 WOOD TREATMENT/WOOD PRESERVING WITH CREOSOTE

Basis for Input Data

1. There is no 7-PAH emission factor for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 1.94E-03 lb/ft^3 (0.0311 kg/m^3). This factor was developed from the individual PAH emission factors from creosote wood treatment process and diluent wood treated as reported in the POM L&E document (U.S. EPA, 1997). (Does not include fugitives from treated wood storage.)

2. The 16-PAH emission factor includes: Acenaphthene, Fluorene, Naphthalene, and Phenanthrene.

3. In 1990, 93.2E+06 ft^3 of wood were treated with creosote in the United States (Bartlow, 1997).

Calculations

$$16\text{-PAH Annual Emissions} = 1.94E-03 \text{ lb/ft}^3 * 93.2E+06 \text{ ft}^3 = 180{,}808 \text{ lbs} = 90.4 \text{ tons}$$

B.47 CIGARETTE SMOKE

Basis for Input Data

1. The emission factor for the 7-PAH group was 2.08E-09 lb/cigarette (9.43E-10 kg/cigarette) and the 16-PAH emission factor was 1.38E-08 lb/cigarette (6.26E-09 kg/cigarette). These factors were developed from the individual PAH emission factors from cigarette as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene and Chrysene

   The 16-PAH emission factor includes: Benz(a)anthracene, Chrysene, Anthracene, Fluoranthene, Phenanthrene and Pyrene.

3. In 1992, 5.00E+11 cigarettes were consumed in the United States (USDA, 1993).

Calculation

7-PAH Annual Emissions = 2.08E-09 lb/cigarette * 5.00E+11 cigarettes = 1,040 lbs
= 0.520 tons

16-PAH Annual Emissions = 1.38E-08 lb/cigarette * 5.00E+11 cigarettes = 6,900 lbs
= 3.45 tons

B.48 CREMATORIES

Basis for Input Data

1. The emission factor for the 7-PAH group was 7.07E-11 lb/body (3.21E-11 kg/body) and the 16-PAH emission factor was 4.16E-08 lb/body (1.89E-08 kg/body). These factors were developed from the individual PAH emission factors from crematory stacks as reported in the POM L&E document (U.S. EPA, 1997).

2. The 7-PAH Emissions factor includes: Benz(a)anthracene, Benzo(a)pyrene and Chrysene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Acenaphthene, Acenapthylene, Anthracene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1992, 4.00E+05 cremations were performed in the United States (Cremation Association of North America, 1992).

Calculation

7-PAH Annual Emissions = 7.07E-11 lb/body * 4.00E+05 bodies = 2.83E-05 lbs
= 1.42E-08 tons

16-PAH Annual Emissions = 4.16E-08 lb/body * 4.00E+05 bodies = 0.0166 lbs
= 8.33E-06 tons

B.49 GASOLINE DISTRIBUTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source category because none of the 7-PAH were reported in the available test data.

   The 16-PAH emissions for this source category only include naphthalene. A single 16-PAH emission factor could not be developed for this source category because the nature of a significant amount of the national emissions do not lend themselves to establishing emission factors of the type developed for other POM categories.

2. Instead of developing an overall emission factor, national emissions were calculated as follows.

   To develop the Gasoline Distribution (Stage I) NESHAP (U.S. EPA, 1994b; U.S. EPA, 1994c), national annual VOC and HAP emissions from the source category were estimated for the base year 1998; emission estimates for 1990 were not provided. For the purposes of this report, 1990 emissions were estimated by scaling down the 1998 emissions estimates in the NESHAP using the ratio of the projected 1998 gasoline consumption (117.9 billion gallons) to the Department of Energy's record of 1990 gasoline consumption (110.5 billion gallons). This approach reduces the 1998 base year emissions by 6.28 percent. Adjustments made in the NESHAP for the level of control projected in 1998 and anticipated future uses of alternative fuels could not be taken into consideration when 1998 emissions were adjusted to 1990 in this survey, so the emissions estimates made here may slightly underestimate the actual 1990 emissions.

As stated previously, national annual VOC and HAP emissions were estimated for different processes throughout the Stage I gasoline distribution network taking into account the projected control programs in each State (LaFlam and Johnson, 1996). According to the documentation for the Gasoline Distribution NESHAP, naphthalene is 0.80 percent of total HAP emissions. Taking this into consideration, national annual naphthalene Stage I emissions are 376 tons for 1998. This estimate was adjusted to reflect emissions in 1990, yielding a national annual naphthalene estimate of 352 tons.

3. The estimating method for emissions from Stage II gasoline distribution sources was taken from the approach for vehicle refueling outlined in the EPA's Technical Guidance - Stage II document (U.S. EPA, 1991a). A VOC emission factor was obtained from MOBILE 4.1, EPA's mobile source emission factor computer model. The VOC emission factors relative to monthly temperatures nationwide were applied to gasoline throughput to estimate emissions. Naphthalene emissions were estimated using the speciation value of 0.05 percent naphthalene in total VOC provided in the documentation for the Gasoline Distribution NESHAP (LaFlam and Johnson, 1996; U.S. EPA, 1994c).

The above emissions estimate approach is conservative because it was assumed that all fuel throughput is via conventional refueling methods and it does not take into consideration any Stage II emission controls. However, the emission factors used in the Stage II document do not include spillage losses.

Calculation

Stage I emissions:

National emissions estimate for Stage I	=	1998 naphthalene emissions estimate (tons/yr) from NESHAP x (100 - percent reduction fuel consumption, 1998 to 1990)
	=	342 Mg x 1.102 tons/Mg x (100 - 6.28) percent
	=	353 tons/yr

Stage II emissions:

National emissions estimate for Stage II	=	VOC emission factor (lb/gal) x gasoline throughput (gal/yr) x naphthalene content
	=	$0.013601 \times 1.11 \times 10^{11} \times 0.0005$
	=	374 tons/yr

Total national emissions estimate for gasoline distribution

	=	353 + 374
	=	727 tons/yr

B.50 NAPHTHALENE PRODUCTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available data.

   The 16-PAH emission factors were 0.523 lb/ton (0.262 kg/Mg) of naphthalene produced and 0.0024 lb/ton (0.0012 kg/Mg) of coke produced. These factors were developed from the individual PAH emission factors from the coal tar distillation process and coke by-product recovery plants as reported in the POM L&E document (U.S. EPA, 1997).

2. The 16-PAH emission factor includes Naphthalene.

3. In 1993, 1.23E+05 tons of naphthalene and 2.70E+07 tons of coke were produced in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

Naphthalene Production

16-PAH Annual Emissions = 0.523 lb/ton * 1.23E+05 tons = 6.41E+04 lbs

= 32.2 tons

Coke Production

16-PAH Annual Emissions = 0.0024 lb/ton * 2.70E+07 tons = 6.48+04 lbs

= 32.4 tons

Total Annual Emissions = 32.2 tons + 32.4 tons = 64.6 tons

B.51 NAPHTHALENE USE - PHTHALIC ANHYDRIDE PRODUCTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 0.34 lb/1000 lbs (0.34 kg/Mg) naphthalene processed. This factor was developed from individual PAH emission factors for storage and transfer of naphthalene used in the production of phthalic anhydride (U.S. EPA, 1997).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 1.54E+08 lbs of naphthalene were consumed to produce phthalic anhydride in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

$$16\text{-PAH Annual Emissions} = 0.34 \text{ lb/1000 lbs} * 1.54E+08 \text{ lbs} = 5.24E+04 \text{ lbs} = 26.2 \text{ tons}$$

B.52 NAPHTHALENE USE - CARBAMATE INSECTICIDE PRODUCTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 0.34 lb/1000 lbs (0.34 kg/Mg) naphthalene consumed. This factor was developed from the individual PAH emission factors for carbamate insecticide production as reported in the POM L&E document (U.S. EPA, 1997).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 2.40E+07 lbs of naphthalene were consumed to produce carbamate insecticides in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

$$16\text{-PAH Annual Emissions} = 0.34 \text{ lb/1000 lbs} * 2.40E+07 \text{ lbs} = 8.16E+03 \text{ lbs} = 4.08 \text{ tons}$$

B.53 NAPHTHALENE USE - NAPHTHALENE SULFONATES PRODUCTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 0.34 lb/1000 lbs (0.34 kg/Mg) naphthalene consumed. This factor was developed from the individual PAH emission factors for naphthalene sulfonate production as reported in the POM L&E document (U.S. EPA, 1997).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 3.84E+07 lbs of naphthalene were consumed to produce naphthalene sulfonates in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

$$16\text{-PAH Annual Emissions} = 0.34 \text{ lb/1000 lbs} * 3.84E+07 \text{ lbs} = 1.31E+04 \text{ lbs} = 6.53 \text{ tons}$$

B.54 NAPHTHALENE - MISCELLANEOUS USES

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 0.34 lb/1000 lbs (0.34 kg/Mg) naphthalene consumed. This factor was developed from the individual PAH emission factors for miscellaneous uses of naphthalene as reported in the POM L&E document (U.S. EPA, 1997).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 7.20E+06 lbs of naphthalene were consumed in miscellaneous uses in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

$$16\text{-PAH Annual Emissions} = 0.034 \text{ lb/100 lbs} * 7.20E+06 \text{ lbs} = 2.45E+03 \text{ lbs} = 1.22 \text{ tons}$$

B.55 NON-ROAD MOBILE VEHICLES AND EQUIPMENT - OTHER

Basis for Input Data

The 1990 base year 7-PAH and 16-PAH national emission estimates for these categories were derived entirely by EPA's Office of Mobile Sources (OMS). The emission estimates are as follows:

7-PAH:	24.0 tons/yr
16-PAH:	47.0 tons/yr

The OMS contact identified in the reference for these estimates should be contacted for further information on the specific estimation procedures used (Cook, 1997).

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