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OFF-HIGHWAY MOBILE SOURCE EMISSION INVENTORY 100% COMPLETION REPORT

Prepared for

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ABSTRACT

Six categories of mobile off-highway sources of pollution have been analyzed, and emissions of HC, CO, NO_X, SO_X and Particulates have been calculated with the aid of a computer for all the 1,989 grid squares comprising the St. Louis AQCR. Equipment categories included were motorcycles, lawn and garden equipment, industrial equipment, construction equipment, farm equipment and outboard motorboats. Emissions contributed by each category were treated separately.

1.0 INTRODUCTION

The purpose of the off-highway mobile source emission inventory was to calculate emissions for the Metropolitan St. Louis Air Quality Control Region (AQCR 070) of a variety of unregulated sources with a spatial resolution corresponding to grid elements[1]. An EPA methodology for determining the criteria pollutant emissions of such sources was used as a guide[2]. Six equipment categories were dealt with: motorcycles, lawn and garden equipment, construction equipment, industrial equipment, farm equipment, and outboard motorboats. Problems were encountered, some significant, in the application of the methodology. Departures from it were made where necessary for optimum utilization of available data. Simplifying assumptions pertaining to area distribution of equipment populations and usage were used to make calculations possible which generally inadequate data would have otherwise prohibited.

The procedures involved in arriving at grid element emission values have been described in detail, all deviations from the recommended methodology noted and explained. This was not, and could not be (considering the quality of existing data on the different machine types) a rigorous computation of off-highway emissions. Instead, this inventory has been an attempt to determine the order of magnitude of emissions at the grid level within the limitations imposed by the nature of the subject.

2.0 OFF-HIGHWAY MOTORCYCLES

2.1 ESTIMATION OF OFF-HIGHWAY MOTORCYCLES IN USE

Among the contributors to off-highway emissions are those motorcycles specially designed for off-road use. This means the so-called "trail bikes", "dirt bikes", and "mini-bikes", whose popularity has burgeoned in the last few years. The primary problem with assessing the emissions impact of these vehicles was that of accurately determining the number in use in a given area. There is no registration requirement for off-highway motorcycles in either Illinois or Missouri. Thus, it was assumed for this emission inventory that the number used off the highway was equal to the number of unregistered motorcycles.

The estimate for unregistered motorcycles cited in Reference 2 is 15% of the total motorcycle population of the St. Louis AQCR. An approximation of total motorcycles per county was obtained by augmenting the number of county registrations utilizing this percentage. Thus,

$$\text{(1)}\quad \text{Total County Motorcycles} = \frac{\text{County Registrations}}{1-.15} = \frac{\text{County Registrations}}{.85}$$

Off-highway motorcycles in a county were calculated by taking 15% of total county motorcycles, or

$$\text{(2)}\quad \text{Off-Highway Motorcycles Per County} = .15 \times \text{Total County Motorcycles}$$
$$= .15\ \frac{\text{County Registrations}}{.85}$$
$$= .18 \times \text{County Registrations}$$

The number of motorcycles registered per county was available from References 3 and 4 for Missouri and Illinois, respectively. This number together with the calculated number of total and off-highway motorcycles per county appears in Table 1.

It is recognized that some registered motorcycles were used both on and off the highway. However the 15% estimate is of limited accuracy, and for this reason dual-use cases were eliminated from consideration in the inventory.

TABLE 1
MOTORCYCLE REGISTRATIONS,
TOTAL MOTORCYCLES AND OFF-HIGHWAY MOTORCYCLES PER COUNTY

COUNTY	COUNTY I.D.	REGISTRATIONS	TOTAL MOTORCYCLES (including unregistered)	OFF-HIGHWAY MOTORCYCLES (unregistered)
St. Louis County	4300	15,567	18,314	2,747
St. Louis City	4280	7,263	8,545	1,282
St. Clair	6900	5,071	5,966	895
Madison	4680	6,129	7,211	1,082
Jefferson	2280	3,019	3,552	533
St. Charles	4160	3,263	3,839	576
Franklin	1680	1,673	1,968	295
Clinton	1440	721	848	127
Monroe	5180	552	649	97
Randolph	6460	999	1,175	176
Bond	0520	506	595	89
Washington	7920	300	353	53

2.2 ASSUMPTIONS PERTAINING TO TYPICAL ENGINE SIZE, TYPE, AND ANNUAL MILEAGE

To facilitate the computation of emissions, a "typical" off-highway motorcycle was defined. The characterization required an average value, based on representative sampling, for each of three parameters:

1) engine size (engine displacement in cubic centimeters)
2) engine type (2-stroke or 4-stroke and population distribution between 2-stroke and 4-stroke)
3) annual mileage

No quantitative information on these parameters was available which was strictly applicable to off-highway motorcycles - only general statistics describing the national motorcycle population as a whole. A combination of the general statistics and qualitative information pertaining specifically to "trail bikes" provided the basis for the assumed parameter values. A departure from the recommended methodology[2] was required at this point as it provided only for total motorcycle emissions, and no technique for isolating off-highway emissions from the rest was discussed.

Statistical information utilized in assigning values is contained in Table 2[2]. The data contained in it refer to the national motorcycle population. It was felt the most straightforward method to assign a single parametric value was to determine the size range in which off-highway motorcycles belong, and then use the values for annual mileage and distribution which correspond to the particular range. By taking this approach extensive manipulation of data of somewhat limited applicability was avoided.

TABLE 2[2]

ANNUAL MILEAGE AND POPULATION DISTRIBUTION
FOR MOTORCYCLES AT THE NATIONAL LEVEL

ENGINE SIZE	ANNUAL MILEAGE	RATIO OF 2-STROKE TO 4-STROKE	
		2-STROKE	4-STROKE
90cc or less	750	11	9
90-191cc	1400	19	8
191-290cc	2100	8	3
over 290cc	3000	13	29

Motorcycles were grouped according to engine displacement[5,6] as follows:

1) under 100cc - almost exclusively mini-bikes
2) 100cc - strictly dirt-bikes and trail bikes
3) 125cc - by far "the biggest class of all... considered somewhat small for safe street riding... strictly for dirt and competition riding."
4) 175cc - "this class is primarily for the dual-purpose and dirt-riding enthusiast". Second only to the 125cc category for off-highway use.

5) 250cc - the weight factor rules out "the big... cycles displacing over 250cc's, as well as the overweight 250s" for off-road use. An extremely small number of motorcycles displacing 250cc and above are used by an elite group of serious racing enthusiasts.

As this analysis of different motorcycle sizes revealed, the 90-190cc range was the most appropriate range within which the "typical" off-highway motorcycle would fall. From Table 2, then, the corresponding annual mileage was assumed to be 1400; 2-stroke and 4-stroke motorcycles were assumed to be distributed in a 19 : 8 ratio respectively.

2.3 OFF-HIGHWAY MOTORCYCLE EMISSION FACTORS

Recommended emission factors[2] are shown in Table 3. Separate emission factors for 2-stroke and 4-stroke engines were available. Since it was assumed that the two different types of engines occurred in a 19 : 8 ratio, a composite emission factor was computed by combining the two factors in a weighted average (Table 3) as, for example:

(3) SO_X Off-Highway Emission Factor, kg/mile =

$$\frac{(.040 \times 10^{-3} \text{ kg/mile} \times 19) + (.023 \times 10^{-3} \text{ kg/mile} \times 8)}{19 + 8}$$

$$= .035 \times 10^{-3} \text{ kg/mile } SO_X$$

2.4 EMISSIONS PER COUNTY DUE TO OFF-HIGHWAY MOTORCYCLES

To calculate county emissions a modified version of the equation used in the recommended methodology[2] was used to compute off-highway emissions instead of total motorcycle emissions. Thus,

(4) County Emissions, kg/yr = Off-Highway Motorcycles in County x Emission Factor, kg/mile x 1400 miles/yr

where 1400 miles/year is the assumed average value for annual mileage. Off-highway motorcycle emissions per county appear in Table 4. For example the emissions of SO_X in Franklin County have been calculated as:

(5) County Emissions, kg/yr = 295 x (.035 x 10^{-3} kg/mile) x (1400 miles/yr)
= 14.5 kg/yr

where 295 is from Table 1 and .035 x 10^{-3} kg/mile is the factor for SO_X from Table 3.

TABLE 3

OFF-HIGHWAY MOTORCYCLE EMISSION FACTORS

ENGINE TYPE	KG/MILE OF EMISSIONS x 10^{-3}				
	HC	CO	NO_X	PART	SO_X
2-Stroke	24.0	32.4	0.06	0.33	0.040
4-Stroke	4.0	39.6	0.36	0.04	0.023
Weighted Composite (2-Stroke & 4-Stroke combined in a 19:8 ratio)	18.0	34.5	0.148	0.244	0.035

NOTE: These factors allow for evaporative hydrocarbon emissions.

TABLE 4

OFF-HIGHWAY MOTORCYCLE EMISSIONS PER COUNTY

COUNTY		EMISSIONS, KG/YR x 10^3				
		HC	CO	NO_X	PART	SO_X
St. Louis County	(4300)	69.2	133	.569	.938	.135
St. Louis City	(4280)	32.3	61.9	.266	.438	.063
St. Clair	(6900)	22.6	43.2	.185	.306	.044
Madison	(4680)	27.3	52.3	.224	.370	.053
Jefferson	(2280)	13.4	25.7	.110	.182	.026
St. Charles	(4160)	14.5	27.8	.119	.197	.028
Franklin	(1680)	7.43	14.2	.061	.101	.0145
Clinton	(1440)	3.20	6.13	.026	.043	.0062
Monroe	(5180)	2.44	4.69	.020	.033	.0057
Randolph	(6460)	4.44	8.50	.037	.060	.0086
Bond	(0520)	2.24	4.30	.018	.030	.0044
Washington	(7920)	1.34	2.56	.011	.018	.0026

2.5 GRID ELEMENT EMISSIONS

Knowing county emissions, grid element emissions were calculated according to the relation:

$$\text{(6)}\quad \text{Grid Element Emissions, kg/yr} = \text{County Emissions, kg/yr} \times \frac{\text{Grid Population}}{\text{County Population}}$$

This relation expresses the direct proportionality assumed between motorcycle emissions and population as recommended in Reference 2.

Two more assumptions are implicit in this approach; first, that unregistered motorcycles are distributed uniformly over the counties, and second that their usage is also uniformly distributed over the counties, in proportion to county population. While assumption (1) may be realistic, assumption (2) is not, but no better way is readily available.

For an illustration of the calculation of grid element emission, SO_X emissions from grid #1 have been calculated from data in Table 6.

$$\text{(7)}\quad \text{Grid Element Emissions of } SO_X\text{, kg/yr} = 14.5 \times \frac{1059}{60{,}459}$$

$$\text{(Grid \#1 - off-highway motorcycles)} = 0.254 \text{ kg/yr}$$

A computer tabulation is available[7], which lists all 1989 grid elements in increasing numberical order, and across from each grid number is printed the identification number of the county in which the grid falls, the grid element population, housing units in the grid, and other useful statistics. Grid number, county I.D. number, and grid populations were the items used from this printout for the motorcycle emission inventory. Table 1 includes the SAROAD county identification numbers, for the purpose of computer identification.

Due to the large number of grid elements and the five separate calculations of emissions of the five primary pollutants required for each grid element or square, it was found advantageous to write a computer program in FORTRAN that would process the available data and yield grid element emissions from off-highway motorcycles.

TABLE 5

COUNTY POPULATIONS

COUNTY I.D. NO.	COUNTY NAME	POPULATION
4300	St. Louis County	996,515
4280	St. Louis City	578,493
6900	St. Clair	309,777
4680	Madison	230,290
2280	Jefferson	102,223
4160	St. Charles	101,713
1680	Franklin	60,459
1440	Clinton	29,538
5180	Monroe	21,193
6460	Randolph	32,289
0520	Bond	14,014
7920	Washington	13,852

TABLE 6

SAMPLE CALCULATION DATA

OFF-HIGHWAY MOTORCYCLES

VARIABLE	VALUE	SOURCE OF VALUE
Grid Element Number	1	Specified
Pollutant	SO_X	Specified
County	Franklin (1680)	Reference 7
County Emissions (Off-Highway)	14.5 kg/yr	Table 4
County Population	60,459	Table 5
Grid Element Population	1059	Reference 7

3.0 LAWN AND GARDEN EQUIPMENT EMISSIONS

The lawn and garden category includes several types of equipment, in particular riding mowers, walking mowers, garden tractors, and motor tillers. Snowthrowers have not been included in the inventory for two reasons. First, they represent only a very small percentage of lawn and garden equipment, and second, they are rarely used more than two or three times per year in the St. Louis AQCR.

As for the four types of equipment which were considered, the walking mower is by far the most common, comprising approximately 75% of total equipment units, with riding mowers the next highest at only 9%.[8] Garden tractors and motor tillers account for even less, approximately 5% of total units in each case.[8] Two types of engines occur as a rule, either 2-stroke or 4-stroke, and they make up 6% and 94% of small utility engines respectively.[8] So-called "typical" horsepower ratings for them are based on population estimates of walking mowers, garden tractors, etc., coupled with a knowledge of the engine types found most frequently to occur in a particular application. Thus, the 2-stroke is rated on the average at 3.0 horsepower, and the 4-stroke at 3.5 horsepower.[2]

To be sure, there are still certain difficulties involved in trying to determine the number of small utility engines in use and precisely how and where those engines are being used. No registration data exists and there is no truly adequate sales or production information available. Furthermore, no reliable distribution statistics as to type and size of engines in use have been compiled. In spite of these obstacles, estimates have been made which provide sufficient groundwork for an emissions inventory with grid element resolution. But it must be added that with present limited information, emission figures at the grid level are only approximations, meant solely to give an idea of the order of magnitude of emissions per grid resulting from the off-highway mobile sources under consideration.

More encouraging are the emission factors which have been derived for small utility engines. A variety of engines of the type used in lawn and garden equipment have been tested in the laboratory and their emissions measured accurately under different loads.[2] Some such engines have even been tested, albeit on a limited basis, while oeprating under normal work-loads in the field, exhausts being collected in bags or constant-volume samplers during the grass-cutting or other characteristic operation. So, as might be expected, the emission factors for such mobile sources are quite reliable as long as operating conditions are taken into account. As is natural, simulated operations and actual field operations can be at variance with one another, and the human factor will always yield different operating patterns. Hence, while emission factors may be good, it is in the application of them that caution must be exercised. Recommended emission factors for lawn and garden equipment are in Table 7[2].

A few assumptions were made in deriving and applying the factors in Table 7 which bear mentioning here. They pertain to the seasonal nature and variation with climate of equipment usage. In Reference 2, it was assumed that national mean operating days per year amounted to 213, and the average usage time for the nation as a whole was 50 hours per year. The average number of freeze-free days (or equivalently mean operating days) per year in the St. Louis area is 190 $\pm$ 40; so 190 was used as a county mean.[9] (The 190 day figure is more recent than the 205 day figure used in the recommended methodology.[2]) It was assumed that there were 2.7 million 2-stroke engines and 50.2 million 4-stroke engines,[2] and using the emission factors in Table 7 in conjunction with the 50 hour usage figure national emissions (kg/yr) were calculated for each of the primary pollutants. Emissions were apportioned to the twelve AQCR 070 counties on the basis of housing units per county. The total number of one-unit housing structures in the nation was assumed to be 46.8 million.

This brings up an important point about the significance of housing structures in the inventory. A direct relationship was assumed between one-unit housing structures in a given area and the number of small utility engines in use in that area, on the strength of the excellent agreement between the two found in the U.S. Census publications. Since housing units and engines can be assumed to be directly proportional, a knowledge of housing structures per grid makes possible grid-element apportionment of emissions on this basis.

TABLE 7

EMISSION FACTORS FOR LAWN AND GARDEN EQUIPMENT

UNITS	ENGINE TYPE	EMISSION FACTORS				
		HC	CO	NO_X	PART	SO_X
G/HR	2-STROKE	300	660	2.1	9.4	0.8
	4-STROKE	37	380	4.2	0.6	0.5
KG/YR	2-STROKE	15	33	0.01	0.47	0.04
	4-STROKE	1.8	19	0.21	0.03	0.02

NOTE: These factors allow for evaporative hydrocarbon emissions.

Of course, this is oversimplifying the matter somewhat, since a certain number of lawnmowers, tillers, etc., are used in commercial application. There are additional small utility engines arising from households with two or more pieces of lawn and garden equipment. Whether these "extra" engines are offset by the households which have only electric equipment is uncertain. To obtain a more accurate inventory, it would have been necessary to locate each commercial organization and obtain information on the utilization of ground maintenance equipment. A survey of households with more than one piece of lawn and garden machinery would have been necessary, too. Finally, an inventory of households with electric lawn mowers, edgers, and the like would have had to be made. Since this was felt to be very impractical, it was decided the best course to follow was assumption of a one-to-one correspondence between one-unit housing structures and small utility engines.

The value of the one-to-one relation becomes apparent in the equation used to calculate lawn and garden equipment emissions at the county level:

(8) $$\text{County Emissions, kg/yr} = \text{National Emissions, kg/yr} \times \frac{\text{County One-Unit Housing Structures}}{\text{National One-Unit Housing Structures}} \times \frac{\text{County Mean Operating Days}}{213}$$

where county mean operating days = 190 for the St. Louis AQCR.[9]

The national emissions total was calculated utilizing the emission factors in Table 7 which are in kg/yr. As previously mentioned it was assumed that 2.7 million 2-stroke engines and 50.2 million 4-stroke engines were used nationally. Thus for CO emissions, for example,

(9) National Emissions of CO = 2-stroke emissions + 4-stroke emissions

$$= (33 \text{ kg/yr} \times 2.7 \times 10^6) + (19 \text{ kg/yr} \times 50.2 \times 10^6)$$

$$= 1.043 \times 10^9 \text{ kg/yr}$$

Then to calculate county emissions of CO, from Madison County for instance, we have after substituting the proper values into equation 8:

(10) County Emissions, kg/yr $= 1.043 \times 10^9 \text{ kg/yr} \times \frac{65{,}533}{46.8 \times 10^6} \times \frac{190}{213}$

$$= 1.303 \times 10^6 \text{ kg/yr of CO}$$

In Table 8 emissions for all AQCR 070 counties are shown (in units of 10^3 kg/yr).

TABLE 8

EMISSIONS AND ONE-UNIT HOUSING STRUCTURES PER COUNTY

COUNTY	I.D. NO.	ONE UNIT HOUSING STRUCTURES	EMISSIONS 10^3 kg/yr				
			HC	CO	NO_X	PART	SO_X
St. Louis County	4300	235,202	586	4675	47.4	12.4	4.99
St. Louis City	4280	81,784	204	1625	16.5	4.33	1.73
St. Clair	6900	68,769	171	1367	13.9	3.64	1.46
Madison	4680	65,533	163	1303	13.2	3.47	1.37
Jefferson	2280	27,593	68.8	549	5.6	1.46	.58
St. Charles	4160	21,631	53.9	430	4.36	1.14	.46
Franklin	1680	15,882	39.6	316	3.20	.84	.34
Clinton	1440	7,788	19.4	155	1.57	.41	.17
Monroe	5180	5,383	13.4	107	1.08	.28	.11
Randolph	6460	8,624	21.5	171	1.74	.46	.18
Bond	0520	4,490	11.2	89.3	.90	.24	.95
Washington	7920	4,848	12.1	96.4	.98	.26	.102

Once emissions per county are known, emissions per grid square follow from the relation

$$(11)\ \text{Grid Element Emissions, kg/yr} = \frac{\text{Grid One-Unit Structures}}{\text{County One-Unit Structures}} \times (\text{County Emissions kg/yr})$$

Grid one-unit structures were available from Reference 7. County one-unit structures, found in Reference 2, have been included in Table 8.

TABLE 9

DATA FOR SAMPLE LAWN AND GARDEN EQUIPMENT

EMISSIONS CALCULATION

VARIABLE	VALUE	SOURCE
Pollutant	CO	Specified
Grid Element	281	Specified
Grid Element One-Unit Structures	68	Reference 7
County	Madison (4680)	Table 8 (or Ref. 7)
County One-Unit Structures	65,533	Table 8
County Emissions	1303×10^6 kg/yr	Table 8

To better illustrate the procedure, emissions of CO from grid element #281 will be calculated here. The necessary data has been assembled in Table 9 for convenience.

$$(12)\ \underset{\text{Grid \#281}}{\text{Grid Element Emissions, kg/yr of CO}} = \frac{68}{65{,}533}\ (1.303 \times 10^6\ \text{kg/yr})$$

$$= 1.35 \times 10^3\ \text{kg/yr}$$

Lawn and garden equipment emissions from all grids have been calculated with the aid of a Fortran program.

4.0 CONSTRUCTION EQUIPMENT EMISSIONS

Construction equipment types considered in the inventory are listed in Table 10, along with estimated populations, usage, and rated horsepower. Since few data are available on either sales or population of the various machines estimates were heavily relied upon. Some machines, like tracklaying tractors, wheel loaders, and scrapers are better represented in the literature than others. The major sources of data on construction equipment are generalized national figures on units shipped per year, annual usage, total horsepower in use, load factors, and duty cycles[10]. Specific population data by machine type and manufacturer, or engine type are not available[2].

Composite emission factors for the ten construction categories were developed, assuming a distribution for each category composed of test engines in the same combination[10]. These factors were meant to reflect not only the composition of population by size and type of engine, but the typical duty or operating cycles as well. Taken together with the estimates in Table 10 of machinery population, etc., the factors were used to calculate national emissions of construction equipment[10]. The results are shown in Table 11.

In arriving at the numbers in Table 11, three assumptions supplemented the estimates in Table 10. First, construction equipment life (in years), found by dividing service life (in hours) by usage (in hours/year), could be used along with typical annual shipments to estimate the number of units in service, or population. Second, emissions from construction engines could be estimated by combining the results of a number of laboratory tests. Third, engine operating cycles could be deduced from manufacturers' operating data to a reasonable approximation. The tests took evaporative hydrocarbon emissions into account.

National emissions were apportioned to the states of Illinois and Missouri by construction volume (in dollars) according to the relation:

$$\text{(13) State Emissions, kg/yr} = (\text{National Emissions, kg/yr}) \times \frac{(\text{State Construction Volume})}{(\text{National Construction Volume})}$$

TABLE 10

ESTIMATED CONSTRUCTION MACHINERY POPULATIONS, USAGE, RATED HORSEPOWER, AND SERVICE LIFE[10]

Equipment Type	Population	Usage, hr/yr	Horsepower	Service Life, hr
Tracklaying Tractors	197,000	1050	120	10,000
Tracklaying Loaders	86,000	1100	65	10,000
Motor Graders	95,300	830	90	12,000
Scrapers	27,000	2000	475	12,000
Off-highway Trucks	20,800	2000	400	12,000
Wheel Loaders	134,000	1140	130	12,000
Wheel Tractors	437,000	740	75	12,000
Rollers	81,600	740	75	12,000
Wheel Dozers	2,700	2000	300	12,000
General Purpose	100,000	1000	120	---

TABLE 11

ESTIMATED NATIONAL CONSTRUCTION EQUIPMENT EMISSIONS[10]

	EMISSIONS IN KG/YR x 10^6				
Fuel	HC	CO	NO_X	PART	SO_X
Diesel	72	220	820	63	65
Gasoline	56	1100	36	2.2	1.6
Total	128	1320	856	65.2	66.6

Dollar volume of construction was available only at the national and state levels so could not be used for a more refined distribution of emissions. Construction acreage was known for the St. Louis AQCR counties. State construction was not known, making it impossible to determine the county percentages of state construction. Consequently emissions were allocated to the counties by population. This represented the least desirable method but is the only viable alternative since state and county populations were both known quantities. Population can be considered to be a sufficiently reliable indicator of ongoing construction, there being an approximately proportional relationship between the two. State emissions were then apportioned to the counties by the relation.

$$(14)\ \text{County Emissions, kg/yr} = \text{State Emissions, kg/yr} \times \frac{\text{County Population}}{\text{State Population}}$$

Emissions contributed by construction equipment to each of the twelve counties under consideration are shown in Table 12. Homebuilding and other light construction emissions were taken to be negligible compared to contracted construction jobs in the county apportionment computations. Also, construction expenditures in heavy construction, and highway and bridge construction were weighted by a factor of 3 relative to building construction.

Using the values for county emissions set forth in Table 12, grid element emissions were calculated. Although the methodology by Hare[2] suggests apportionment of county emissions to the grid elements by population, a different approach was taken for the present inventory. Recently, a computer tabulation has become available,[11] which assigns to each of the grid elements a value for construction acreage. This makes it possible to use it rather than population to allocate emissions to the individual grid elements as follows:

$$(15)\ \text{Grid Element Emissions, kg/yr} = \frac{(\text{Grid Construction Acreage})}{(\text{County Construction Acreage})} \times (\text{County Emissions, kg/yr})$$

It was assumed that the areas experiencing construction had remained more or less the same since the time when construction acreage allotments were made. Construction acreage per county may be found in Table 13.

As an example of the calculation, emissions of NO_X from Grid Number 61 have been calculated. Pertinent data for the calculation are in Table 14.

$$(16)\ \text{Grid Element Emissions, kg/yr} = \frac{(155 \text{ acres})}{(1416 \text{ acres})} \times (4.51 \times 10^5 \text{ kg/yr}) = 4.94 \times 10^4 \text{ kg/yr}$$

As with the other off-highway categories calculation for the 1989 AQCR grid squares was accomplished through the aid of a Fortran program.

TABLE 12

CONSTRUCTION EQUIPMENT EMISSIONS PER COUNTY[2]

COUNTY	I.D. NO.	EMISSIONS, 10^3 kg/yr				
		HC	CO	NO_X	PART	SO_X
St. Louis County	4300	689	7,100	4,610	351	358
St. Louis City	4280	451	4,650	3,010	230	234
St. Clair	6900	175	1,810	1,170	89.3	91.2
Madison	4680	154	1,580	1,030	78.2	79.9
Jefferson	2280	76.3	787	510	38.9	39.7
St. Charles	4160	67.5	696	451	34.4	35.1
Franklin	1680	40.1	413	268	20.4	20.8
Clinton	1440	17.4	180	116	8.87	9.06
Monroe	5180	11.6	120	77.6	5.91	6.03
Randolph	6460	19.2	198	128	9.78	9.99
Bond	0520	8.60	88.7	57.5	4.38	4.48
Washington	7920	8.46	87.3	56.6	4.31	4.40

TABLE 13

CONSTRUCTION ACREAGE PER COUNTY[11]

COUNTY	I.D. NO.	TOTAL CONSTRUCTION ACREAGE
St. Louis County	4300	4,789
St. Louis City	4280	292
St. Clair	6900	1,718
Madison	4680	1,535
Jefferson	2280	1,178
St. Charles	4160	1,416
Franklin	1680	431
Clinton	1440	302
Monroe	5180	196
Randolph	6460	339
Bond	0520	175
Washington	7920	93

5.0 INDUSTRIAL EQUIPMENT

Fork lifts, motorized utility carts, small tractors and wheel loaders, quarrying machinery, portable generators, and any other fuel consuming mobile equipment used at industrial plants or in the performance of industrial operations, all fall within the scope of the industrial equipment category. In general their engines may be divided into two broad categories - small utility engines similar to those used in lawn and garden, or heavy-duty engines.

Determination of engine population and size distributions has been accomplished by studying shipment and production statistics for small utility and heavy-duty industrial engines[10]. Obtaining accurate estimates involved separation of locomotive engines and so-called "miscellaneous four-stroke small utility engines" from the available statistics. Pertinent estimates for heavy-duty engines may be found in Table 15. Service life of light-duty industrial gasoline engines was assumed to be 600 hours and annual usage 100 hours on the average[10].

TABLE 15[10]

NATIONAL POPULATION, RATED POWER, AND ANNUAL USAGE OF HEAVY-DUTY AND LIGHT-DUTY INDUSTRIAL ENGINES

	HORSEPOWER	USAGE, HR/YR	POPULATION
Diesel	125	600	417,000
Gasoline (Heavy-duty)	55	300	990,000
Gasoline (Light-duty)	3.86	100	5,800,000

There are no really typical duty cycles (fractions of operating time spent in various rpm or speed ranges) for industrial engines since applications are so diverse. For heavy-duty gasoline and diesel engines a "general purpose industrial" cycle has been proposed[10] using special weighting factors corresponding to more than twenty different operating modes. Composite emission factors were devised to represent the variety of models on the market. They were based on the weighted emissions of twelve test engines. No attempt at a rigorous correlation with population was made due to the general lack of specificity characteristic of available statistics[10].

Light-duty engine emission factors were developed along similar lines. Recommended emission factors for the industrial category are presented in Table 16. National emissions from industrial engines have been computed using the information in Tables 15 and 16. Resulting annual totals are in Table 17.

TABLE 16

RECOMMENDED EMISSION FACTORS FOR INDUSTRIAL ENGINES[2]

ENGINE TYPE	UNITS	EMISSION FACTORS				
		HC	CO	NO_X	PART	SO_X
Heavy-Duty Diesel	g/hp. hr.	1.12	3.03	14.0	1.00	0.931
Heavy-Duty Gasoline	g/hp. hr.	6.68	199	5.16	0.327	0.268
Light-Duty Gasoline	g/hr.	29.2	386	7.68	0.68	0.60

NOTE: Allowance for evaporative hydrocarbon emissions was incorporated into these factors.

TABLE 17[10]

NATIONAL TOTALS OF EMISSIONS FROM INDUSTRIAL ENGINES

ENGINE TYPE	EMISSIONS, 10^6 kg/yr				
	HC	CO	NO_X	PART	SO_X
Heavy-Duty Diesel	35.0	94.8	437.9	31.3	29.1
Heavy-Duty Gasoline	109.1	3,251	84.3	5.34	4.37
Light-Duty Gasoline	16.9	133	4.5	.39	.35
TOTALS	161.0	3,478.8	526.7	37.03	33.82

A method has been developed[2] to apportion national emission estimates directly to counties using the relation

(17) County Emissions, kg/yr = (National Emissions, kg/yr)

$$\times \frac{(\text{County Total of A + B + C})}{(\text{National Total of A + B + C})}$$

where A = value added by manufacturing establishments

B = sales of wholesale trade establishments, and

C = value of shipments and receipts of mineral industries

Quantities A, B, and C are considered to be reliable indicators of industrial activity. Their sum is proportional (directly, to a good approximation) to industrial equipment usage. Values for A, B, and C obtained from Reference 12 are in Table 18, and emissions per county computed with these values may be found in Table 19.

The final step was the apportionment of county emissions to all the grid elements. Because industrial equipment would, by definition, only be found at industrial plants, a listing of those grid squares containing such plants along with the number of plants contained in each provided the basis for apportioning emissions.

Using References 13, 14, and 15 a listing of all the industrial plants in AQCR 070 was compiled including the grid elements or squares in which these 194 plants were located. Total grid squares with industrial plants in them numbered 150. The number of industrial plants (190) represents the most complete tabulation available in the most recent Regional Air Pollution Study (RAPS) emission inventory. Admittedly, some industrial plants have not been accounted for. Nonetheless, apportionment of emissions to grid elements on the strength of this data was felt to produce the most accurate results.

TABLE 18[8]

INDUSTRIAL EQUIPMENT COUNTY APPORTIONMENT DATA

County	MILLIONS OF DOLLARS (1972)		
	A (= value added) $	B (= wholesale sales) $	C (= minerals) $
St. Louis County	1,285.8	3,065.356	9.8
St. Louis City	1,793.5	4,518.156	0.7
St. Clair	267.3	519.297	0.0
Madison	645.2	229.629	2.8
Jefferson	66.4	17.333	3.0
St. Charles	44.8	33.644	0.0
Franklin	56.0	25.699	0.0
Clinton	17.1	17.391	0.0
Monroe	0.9	12.829	0.0
Randolph	30.3	14.394	18.4
Bond	13.2	14.583	0.0
Washington	2.3	15.643	2.8
U.S. TOTALS, $	261,983.8	459,475.967	25,848.7

TABLE 19

INDUSTRIAL EQUIPMENT EMISSIONS PER COUNTY

County	EMISSIONS, 10^3 kq/yr				
	HC	CO	NO_x	PART	SO_x
St. Louis County	940	20,316	1,950	216	198
St. Louis City	1,360	29,396	4,451	313	286
St. Clair	169	3,653	553	38.9	35.5
Madison	188	4,070	616	43	39.6
Jefferson	16.9	365	55.3	3.89	3.55
St. Charles	18.0	390	59.0	4.14	3.79
Franklin	4.53	119	18.1	1.27	1.16
Clinton	7.44	161	24.3	1.71	1.56
Monroe	2.96	64	9.7	.68	.62
Randolph	13.6	294	44.5	31.3	2.85
Bond	5.99	129	19.6	1.37	1.26
Washington	4.48	96.7	14.6	1.03	.94

County emissions were apportioned by the equation

$$(18)\ \text{Grid Element Emissions, kg/yr} = (\text{County Emissions, kg/yr}) \times \frac{(\text{Grid Industrial Plants})}{(\text{County Industrial Plants})}$$

As an illustration, the emissions of SO_X from grid #1008 have been calculated. Essential data are presented in Table 20.

$$(19)\ \text{Grid Element Emissions, kg/yr of } SO_X \text{ grid \#1008} = (286 \times 10^3 \text{ kg/yr}) \times \frac{2}{31} = 1.85 \times 10^4 \text{ kg/yr}$$

Emissions from all grid elements were calculated with the aid of a computer.

There are certain limitations on the accuracy of this and other industrial emissions calculations. Most severe is the necessity of starting with national totals and making successive apportionments from them. National totals are good estimates only and must be considered in that light. This point source listing has been updated with the latest RAPS emission inventory data.

TABLE 20

INDUSTRIAL EQUIPMENT SAMPLE CALCULATION DATA

VARIABLE	VALUE	SOURCE
Pollutant	SO_X	Specified
Grid Element	1008	Specified
Grid Industrial Plants	2	Plant Listing
County	St. Louis City (4280)	Reference 7
County Industrial Plants	31	RAPS emission inventories
County Emissions	286×10^3	Table 19

6.0 FARM EQUIPMENT

Among the equipment types used on farms which were taken into consideration in this inventory were farm tractors, garden tractors used on farms, and self-propelled combines, forage harvesters, and balers. In addition, irrigation pump engines ("miscellaneous heavy-duty"), and the auxiliary engines ("miscellaneous light-duty") used on some of the larger machinery were considered. Extensive information on both the production and population of such equipment was available, a great deal on tractors in particular. However, a breakdown in terms of size and types of engines used in the current population did not exist, requiring that estimates be made.

Much effort has been expended in the development of emission factors for farm machinery by C. T. Hare[10] and others. A detailed population and usage analysis of farm tractors and other related equipment preceded emission factor computation. Annual usage rates were estimated from either survey data (available for tractors) or consideration of the fact that the usage of special-purpose farm machinery was dictated by the crop acreage for which it was needed. Annual usage estimates of the various equipment types are presented in Table 21, along with typical horsepower ratings and load factors.

TABLE 21

FARM EQUIPMENT ANNUAL USAGE ESTIMATES[10]

TYPE OF EQUIPMENT	ESTIMATE ANNUAL USAGE, (HRS)	HORSEPOWER	LOAD FACTOR
Diesel Tractor	490	80.2	0.57
Gasoline Tractor	291	40.9	0.57
Self-propelled Combine	73	110.0	0.52
Pull Combine	52	25.0	0.52
Balers	24	40.0	0.52
Forage Harvesters	120	140.0	0.52
Miscellaneous Heavy-duty	50	30.0	0.52
Miscellaneous Light-duty	50	3.5	0.40

Test engines on which much data had been gathered were assumed to represent each field application. For each engine a typical duty or operating cycle (estimated from manufacturers operating data and field operation data) was assumed, composite load factors were derived, and finally emission factors were computed. Resulting emission factors in kg/hr are in Table 22.

To calculate emissions from farm equipment, the following relationship was used for this inventory:

$$(20)\ \text{County Emissions, kg/yr} = \Sigma\ (\text{Equipment Population}) \times (\text{Annual Usage}) \times (\text{Emission Factor kg/yr})$$

where the summation was taken over the equipment type used. Specific data on equipment populations per county were available from Reference 16. This data in conjunction with annual usage, emission factors (kg/yr) from Tables 21 and 22, made it possible to arrive at emissions per county (presented in Table 23.

In apportioning county emissions to grid elements, the following relation was used:

$$(21)\ \text{Grid Element, kg/yr} = (\text{County Emissions, kg/yr}) \times \frac{(\text{Farm Acreage in Grid})}{(\text{County Farm Acreage})}$$

County farm acreage is presented in Table 24. Acreage per grid element is available from Reference 11. As explained therein, farm acreage was allocated to grid squares by means of land use maps and aerial photographs.

To exemplify the grid-apportionment procedure, the emissions of CO from Grid #1 have been calculated. All necessary data are gathered in Table 25.

$$(22)\ \text{Grid Element Emissions, kg/yr of CO} = 2.08 \times 10^6\ \text{kg/yr} \times \frac{3,172}{79,490}$$

$$= 8.3 \times 10^4\ \text{kg/yr}$$

As with all other categories under consideration, emissions of the five criteria pollutants have been calculated with the aid of a computer.

TABLE 22

RECOMMENDED EMISSION FACTORS FOR FARM EQUIPMENT[2]

TYPE OF EQUIPMENT	EMISSION FACTORS, KG/HR				
	HC	CO	NO_X	PART	SO_X
Diesel Tractor	0.078	0.154	0.429	0.059	0.040
Gasoline Tractor	0.208	3.34	0.155	0.009	0.006
Self-propelled Combine	0.300	6.37	0.408	0.054	0.034
Pull Combine	0.116	2.83	0.068	0.005	0.004
Balers	0.183	4.53	0.108	0.008	0.006
Forage Harvesters	0.122	0.297	0.657	0.110	0.067
Miscellaneous Heavy-duty	0.082	1.73	0.112	0.015	0.009
Miscellaneous Light-duty	0.029	0.363	0.007	0.001	0.001

Allowance made for evaporative hydrocarbon emission.

TABLE 23

FARM EQUIPMENT EMISSIONS PER COUNTY[2]

COUNTY	EMISSION, 10^3 KG/YR				
	HC	CO	NO_X	PART	SO_X
St. Louis County	68.3	803	114	13.3	8.8
St. Louis City	-----	-----	---	----	----
St. Clair	225	2,690	376	44.6	29.4
Madison	268	3,190	448	53.0	35.0
Jefferson	75.8	885	127	15.0	9.9
St. Charles	160	1,900	268	31.7	20.9
Franklin	180	2,080	305	36.1	23.8
Clinton	179	2,110	309	37.3	24.5
Monroe	134	1,600	224	26.5	35.0
Randolph	175	2,080	296	35.2	23.2
Bond	118	1,410	199	23.7	15.6
Washington	181	2,180	306	36.6	24.1

TABLE 24

FARM ACREAGE PER COUNTY[11]

COUNTY	FARM ACREAGE
St. Louis County	37,542
St. Louis City	-0-
St. Clair	213,772
Madison	188,815
Jefferson	29,712
St. Charles	12,147
Franklin	79,490
Clinton	192,865
Monroe	111,714
Randolph	165,034
Bond	130,252
Washington	212,114

TABLE 25

DATA FOR SAMPLE CALCULATION OF
FARM EQUIPMENT EMISSIONS FROM A GRID ELEMENT

VARIABLE	VALUE	SOURCE
Pollutant	CO	Specified
Grid Element	1	Specified
Farm Acreage in Grid	3172	Reference 11
County	Franklin (1680)	Ref. 11 or Ref. 5
County Farm Acreage	79,490	Table 24
County Emissions	2.08×10^6 kg/yr	Table 23

7.0 OUTBOARD MOTORBOATS

This part of the off-highway inventory included boats powered by outboard engines and used on the St. Louis AQCR waterways. For the sake of brevity the boats were termed "outboards". Emission factors for the engines used in the boating applications were developed from the study of a limited number of test engines in the laboratory[17].

Simulation of outboard engine performance was hindered somewhat by the complexity of the real-life operating conditions. Engine exhaust outlets are normally below water, but if the boat is bobbing on the water surface, expecially if the water is rough, it is possible for some exhaust to be released in sporadic bursts directly into the atmosphere. While bubbling through water a certain portion of the exhaust pollutants are removed and therefore do not reach the atmosphere. The extent of the scrubbing process is highly dependent on water turbulence, and in a more subtle way on the chemical composition of the water itself. Crude simulation of this bubbling process has been attempted by researchers and measurements made to determine the extent of pollutant removal. Their test results played an important role in emission factor development. Direct emission to the atmosphere of pollutants has not been allowed for in the emission factors recommended in the Reference 2 methodology and used in this inventory. The emission factors are presented in Table 26. They represent the best-researched factors available. Note that the factor for particulates is zero; all particulates are removed in the water.

To determine emissions from a given area it was necessary to use emission factors in conjunction with usage and population data. Population data was in the form of boat registrations. For Missouri, Reference 3 provided separate figures for motorboats and boat motors per county. These two figures were added with the assumption that the total would be a reasonable representation of total outboards per county. This was done for two reasons: First, when motorboats are sold they invariably come with an engine, thus boat and motor would be registered as one unit. Since outboards are the most abundant of motorboats, this is a good partial count of them. Second, although a certain number of outboard engines registered individually may be sitting idle in storage sheds, perhaps only infrequently used, there are very likely an equal number of unregistered outboards in use during the boating season. Therefore boat motor registration could very well represent additional outboards, and were added to motorboat registrations with this in mind.

For Illinois the only registration statistics kept are in terms of "certified watercraft per county". It was assumed that this number equalled outboards per county. Any watercraft which were not outboards (e.g. inboard motorboats) would be offset by those outboards which were unregistered. The end result would be an approximation of the actual number in use. Boat totals for the twelve AQCR 070 counties are in Table 27.

The remaining factor considered before area emissions could be analyzed was outboard usage. Those boats registered in a county are not necessarily used in that county. In fact, many boats registered in the St. Louis AQCR are not only used outside the counties they were registered in, but outside the AQCR as well. As a consequence, the calculated emissions are likely to be on the higher side. Because the majority of Missouri residents use their boats primarily in Missouri, and Illinois residents in the state of Illinois, it was decided to first calculate emission totals of the criteria pollutants contributed by all motorboats registered in all counties within AQCR 070 in each state. State emissions were calculated by the following relation:

(23) Motorboat Emissions in AQCR by state

= (State Motorboat Registrations in AQCR)

x (Emission Factors, kg/unit yr.)

Using the data in Tables 26 and 27 in (23) yielded the values for state emissions which comprise Table 28.

The next step was to allocate state emissions to the 12 counties in the St. Louis Region. Emissions were apportioned according to the amount of navigable water area in each county. This method was chosen because navigable surface waters determined boat usage in a county. Recreational suitability of the water also plays a role; however no statistics were available on the popularity of the different waterways. Apportionment to counties was accomplished via the relation.

$$\text{(24) County Emissions, kg/yr} = \text{AQCR/State Emissions} \times \frac{\text{County Surface Water}}{\text{AQCR/State Surface Water}}$$

where "AQCR/State Emissions" and "AQCR/State Surface Water" totals were for the St. Louis AQCR in each state, and "Surface Water" means navigable surface water area. Outboard emissions per county appear in Table 29 along with the surface water data used to calculate them.

As the final step, emissions at the grid level were calculated (with the aid of a computer) using the relation

$$\text{(25) Grid Element Emissions, kg/yr} = \text{County Emissions, kg/yr} \times \frac{\text{Grid Surface Water}}{\text{County Surface Water}}$$

Again it was assumed that boat usage was directly proportional to navigable water area. To illustrate the calculation, the emission of HC from grid #1019 were calculated. Necessary data are collected in Table 30.

$$\text{(26) Grid Element Emissions of HC, kg/yr} = (2.964 \times 10^6 \text{ kg/yr}) \times \frac{(1 \text{ km}^2)}{(90.7 \text{ km}^2)} = 3.26 \times 10^4 \text{ kg/yr}$$

Surface water area per grid square was determined by drawing the waterways onto the grid system and estimating as accurately as possible the percentage of a grid covered by water. Specific waterways considered to have sufficient boating activity for inventory purposes were:

a. Mississippi River
b. Missouri River
c. Meramec River
d. Alton Lake
e. Carlysle Lake
f. Lake St. Louis

TABLE 26

OUTBOARD EMISSION FACTORS (KG/UNIT HR.)

HC	CO	NO_X	SO_X	PART
0.769	2.28	.0045	.0044	0

NOTE: Evaporative hydrocarbon emissions have not been measured and are not reflected by these factors.

KG PER UNIT-YEAR (ASSUMING 70 HRS/YR OVER OPERATION)

HC	CO	NO_X	SO_X
53.83	159.6	.315	.308

TABLE 27

OUTBOARD REGISTRATIONS PER COUNTY

MISSOURI[3]		ILLINOIS[18]	
COUNTY	REGISTERED OUTBOARDS	COUNTY	REGISTERED OUTBOARDS
St. Louis County	62,768	Bond	506
St. Louis City	16,013	Clinton	1,166
Jefferson	11,607	Madison	8,489
St. Charles	10,779	Monroe	685
Franklin	5,837	Randolph	1,523
		St. Clair	7,923
		Washington	483
TOTAL	107,004	TOTAL	20,775

TABLE 28

STATE OUTBOARD EMISSIONS IN THE AQCR
(KG/YR x 10^6)

	HC	CO	NO_x	SO_x
Missouri	5.759	17.07	.0337	.0329
Illinois	1.112	3.315	.00654	.00639

TABLE 29

OUTBOARD EMISSIONS AND NAVIGABLE SURFACE WATER PER COUNTY

COUNTY	SURFACE WATER[2] KM^2	EMISSIONS, 10^3 KG/YR			
		HC	CO	NO_x	SO_x
St. Louis County	45.6	1,490.0	4,418	8.723	8.528
St. Louis City	9.8	321.8	953.8	1.883	1.841
St. Clair	5.7	31.54	310.1	.1846	.1805
Madison	32.8	179.2	594.2	1.049	1.025
Jefferson	8.8	288.0	853	1.685	1.648
St. Charles	90.7	2,964.0	8,786	17.34	16.96
Franklin	21.5	703.1	2,083	4.114	4.022
Clinton	99.5	550.5	1,632	3.222	3.149
Monroe	23.6	130.5	386.8	.7634	.7464
Randolph	31.6	174.9	518.6	1.024	1.001
Bond	7.8	43.0	127.5	.2517	.2461
Washington	1.6	8.602	25.5	.0503	.0492

TABLE 30

DATA FOR SAMPLE CALCULATION OF GRID EMISSIONS

VARIABLE	VALUE	SOURCE
Pollutant	HC	Specified
Grid Element	1019	Specified
County	St. Charles (4160)	Reference 5
County Emissions	2.964×10^6 kg/yr	Table 29
County Surface Water	90.7 km^2	Table 29
Grid Surface Water	1 km^2	Map with grid overlay

8.0 TEMPORAL APPORTIONMENT

Annual emission totals of the several off-highway mobile source types had to be temporally distributed over the year to reflect diurnal and seasonal variation of usage. To accomplish this end each equipment category was assigned an annual operating pattern which was felt to most closely approximate real-life use during a calendar year. The operating patterns assumed were as follows:

1.	Off-highway motorcycles	March through October	9 AM - 7 PM
2.	Lawn and garden equipment	April through September	9 AM - 7 PM
3.	Construction equipment	March through October	6 AM - 6 PM
4.	Industrial equipment	Year round	8 AM - 6 PM
5.	Farm equipment	March through October	5 AM - 7 PM
6.	Outborad motors	April through September	9 AM - 7 PM

All the days in the month were included, no distinction being made for weekends. Total yearly operating hours were found by multiplying together operating hours per day, operating days per month, and operating months per year. Then the annual emissions total was divided by yearly operating hours to give emissions per hour.

9.0 SUMMARY

Emissions of criteria pollutants for each of the six types of off-highway sources have been calculated for each grid square in the St. Louis AQCR. The methodology has been described, with any departure from the methodology reported in EPA-450/3-75-002 justified. Most of the data which formed the basis of the inventory was two years old, and many assumptions on equipment populations and usage were made where data were not available.

A Fortran program has been prepared in order to compute emissions from the nearly 2,000 grid squares for each of the six equipment types. Sample calculations for each category showed that the magnitude of emissions from off-highway mobile sources is by no means insignificant at the grid element level (see sample in Figure 1).

M-CYCL : OFF HIWAY MOTORCYCLES
LWN&GDN: LAWN & GARDEN EQUIPMENT
FRM EQ : FARM EQUIPMENT
CONSTR : CONSTRUCTION EQUIPMENT
IND EQ : INDUSTRIAL EQUIPMENT
OUTBD : OUTBOARD MOTORS
UNITS : KG/YR

GRID	POLT	M-CYCL	LWN&GDN	FRM EQ	CONSTR	IND EQ	OUTBD	TOTAL
1	HC	8.6717+01	4.7226+02	7.1641+03	1.3690+03	0.0000	0.0000	9.1120+03
	CO	1.6601+02	3.6794+03	8.3016+04	1.4099+04	0.0000	0.0000	1.0096+05
	NOX	7.0311-01	3.8140+01	1.2173+04	9.1491+03	0.0000	0.0000	2.1361+04
	PART	1.1718+00	9.7593+00	1.4408+03	6.9642+02	0.0000	0.0000	2.1482+03
	SOX	2.5390-01	2.4679+00	9.4990+02	7.1008+02	0.0000	0.0000	1.6627+03
2	HC	8.4603+01	4.5485+02	7.1841+03	1.4248+03	0.0000	0.0000	9.1484+03
	CO	1.6197+02	3.5437+03	8.3016+04	1.4675+04	0.0000	0.0000	1.0140+05
	NOX	6.8597-01	3.6734+01	1.2173+04	9.5225+03	0.0000	0.0000	2.1733+04
	PART	1.1433+00	9.3995+00	1.4408+03	7.2485+02	0.0000	0.0000	2.1762+03
	SOX	2.4771-01	2.3769+00	9.4990+02	7.3906+02	0.0000	0.0000	1.6916+03
3	HC	1.3729+02	7.1818+02	7.1841+03	1.4528+03	2.8312+02	0.0000	9.7754+03
	CO	2.6282+02	5.5953+03	8.3016+04	1.4962+04	7.4375+03	0.0000	1.1127+05
	NOX	1.1131+00	5.8000+01	1.2173+04	9.7092+03	1.1312+03	0.0000	2.3073+04
	PART	1.8552+00	1.4841+01	1.4408+03	7.3906+02	7.9375+01	0.0000	2.2759+03
	SOX	4.0197-01	3.7530+00	9.4990+02	7.5355+02	7.2500+01	0.0000	1.7801+03
4	HC	2.5740+01	1.3275+02	1.7960+03	2.1419+02	0.0000	5.3770+03	7.5457+03
	CO	4.9277+01	1.0343+03	2.0754+04	2.2060+03	0.0000	1.5930+04	3.9974+04
	NOX	2.0870-01	1.0721+01	3.0433+03	1.4315+03	0.0000	3.1462+01	4.5171+03
	PART	3.4783-01	2.7434+00	3.6020+02	1.0896+02	0.0000	0.0000	4.7226+02
	SOX	7.0364-02	6.9373-01	2.3747+02	1.1110+02	0.0000	3.0759+01	3.8010+02
5	HC	6.9774+01	4.0044+02	1.7960+03	4.2838+02	0.0000	0.0000	2.6946+03
	CO	1.3358+02	3.1198+03	2.0754+04	4.4120+03	0.0000	0.0000	2.8419+04
	NOX	5.6573-01	3.2340+01	3.0433+03	2.8630+03	0.0000	0.0000	5.9391+03
	PART	9.4289-01	8.2751+00	3.6020+02	2.1793+02	0.0000	0.0000	5.8735+02
	SOX	2.0429-01	2.0926+00	2.3747+02	2.2220+02	0.0000	0.0000	4.6197+02
6	HC	3.4328+01	1.7410+02	1.7960+03	4.2838+02	0.0000	0.0000	2.4328+03
	CO	6.5718+01	1.3564+03	2.0754+04	4.4120+03	0.0000	0.0000	2.6588+04
	NOX	2.7833-01	1.4061+01	3.0433+03	2.8630+03	0.0000	0.0000	5.9206+03
	PART	4.6389-01	3.5979+00	3.6020+02	2.1793+02	0.0000	0.0000	5.8219+02
	SOX	1.0051-01	9.0981-01	2.3747+02	2.2220+02	0.0000	0.0000	4.6069+02
7	HC	3.4328+01	1.7410+02	1.7960+03	4.2838+02	0.0000	0.0000	2.4328+03
	CO	6.5718+01	1.3564+03	2.0754+04	4.4120+03	0.0000	0.0000	2.6588+04
	NOX	2.7833-01	1.4061+01	3.0433+03	2.8630+03	0.0000	0.0000	5.9206+03
	PART	4.6389-01	3.5979+00	3.6020+02	2.1793+02	0.0000	0.0000	5.8219+02
	SOX	1.0051-01	9.0981-01	2.3747+02	2.2220+02	0.0000	0.0000	4.6069+02
3	HC	3.4328+01	1.7410+02	1.7960+03	4.2838+02	0.0000	0.0000	2.4328+03
	CO	6.5718+01	1.3564+03	2.0754+04	4.4120+03	0.0000	0.0000	2.6588+04
	NOX	2.7833-01	1.4061+01	3.0433+03	2.8630+03	0.0000	0.0000	5.9206+03
	PART	4.6389-01	3.5979+00	3.6020+02	2.1793+02	0.0000	0.0000	5.8219+02
	SOX	1.0051-01	9.0981-01	2.3747+02	2.2220+02	0.0000	0.0000	4.6069+02

FIGURE 1 - SAMPLE/FORTRAN PROGRAM

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