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Regional Air Pollution Study

Heat Emission Inventory

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REGIONAL AIR POLLUTION STUDY
Heat Emission Inventory

by

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ABSTRACT

As part of the St. Louis Regional Air Pollution Study (RAPS), a heat emission inventory has been assembled. Heat emissions to the atmosphere originate, directly or indirectly, from the combustion of fossil fuels (there are no nuclear plants in the St. Louis AQCR). With the exception of a small amount of energy radiated into space as light, and the energy carried out of the AQCR by cooling water (primarily the Mississippi River), all of the energy released by the combustion of fuels is sooner or later released to the atmosphere as heat, either at the the point of production (the power stations) or where it is consumed.

This report deals with heat emissions from point sources as well as area sources. Heat emissions from point sources account for about 11 percent in the AQCR. Point source emissions are, however, in the form of concentrated plumes, while other heat emissions are diffused. Thus, the meteorological dispersion behavior of these sources is likely to be quite different.

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1.0 INTRODUCTION

As part of the St. Louis Regional Air Pollution Study (RAPS), a heat emission inventory has been assembled. Heat emissions to the atmosphere originate, directly or indirectly, from the combustion of fossil fuels (there are no nuclear plants in the St. Louis AQCR). With the exception of a small amount of energy radiated into space as light, and the energy carried out of the AQCR by cooling water (primarily the Mississippi River), all of the energy released by the combustion of fuels is sooner or later released to the atmosphere as heat, either at the point of production (the power stations) or where it is consumed.

In the production of power, only a fraction of the energy released when the fuel is burned is emitted as heat emissions to the atmosphere. The remaining fraction of energy is converted to heat at the point of ultimate use. This is true whether the fuel is natural gas, electricity, gasoline or other sources.

This report deals with heat emissions from point sources as well as area sources. Heat emission from point sources is only a small, albeit an important fraction of the total heat emissions. It is estimated that point source heat emissions account for about 11 percent of the total emissions in the AQCR. Point source emissions are, however, in the form of concentrated plumes, while other heat emissions are diffused. Thus, the meteorological dispersion behavior of these sources is likely to be quite different.

Very few studies of heat emission inventories have been reported in the literature. Beaty and Kircher (1) reported on a study of heat emissions in the Columbus, Ohio, area. Dr. R. Bornstein (2) of San Jose State University is currently working on a heat inventory of New York City.

2.0 SOURCES OF HEAT EMISSIONS IN THE ST. LOUIS AQCR

A first approximation of the amount of heat generated by the combustion of fuels in the St. Louis Air Quality Control Region (AQCR) can be obtained from fuel combustion figures of the 12 counties making up the AQCR. The breakdown is shown in Tables 1 and 2.

The data presented in these tables indicate that coal supplies 70 percent of the energy requirement of stationary point sources, but only 2.6 percent of the area sources. Natural gas supplies 20.5 percent of the requirement of point sources, but 69 percent of the area sources. The totel amount of heat generated by both stationary and mobile sources is of the order of 869 x 10^{12} Btu per year.

The amount of heat actually released to the atmosphere is, however, considerably less. There are several reasons for this. In a utility boiler, about 85 percent of the energy created by burning fuels is used in the production of steam (large utilities do a little better). Thus, about 15 percent of the heat content of the fuel escapes in the stack gases, which constitute the "point" heat emission sources. This amounts to about 61 x 10^{12} Btu. Less than half of the remaining 85 percent is converted to electricity, which eventually is released as an "area" source of heat. The other half--actually, about 55 percent--is carried off by cooling water, which in this area is the Mississippi River. Since this raises the river water temperature only minimally, virtually none of this heat is given off to the atmosphere. Additionally, about 15 percent of the power produced is used outside the AQCR. The total amount of heat released to the atmosphere in the St. Louis AQCR is estimated at 535 x 10^{12} Btu per year.

By contract, essentially all of the heat released by area sources (space heating, cars and trucks, as well as a minor amount of process heating) is emitted as heat emissions to the atmosphere. The heat produced by the burning of fuel used for space heating is given off continuously to the

TABLE 1 - POINT SOURCE FUEL CONSUMPTION

County	Coal (Bitum.) Tons	Residual Oil 10^3 gal	Distillate Oil 10^3 gal	Diesel Fuel 10^3 gal	Natural Gas 10^6 cu.ft.
(Illinois)					
Bond	---	---	742	60	---
Clinton	4,144	---	277	---	221
Madison	2,681,251	152,506	55,786	---	57,425
Monroe	---	---	---	---	---
Randolph	5,952,699	100	686	37	159
St. Clair	158,077	28,832	4,712	---	5,606
Washington	250	---	156	---	---
(Missouri)					
Franklin	5,673	3,401	3,525	---	41
Jefferson	18,760*	850	450	---	1,538
St. Charles	1,561,433	---	786	---	184
St. Louis (City)	205,266	1,076	191	---	5,032
St. Louis (County)	2,282,034	4,065	638	---	13,177
Total point source fuel consumption	12,869,587	190,830	67,949	97	83,383
Aver. Btu x 10^6/ SCC unit	22	150	140	140	1,000
Total heat content Btu x 10^{12}	283	29	9.5	---	83
All Point Sources	405 x 10^{12} Btu				

* Listed as anthracite

TABLE 2 - AREA SOURCE FUEL CONSUMPTION

County	Coal (Bitum.) Tons	Residual Oil 10^3 gal	Distillate Oil 10^3 gal	LPG 10^3 gal	Natural Gas 10^6 cu.ft.	Electricity 10^6 KWH	Gasoline 10^3 gal	Diesel Fuel 10^3 gal
(Illinois)								
Bond	3,020	220	1,840	5,475	600	195 *	12,431	610
Clinton	5,160	320	2,220	8,805	1,360	211 *	13,309	1,280
Madison	61,020	3,250	25,210	39,630	18,370	1,684	111,833	21,254
Monroe	2,120	190	1,270	13,340	580	148 *	9,983	6,392
Randolph	8,540	420	3,100	13,505	1,370	245 *	16,054	6,620
St. Clair	56,410	3,320	22,640	44,920	16,480	1,145	116,286	16,285
Washington	3,530	160	1,200	9,785	680	127 *	10,408	652
(Missouri)								
Franklin	34,540	220	7,680	55,560	2,940	383	32,242	5,932
Jefferson	940	250	7,260	89,540	13,940	989	57,991	7,094
St. Charles	1,330	420	9,420	56,340	2,870	566	54,494	38,580
St. Louis (City)	330,500	10,000	78,000	16,620	60,000	4,597	217,680	23,970
St. Louis (County)	38,550	5,210	61,280	44,510	43,800	9,806	333,346	64,143
Total area source consumption	545,660	23,980	211,120	398,030	162,990	20,096	986,057	192,812
Aver. Btu x 10^6/ SCC unit	22	150	140	95	1,000	3,410	125	140
Total heat content Btu x 10^{12}	12	4	30	38	163	68	123	27
Total Btu all areas			464×10^{12}					

* Estimated

atmosphere. One might expect that automobiles and electric motors convert a sizeable fraction of the energy they use into work, rather than waste-heat. Actually, only a time delay is involved. All kinetic energy stored, for example, in a moving automobile is converted to heat by friction and given up to the atmosphere, whether the friction is air resistance, rolling resistance or braking. Thus, the full amount of the heat content of fuels used in area sources plus a large fraction of the fuel used in point sources constitutes diffuse heat emission.

3.0 POINT SOURCE HEAT EMISSION INVENTORY

In the framework of RAPS, most point source heat emissions are analogous to pollutant emissions. Just as in the case of sulfur dioxide (SO_2), emissions are directly related to fuel consumption, and can be calculated by the application of an appropriate factor. In some cases, the factors are applied to production of throughput figures.

Fuel consumption data were gathered in two ways: for major sources, defined as those emitting individually more than 0.1 percent of the total amount of a pollutant, measured hourly fuel consumption data were collected; for minor sources, emitting between 0.1 percent and 0.01 percent of a pollutant, averaged numbers, based on annual data, were collected. Very small sources (< 0.01 percent) were included in area emissions.

Thus, the determination of point source heat emissions involved the development of appropriate heat emission factors and the methodology for coding and entering these factors into the RAPS emission data bank.

3.1 HEAT EMISSION FACTORS

The amount of heat which is discharged to the atmosphere by a point source--a stack--corresponds to that portion of the heat value of the fuel which is not utilized in the process. In the case of a boiler, it is that portion which is not converted to steam; in a glass melting furnace, it is that part which is not utilized to produce the melt (the heat content of the melt is released and is accounted for as an area heat emission).

Thus, in order to calculate the amount of heat emitted by a source, we need to know the amount of fuel consumed (or materials produced) per unit time, the heat value of the fuel, and the efficiency of the operation. These three factors were considered in deriving the heat emission factors for each source. These factors were keyed into the Standard Classification Code (SCC); thus, they will give values of the heat emission in units of

10^6 Btu per SCC unit. SCC units are: tons (for coal, etc.), 10^3 gal. (for oil, etc.) and 10^6 cu. ft. (for gases). The factors were designated by the code HEM and were entered into the RAPS file together with the appropriate source code (the first 15 spaces on each card). The coding card is always associated (preceded) by a source identification card (Card 4), which contains the fuel heat content information. A typical coding form is shown in Figure 1.

Heat emission factors (HEM) cover a wide range of values. Those based on fuel consumption tend to average around .20, indicating a fuel conversion efficiency of 80 percent; their range is from .109 for the most efficient, modern power plants of the large utilities to .30 for older industrial installations. In-process fuel consumption is less efficient, with values generally of the order of .35, indicating 65 percent fuel utilization as, for example in a glass furnace. Even higher factors characterize municipal incinerators (.40). Finally, factors of 1.0 appear where fuel is wasted, such as in refinery flares.

Some heat emission factors are based on throughput or material produced. Such factors are no longer directly related to combustion efficiency and can, therefore, have any numberical value. For example, heat emission from a power plant for which fuel consumption data are available, are calculated:

Heat emission = datum (e.g. fuel/year) X heat content (Btu X 10^6/SCC unit) X HEM

For the plant shown on the coding form (Figure 1):

Heat emission = 125 (gal X 10^3/year) X 130 (Btu X 10^6/gal X 10^3) X 0.20 =

3250 X 10^6 Btu/year

Sometimes fuel consumption data are not available, and the HEM factor may be attached to a calculated mass emission value. An example of the derivation of such a factor might be a cement kiln which has an annual calculated mass emission of 898 tons of particulates. Stack conditions are as follows:

gas flow: 270,000 SCF/min.
gas temperature: 500°F
ambient temperature: 56°F (average)

RAPS POINT SOURCE CODING FORM — PART I — DATE ____ COMPILER ____

PLANT (Card 1)	State, County; Plant ID; Plant Name; Street Address; City; SIC; Sequence; Own; Actn	140520; 01; COATE STEEL PROD; W FRANKLIN; 62246; 3312; P; A
STACK (Card 2)	State, County; Plant ID; Stack ID; UTM Zone; UTM Coordinates horizontal, Km; vertical, Km; Area ID; Temp., °F; Stack Ht. ft.; Boiler Design Cap. 10^6 Btu/hr; Stack Dia. ft.; Flow Rate, cfm; Sequence; Actn	140520; 01; 01; 16; 2805; 4307; 1795; 450; 35; A
CONTROLS (Card 3)	State, County; Plant ID; Stack ID; Pri. SO_2; Sec. SO_2; Effic %; Pri. CO; Sec. CO; Effic %; Pri. NO_x; Sec. NO_x; Effic. %; Pri. HC; Sec. HC; Effic. %; Pri. Part.; Sec. Part.; Effic. %; Year; Sequence; Actn	

EMISSION FACTORS

SOURCE (Card 4)	State, County; Plant ID; Stack ID; Point ID; Fuel Heat Cont 10^6 Btu/SCC (1); Sulfur in Fuel %; Ash in Fuel %; Method; Pollutant; Units; TI (2); Start Date (3); Start Hour; Stop Date (3); Stop Hour; Thermal Eff. %; SCC I II III IV; Sequence; Actn	140520; 01; 01; 01; 130; 60; 3; HEM; GAL; A; 75001; 00; 75365; 23; 39000599; A
DATA (Card 5)	State, County; Plant ID; Stack ID; Point ID; Annual Data; Pattern; Sequence; Type; Actn	140520; 01; 01; 01; 125; D1-365, W1-7, H00-23; 3; A
DATA (Card 5)	State, County; Plant ID; Stack ID; Point ID; Annual Data; Pattern; Sequence; Type; Actn	
DATA (Card 5)	State, County; Plant ID; Stack ID; Point ID; Annual Data; Pattern; Sequence; Type; Actn	
DATA (Card 5)	State, County; Plant ID; Stack ID; Point ID; Annual Data; Pattern; Sequence; Type; Actn	
DATA (Card 5)	State, County; Plant ID; Stack ID; Point ID; Annual Data; Pattern; Sequence; Type; Actn	
DATA (Card 5)	State, County; Plant ID; Stack ID; Point ID; Annual Data; Pattern; Sequence; Type; Actn	
DATA (Card 5)	State, County; Plant ID; Stack ID; Point ID; Emission Factor; Sequence; Type; Actn	140520; 01; 01; 01; 020; A

P=Private
L=Local
S=State
F=Federal
U=Utility

A- Add
C- Change

(1) Tons, 10^3 gal, 10^6 cu.ft.
(2) Time Interval (A,M,W,D,S,H)
(3) Year, Julian Date (YYDDD)

Method:
1. Emission measurement
2. Material balance
3. Emission factor (AP-42)
4. Guess
5. Special emission factor
6. New construction
7. Facility closed
8. Calculated mass emissions

Type:
1. Process data
2. Emission data
3. Annual pattern
4. Non-criteria pollutants
5. Heat emissions

FIGURE 1 - EXAMPLE OF HEAT EMISSION CODING FORM

The sensible heat of the stack gases is about 0.02 Btu/^{o}F/SCF. Thus, the total heat emitted is:

$$\text{Heat emission} = 270{,}000\left(\frac{\text{SCF}}{\text{min.}}\right) \times 0.02 \left(\frac{\text{Btu}}{^{o}\text{F} \times \text{SCF}}\right) \times (500-56)\ ^{o}\text{F} \times 60 \left(\frac{\text{min.}}{\text{hr.}}\right) \times 8760\left(\frac{\text{hrs.}}{\text{yr.}}\right) =$$

$$1{,}260{,}178 \times 10^6 \text{ Btu/yr.}$$

The heat emission factor becomes:

$$\text{HEM} = 1{,}260{,}178/898 = 1403.3$$

The computer is programmed to calculate heat emissions:

$$\text{Heat emission} = \text{datum} \times \text{heat content} \times \text{HEM}$$

If heat content is zero (as it is in this case), the program will substitute one (1) and proceed with the calculation:

$$\text{Heat emission} = 898 \times 1403.3 = 1{,}260{,}178 \times 10^6 \text{ Btu/yr.}$$

The result is always in Btu X 10^6. A listing of heat emission factors for specific points in the St. Louis AQCR, arranged by state, county, point and SCC codes, is given in Table 3.

TABLE 3 - EXAMPLES OF POINT SOURCE HEAT EMISSION FACTORS (HEM)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
***					
*	MUNICIPAL POWER PLANT BREESE	01	10100208	HEM	.200
*	CARLYLE MUNICIPAL POWER	01	20100301	HEM	.200
*	ILLINOIS POWER CO. WOOD RIVER	01	10100501	HEM	.131
*	ILLINOIS POWER CO. STALLING	01	10100501	HEM	.200
*		04	10100501	HEM	.200
*	UNION ELECTRIC CO. VENICE	01	10100501	HEM	.139
*	AMOCO OIL REFINERY	01	30600102	HEM	.150
*		03	30600102	HEM	.150
*		05	30600102	HEM	.150
*		06	30600102	HEM	.150
*		07	30600102	HEM	.200
*		09	30600103	HEM	.250
*		10	30600103	HEM	.250
*		12	30600103	HEM	.250
*		14	30600108	HEM	.250
*		17	30600102	HEM	.250
*		21	30600999	HEM	1.000
*		22	30600999	HEM	.200
*		23	30600999	HEM	1.000
*		24	30600999	HEM	.200
*	CLARK OIL CO.	01	30600102	HEM	.250
*		02	30600102	HEM	.250
*		03	30600102	HEM	.250
*		04	30600102	HEM	.250
*		05	30600102	HEM	.250
*		06	30600102	HEM	.250
*		08	30600102	HEM	.250

(continued)

TABLE 3 (continued)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
*	CLARK OIL CO.	09	30600102	HEM	.250
*		10	30600102	HEM	.250
*		11	30600102	HEM	.250
*		12	30600102	HEM	.250
*		13	30600102	HEM	.250
*		14	30600102	HEM	.250
*		15	30600102	HEM	.250
*		16	30600102	HEM	.250
*		17	30600102	HEM	.250
*		18	30600102	HEM	.250
*		19	30600102	HEM	.250
*		51	30600102	HEM	.250
*		52	30600102	HEM	.250
*		53	30600102	HEM	.250
*	OLIN CORP.	25	10200602	HEM	.200
*		26	10200602	HEM	.200
*		27	30400204	HEM	.340
*		28	30400204	HEM	.340
*	AMERICAN STEEL FOUNDRY	01	30400701	HEM	.340
*		02	30400701	HEM	.340
*		03	10200402	HEM	.200
*	GRANITE CITY STEEL	05	30300802	HEM	85200.000
*		06	30300802	HEM	85200.000
*		08	30300803	HEM	69100.000
*		09	30300803	HEM	5748.000
*		10	30300903	HEM	5824.000
*		14	30300920	HEM	1375.600
*		19	10299997	HEM	87118.000
*		20	10299997	HEM	86993.000
*		21	10299998	HEM	238.500
*		22	10299997	HEM	1944.700

(continued)

TABLE 3 (continued)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
*	GRANITE CITY STEEL	23	10299997	HEM	1947.700
*	NESTLE CO. INC.	01	10200402	HEM	.200
*		02	10200402	HEM	.200
*		03	10200402	HEM	.200
*		04	10200402	HEM	.200
*	OWENS-ILLINOIS INC.	01	10200402	HEM	.200
*		01	10200602	HEM	.200
*		04	39000408	HEM	.350
*		05	39000408	HEM	.350
*		06	39000408	HEM	.350
*		07	39000408	HEM	.000
*		08	39000408	HEM	.350
*		09	39000408	HEM	.350
*		10	39000408	HEM	.350
*		11	39000408	HEM	.350
*	SHELL OIL CO.	01	30600104	HEM	.108
*		02	30600104	HEM	.108
*		03	30600104	HEM	.108
*		04	30600104	HEM	.108
*		05	30600104	HEM	.108
*		06	30600104	HEM	.108
*		07	30600104	HEM	.108
*		13	30600104	HEM	.108
*		14	30600104	HEM	.108
*		15	30600104	HEM	.108
*		17	30600104	HEM	.108
*		18	30600104	HEM	.108
*		19	30600104	HEM	.108
*		21	30600104	HEM	.108
*		22	30600104	HEM	.108
*		24	30600104	HEM	.108

(continued)

TABLE 3 (continued)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
*	SHELL OIL CO.	30	30600104	HEM	.108
*		31	30600104	HEM	.108
*		33	30600104	HEM	.108
*		34	30600104	HEM	.108
*		39	30600104	HEM	.108
*		41	30600104	HEM	.108
*		46	10200601	HEM	.108
*			10200601	HEM	.108
*		48	10200601	HEM	.108
*			10200601	HEM	.108
*		50	10200601	HEM	.108
*		51	10200601	HEM	.108
*		52	10200601	HEM	.108
*		53	10200601	HEM	.108
*		78	10200601	HEM	.108
*		79	10200601	HEM	.108
*	LACLEDE STEEL CO.	01	10200401	HEM	.350
*		02	10200401	HEM	.350
*		03	30300905	HEM	.120
*		04	30300905	HEM	.120
*		06	39000499	HEM	.350
*		08	39000499	HEM	.350
*		11	39000699	HEM	.350
*	GRANITE CITY ARMY DEPOT	02	10300402	HEM	.200
*		03	10300402	HEM	.200
*	ALTON BOX BOARD CO.	02	10200401	HEM	.140
*		03	10200202	HEM	.120
*		04	10200202	HEM	.120
*	DUNCAN FOUNDRY	01	10200502	HEM	.200
*		02	10200602	HEM	.200
*	HIGHLAND ELECTRIC PLT	01	10100208	HEM	.204

(continued)

TABLE 3 (continued)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
*	FINLEY PLATING CO.	01	10200603	HEM	.200
*	CONSOLIDATED ALUMINUM CO.	02	10200602	HEM	.200
*	MOSS AMERICAN INC.	01	10200502	HEM	.200
*	ANLIN CO. OF ILLINOIS	01	30199999	HEM	161.140
*	ST. JOSEPHS HOSPITAL	01	10300213	HEM	.200
*	REILLY TAR & CHEM	01	10200402	HEM	.200
*		02	10200402	HEM	.200
*	A O SMITH	01	10200602	HEM	.200
*	COLUMBIA QUARRY PLT #3	05	39000609	HEM	.200
*	ILLINOIS POWER CO. BALDWIN	01	10100203	HEM	.109
*		02	10100203	HEM	.109
*		03	10100202	HEM	.109
*	MENARD BR. ILL. PEN.	01	10300209	HEM	.200
*	STOTZ QUARRY	04	20200401	HEM	.200
*	CARLING/STAG BREWING CO.	01	10200205	HEM	.126
*	SWIFT & CO NATIONAL CITY	01	10200401	HEM	.200
*	MONSANTO CO.	05	10200401	HEM	.129
*		06	10200401	HEM	.129
*		07	10200204	HEM	.129
*		08	10200204	HEM	.129
*		09	10200204	HEM	.129
*		10	10200204	HEM	.129
*		22	30199999	HEM	.005
*	SCOTT AIR FORCE BASE	01	10300402	HEM	.200
*		02	10300402	HEM	.200
*		03	10300402	HEM	.200
*		04	10300402	HEM	.200
*	MASCOUTAH CITY POWER	01	10100208	HEM	.200
*		02	10100208	HEM	.200
*	UNION ELECTRIC CAHOKIA	01	10100401	HEM	.170
*		02	10100401	HEM	.170

(continued)

TABLE 3 (continued)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
*	UNION ELECTRIC CAHOKIA	03	10100401	HEM	.190
*		04	10100401	HEM	.140
*		05	10100401	HEM	.140
*		06	10100401	HEM	.150
*	R FOX LTD	01	10200212	HEM	.200
*	HUNTER PACKING CO.	01	10200502	HEM	.200
*		02	10200502	HEM	.200
*		03	39000631	HEM	.200
*	ST. ELIZABETHS HOSPITAL	01	10300402	HEM	.200
*	AUTOCRAT CORP.	01	10200213	HEM	.200
*	CERRO COPPER PRODUCTS	01	10200603	HEM	.200
*		02	10200603	HEM	.200
*		03	10200603	HEM	.200
*		05	39000605	HEM	.050
*		06	39000605	HEM	.050
*		07	39000605	HEM	.050
*		09	39000605	HEM	.050
*		10	39000605	HEM	.050
*		12	39000605	HEM	.050
*		13	39000605	HEM	.050
*		14	39000605	HEM	.050
*	CERTAIN-TEED	01	10200602	HEM	.200
*			10200502	HEM	.200
*	OBEAR NESTER GLASS	01	10200602	HEM	.200
*		09	39000608	HEM	.350
*		10	39000608	HEM	.350
*		11	39000608	HEM	.350
*	CENTREVILLE TWP HOSPITAL	01	10300401	HEM	.200
*	ALLIED CHEMICAL CORP.	01	10200602	HEM	.200
*	EDWIN COOPER INC.	01	30199999	HEM	400.000
*		02	30199999	HEM	400.000

(continued)

TABLE 3 (continued)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
*	EDWIN COOPER INC.	03	30199999	HEM	5.450
*	COVINGTON STONE CO.	01	20200401	HEM	.200
*	UNION ELECTRIC CO. LABADIE	01	10100201	HEM	.116
*		02	10100201	HEM	.116
*		03	10100201	HEM	.116
*	P.P.G. GLASS	01	10200601	HEM	.200
*	RIVER CEMENT CO.	01	30500699	HEM	1403.000
*	ST. JO LEAD CO.	01	30301001	HEM	96.580
*	USS AGRI-CHEM	08	10200402	HEM	.200
*	UNION ELECTRIC	01	10100201	HEM	.116
*	UNION ELECTRIC CO. SIOUX	01	10100203	HEM	.109
*	PENNSYLVANIA GLASS SAND	02	39000599	HEM	.350
*	AMERICAN CAN CO.	01	39000699	HEM	.300
*	ANHEUSER BUSCH INC.	01	10200202	HEM	.175
*		02	10200202	HEM	.175
*		03	10200202	HEM	.120
*		04	10200601	HEM	.120
*		06	39000630	HEM	.300
*	GENERAL MOTORS ASSEMBLY	01	10200209	HEM	.200
*		101	10200204	HEM	.200
*	GREAT LAKES CARBON	01	30300301	HEM	.300
*		02	30300301	HEM	.300
*		03	10200708	HEM	.200
*	MALLINCKRODT CHEM.	01	10200601	HEM	.200
*		04	10200204	HEM	.200
*		05	10200601	HEM	.200
*	MONSANTO CO.	02	10200602	HEM	.099
*		03	10200602	HEM	.099
*		04	10200402	HEM	.099
*		05	10200402	HEM	.099
*		06	10200209	HEM	.155

(continued)

TABLE 3 (continued)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
*	MUNICIPAL INCINERATOR N.	01	50100101	HEM	.400
*		02	50100101	HEM	.400
*	MUNICIPAL INCINERATOR S.	01	50100101	HEM	.400
*		02	50100101	HEM	.400
*	UNION ELECTRIC, ASHLEY	01	10100401	HEM	.142
*	WASH. UNIV. EUCLID PWR P.	01	10300209	HEM	.200
*	VA HOSPITAL COCHRAN	01	10300401	HEM	.200
*	PROCTER AND GAMBLE	02	10200602	HEM	.200
*	PVO INTERNATIONAL	01	10200205	HEM	.300
*		02	10200205	HEM	.300
*		03	10200205	HEM	.300
*	ALPHA PORTLAND CEMENT	01	39000201	HEM	.300
*	CHRYSLER ASSEMBLY PLANT	08	10200601	HEM	.200
*		09	10200601	HEM	.200
*	CONTINENTAL CAN CO.	01	10200402	HEM	.200
*	EMERSON ELECTRIC	01	10200402	HEM	.200
*	MCDONNELL DOUGLAS CORP.	01	10200601	HEM	.200
*		04	10200602	HEM	.200
*		05	10200602	HEM	.200
*		06	10200602	HEM	.200
*		07	10200602	HEM	.200
*		08	10200602	HEM	.200
*		09	10200602	HEM	.200
*		10	10200602	HEM	.200
*		11	10200602	HEM	.200
*		12	10200602	HEM	.200
*		13	10200602	HEM	.200
*		14	10200602	HEM	.200
*	MISSOURI PORTLAND CEMENT	01	39000201	HEM	.300
*	N L INDUSTRIES	01	10200209	HEM	.150
*		02	10200209	HEM	.150

(continued)

TABLE 3 (continued)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
*	N L INDUSTRIES	03	10200601	HEM	.150
*		04	10200601	HEM	.150
*		05	10200401	HEM	.150
*		06	10200204	HEM	.150
*		10	39000699	HEM	.050
*		11	39000699	HEM	.050
*		13	39000699	HEM	.050
*		16	30102399	HEM	.011
*		17	30102399	HEM	.011
*		18	10200209	HEM	.150
*	UNION ELECTRIC CO. MERAMEC	01	10100201	HEM	.119
*		02	10100201	HEM	.119
*		03	10100201	HEM	.112
*		04	10100201	HEM	.132
*	VA HOSPITAL JEFF BARRACK	01	10300602	HEM	.200
*	WASH. UNIV. CAMPUS PWR.	01	10300209	HEM	.200
*	PENNA GLASS Z SAND CORP.	02	39099998	HEM	.300
*	CHRYSLER TRUCK ASSEMBLY	01	39000699	HEM	.200

4.0 AREA SOURCE HEAT EMISSION INVENTORY

As pointed out in the discussion of heat emissions in the St. Louis AQCR (Section 2.0), by far the major portion of heat is released in the atmosphere from area sources. "Area sources" connotes the sum total of numerous separate point sources, which cannot be measured individually.

Area sources are assigned to a grid system developed for the St. Louis AQCR, which divides the study area into 1989 grid squares (3). These squares vary in size from 1 to 100 km^2, depending on population densities.

Area heat emissions fall into three broad categories:

1) Heat emissions from the burning of fuel in stationary installations (e.g., space heating).

2) Heat emissions from the consumption of electric power, all of which eventually show up as heat.

3) Heat emissions from burning of fuel in mobile sources (e.g., cars, trucks, rail and airport operations).

4.1 HEAT EMISSION FROM STATIONARY COMBUSTION SOURCES

This category consists of several groups: residential heating, commercial heating and industrial heat emissions.

4.1.1 Residential Heating

Residential heating in the AQCR accounts for about 30 percent of the area heat emissions, or about 140 x 10^{12} Btu per year. As shown in Table 4, natural gas accounts for the bulk of it (87 x 10^{12} Btu), followed by LPG, oil, coal and wood, in that order.

In 1974, the price of coal tripled as a result of the coal miners' strike and the increase in oil prices. This increase in price was enough

TABLE 4 - RESIDENTIAL FUEL CONSUMPTION

County	Coal (Bitum.) Tons	Distillate Oil 10^3 gal	Natural Gas 10^6 cu.ft.	Wood Tons	LPG 10^3 gal
(Illinois)					
Bond	2,690	1,530	320	200	5,475
Clinton	3,990	1,280	710	200	8,805
Madison	30,750	11,190	8,980	400	39,630
Monroe	2,040	1,000	250	200	13,340
Randolph	6,370	1,980	490		13,505
St. Clair	41,980	11,210	9,350	1,000	44,920
Washington	3,030	890	370	800	9,785
(Missouri)					
Franklin	1,970	5,930	1,150	4,600	55,560
Jefferson	940	5,770	3,020	2,200	89,540
St. Charles	1,330	5,870	2,620	700	56,340
St. Louis (City)	500	20,000	23,000		16,620
St. Louis (County)	4,150	26,160	36,380	500	44,510
TOTALS	99,740	92,810	86,640	10,800	398,030
Aver. Btu x 10^6 per SCC unit	22	140	1,000	17	95
Total Btu x 10^6	2,194,280	12,993,400	86,640,000	183,600	37,812,850
GRAND TOTAL, Btu			139.8×10^{12}		

to make most residential coal users convert to gas. The residential use of oil has been decreasing at a rate of about ten percent per year. For the purposes of this study, the switch from coal to oil or gas is not too important, since approximately the same number of Btu's would be used to heat a house, no matter which fuel is used. In addition, only two percent of the Btu's for fuel use are attributed to coal.

The assignment of fuel consumed for residential heating to grid squares has been developed in connection with the methodology for the residential emission inventory (4). Briefly, the procedure consists in prorating the county fuel consumption, shown in Table 4 to the grid squares in proportion to the number of housing units they contain, for each fuel type. Information on the numer of housing units per county is contained in Census Bureau data (5) and shown in Table 5. Housing units per grid square were estimated by the contractor from Census Tract maps, superimposed on RAPS grid square maps. The annual use of a fuel type for heating within a grid square is equal to the annual use of that fuel type in the county multiplied by the number of housing units in the grid using that fuel type and divided by the total number of housing units in the county using that fuel type. The reader is encouraged to review reference 4 for more details.

The annual numbers thus obtained were transformed into weighted hourly values using a regression equation developed from actual fuel consumption records in the St. Louis area. The resulting equation takes into consideration ambient temperatures and wind speed and has the following form for fuels used for space heating only (fuel oil, coal, wood):

For temperatures > 68°F: hourly consumption = 0

For temperatures $\leq$ 68°F: hourly consumption = yearly consumption x $[4.849 \times 10^{-4} - 7.0986 \times 10^{-6}T + 1.4614 \times 10^{-6}WS]$

where T = Temperature in °F, WS = wind speed in mph.

For natural gas, a proportionality factor is added to correct for non-space heating use, resulting in the following equations:

At temperatures above 68°F:

$$\text{hourly gas consumption} = \text{yearly consumption} \times \frac{9.4832 \times PF}{8760}.$$

TABLE 5 - HOUSING UNITS BY COUNTIES

Illinois	Housing Units
Bond	5,099
Clinton	8,830
Madison	82,225
Monroe	6,152
Randolph	10,254
St. Clair	91,327
Washington	5,310
Missouri	
Franklin	19,345
Jefferson	33,285
St. Charles	27,911
St. Louis (City)	238,436
St. Louis (County)	291,577
TOTAL	819,751 (1970)

At temperatures below 68°F:

$$\text{hourly gas consumption} = \text{yearly consumption} \times [4.849 \times 10^{-4} - 7.0986 \times 10^{-6} T + 1.4614 \times 10^{-6} WS + \frac{0.4832 \times PF}{8760}].$$

where PF = proportionality factor related to hourly gas flow (4) (Table 6).

TABLE 6 - AVERAGE HOURLY BASELINE GAS FLOWS AND PROPORTIONALITY FACTOR*

Hour	Composite Average Flow (MSCF)	Proportionality Factor
1	5727	0.84
2	5490	0.80
3	5339	0.78
4	5301	0.77
5	5262	0.77
6	5550	0.81
7	6312	0.92
8	7378	1.08
9	7899	1.15
10	7948	1.16
11	8387	1.22
12	8214	1.20
13	8062	1.18
14	7892	1.15
15	7640	1.11
16	7360	1.07
17	7245	1.06
18	7267	1.06
19	7315	1.07
20	7094	1.04
21	6769	0.99
22	6632	0.97
23	6433	0.94
24 (midnight)	5971	0.87
Average hourly flow	6854	1.00

*Reference 4

The software capable of calculating hourly fuel consumption per grid square for each of the five fuels (fuel oil, natural gas, LPG, coal and wood) is operational on the Univac 1110 computer at Research Triangle Park. In order to obtain heat emissions, the fuel consumption figure thus obtained is multiplied by a factor corresponding to the Btu content of the fuels per standard SCC unit for each fuel.

Heat emissions resulting from the use of electric power are discussed in Section 4.2.

4.1.2 Commercial Heating

The estimation of fuel consumed by commercial and institutional heating is again based on the methodology for the commercial area source emissions inventory (4).

The approach was to determine the amount of land used for commercial purposes in each county and for each grid square, using information supplied by the East-West Gateway Council. The total fuel usage indicated in Table 7 for commercial/institutional usage was then apportioned to each grid square in the ratio of land usage for each fuel. An enrichment factor (EF) was used to correct for the use of specific fuels in certain grid squares, since fuel usage depends on location. This factor was equal to the ratio of the fraction of residences in a given grid using a given fuel to the fraction of residences using the same fuel in the county.

TABLE 7 - COMMERCIAL FUEL CONSUMPTION

County	Coal Tons	Fuel Oil 10^3 gal.	Natural Gas 10^6 cu. ft.
(Illinois)			
Bond	--	520	220
Clinton	--	770	450
Madison	--	7,800	4,040
Monroe	--	460	310
Randolph	--	1,020	500
St. Clair	--	8,350	4,570
Washington	--	370	220
(Missouri)			
Franklin	--	960	1,460
Jefferson	--	1,080	9,680
St. Charles	--	1,760	170
St. Louis (City)	100,000	30,000	22,000
St. Louis (County)	--	22,660	--
TOTALS	100,000	75,750	43,620
Aver. Btu x 10^6/SCC	22	140	1,000
Total Btu x 10^6	2,200,000	10,605,000	43,620,000
GRAND TOTAL		Btu 56.4 x 10^{12}	

The annual fuel usage values for each fuel and grid square were divided into hourly segments using the same technique described under residential heating; that is, a fuel consumption equation taking into consideration ambient temperature and wind speed. The hourly fuel consumption values thus obtained are converted into Btu of heat emission using the values in Table 5. Commercial use of electric power is discussed in Section 4.2.1.

4.1.3 Industrial Area Heat Emissions

Industrial heat emissions present a more complex picture than residential or commercial emissions.

It is necessary to treat power plants (utilities) separately from other industrial installations. The heat content of fuel burned at power plants is distributed approximately in the following manner: 15 percent is lost in the stack gases, which are a point source (Section 3.0). About one third of the remaining energy is converted into electric power, which is utilized (i.e., converted to heat) elsewhere (Section 4.2), and the remaining two thirds are carried off in the cooling water, which in the St. Louis area is not recycled, but rather discharged into the Mississippi River. Since this raises the river temperature only minimally, no heat is discharged to the atmosphere. (The exception to this is the Baldwin plant of Illinois Power, which utilizes a very large cooling pond.) Since only insignificant amounts of steam are used for space heating at power plants, they constitute a pure point source of heat and do not contribute to area heat emissions. Their heat emissions are calculated using a HEM factor, as discussed in Section 3.0.

Generally, fuel consumed at non-utility industrial installations is utilized in one form or another at the same general locations. Larger industrial installations include a power house, usually producing process steam. These installations are classified as point sources, since a portion of their heat emissions is channeled into a stack, which is a point source. This tends to amount to about 20 percent of the heat content of fuel used. The steam produced by industrial boilers is used either for space heating or as process heat. The energy thus consumed is released in diffused form and becomes an area source, which can be assigned to a grid square. While all of the heat used for space heating is transferred to the atmosphere, not all of the process heat is, depending on what method of cooling is used. Only if the product is air cooled, as for example, cement clinkers, all of the heat is given off to the atmosphere. If it is water cooled and the cooling water is used only once and then discharged to the river, essentially none is given up to the atmosphere, since the cooling water temperature increases only a few degrees. If direct quenching or cooling towers are used, as in coke ovens or refineries, as much as 80 percent of the heat is converted to latent heat, which is recovered only, if, when and where the water vapor is condensed. Thus it was necessary to derive an Area Heat Emission Factor (AHF) for industrial sources.

This factor (AHF) was determined by examining the manner in which heating and cooling was handled at each source. A specific group factor was assigned to each location and stored as a "special emission factor" in the emission factor file. Multiplying fuel consumption by the heat content of fuel and the AHF gives the amount of heat released to the atmosphere from such sources. AHF's are shown in Table 8.

4.2 ELECTRIC POWER CONSUMPTION

As indicated in Table 2, a total of about 20,096 x 10^6 kwh of electric power is consumed in the AQCR. The breakdown for this consumption is approximately:*

35% Residential	[7034 x 10^6 kwh]
10% Commercial	[2010 x 10^6 kwh]
55% Industrial	[11052 x 10^6 kwh]

As pointed out earlier, essentially all of this energy is eventually converted to heat. This amounts to 68 x 10^{12} Btu, second only to the heat produced by the burning of natural and bottled gas.

4.2.1 Spatial Distribution of Electric Power Consumption

There is a dearth of information on the spatial and temporal distribution of electric power. The only information available was hourly peak loads at substations located in most of the counties of the AQCR. It has been shown empirically that average daily energy can be obtained by dividing the peak hour load figure by two and multiplying by 24, the number of hours in a day.*

*Private communication, Union Electric Company

TABLE 8 - AREA HEAT EMISSION FACTORS (AHF)

*	PLANT	STKID	SCC	PLUTNT	EMFACT
***					
*	MUNICIPAL POWER PLANT	01	10100208	AHF	.1600
*			20100101	AHF	.1600
*			20100201	AHF	.1600
*	CARLYLE MUNICIPAL POWER	01	20100301	AHF	.1600
*	ILLINOIS POWER STALLING	01	10100501	AHF	.1600
*		02	10100501	AHF	.1600
*		03	10100501	AHF	.1600
*		04	10100501	AHF	.1600
*	AMOCO OIL REFINERY	01	30600102	AHF	.1360
*			30600103	AHF	.1360
*			30600108	AHF	.1360
*			30600109	AHF	.1360
*			30600102	AHF	.1360
*			30600103	AHF	.1360
*			30600108	AHF	.1360
*		03	30600102	AHF	.1360
*			30600103	AHF	.1360
*			30600108	AHF	.1360
*			30600109	AHF	.1360
*			30600102	AHF	.1360
*			30600103	AHF	.1360
*			30600108	AHF	.1360
*		05	30600102	AHF	.1360
*			30600103	AHF	.1360
*			30600108	AHF	.1360
*			30600109	AHF	.1360
*		06	30600102	AHF	.1360
*			30600103	AHF	.1360
*			30600108	AHF	.1360

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	AMOCO OIL REFINERY (cont'd)	07	30600102	AHF	.1600
*			30600103	AHF	.1600
*			30600107	AHF	.1600
*		09	30600103	AHF	.1500
*			30600108	AHF	.1500
*		10	30600103	AHF	.1500
*			30600108	AHF	.1500
*		12	30600103	AHF	.1500
*			30600108	AHF	.1500
*		14	30600108	AHF	.1500
*		17	30600102	AHF	.1500
*	CLARK OIL CO	01	30600102	AHF	.1500
*			30600103	AHF	.1500
*		02	30600102	AHF	.1500
*			30600103	AHF	.1500
*		03	30600102	AHF	.1500
*			30600103	AHF	.1500
*		04	30600102	AHF	.1500
*			30600103	AHF	.1500
*		05	30600102	AHF	.1500
*			30600103	AHF	.1500
*		06	30600102	AHF	.1500
*			30600103	AHF	.1500
*		08	30600102	AHF	.1500
*			30600103	AHF	.1500
*		09	30600102	AHF	.1500
*			30600103	AHF	.1500
*		10	30600102	AHF	.1500
*			30600103	AHF	.1500
*		11	30600102	AHF	.1500
*			30600103	AHF	.1500

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	CLARK OIL CO (cont'd)	12	30600102	AHF	.1500
*			30600103	AHF	.1500
*		13	30600102	AHF	.1500
*			30600103	AHF	.1500
*		14	30600102	AHF	.1500
*			30600103	AHF	.1500
*		15	30600102	AHF	.1500
*			30600103	AHF	.1500
*		16	30600102	AHF	.1500
*		17	30600102	AHF	.1500
*			30600103	AHF	.1500
*		18	30600102	AHF	.1500
*			30600103	AHF	.1500
*		19	30600102	AHF	.1500
*			30600103	AHF	.1500
*		51	30600102	AHF	.1500
*			30600103	AHF	.1500
*		52	30600102	AHF	.1500
*			30600103	AHF	.1500
*		53	30600102	AHF	.1500
*			30600103	AHF	.1500
*	OLIN CORP.	25	10200602	AHF	.1600
*		26	10200602	AHF	.1600
*		27	30400204	AHF	.4980
*		28	30400204	AHF	.4980
*	AMERICAN STEEL FOUNDRY	01	30400701	AHF	.4980
*		02	30400701	AHF	.4980
*		03	10200402	AHF	.6400
*			10200602	AHF	.6400

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	NESTLE CO. INC.	01	10200402	AHF	.6400
*			10200602	AHF	.6400
*		02	10200402	AHF	.6400
*			10200602	AHF	.6400
*		03	10200402	AHF	.6400
*			10200602	AHF	.6400
*		04	10200402	AHF	.6400
*			10200602	AHF	.6400
*	OWENS-ILLINOIS INC.	01	10200402	AHF	.6400
*			10200602	AHF	.6400
*			10200402	AHF	.6400
*			10200602	AHF	.6400
*			10200402	AHF	.6400
*			10200602	AHF	.6400
*		04	39000408	AHF	.6500
*			39000608	AHF	.6500
*		05	39000408	AHF	.6500
*			39000608	AHF	.6500
*		06	39000408	AHF	.6500
*			39000608	AHF	.6500
*		07	39000408	AHF	.6500
*			39000608	AHF	.6500
*		08	39000408	AHF	.6500
*			39000608	AHF	.6500
*		09	39000408	AHF	.6500
*			39000608	AHF	.6500
*		10	39000408	AHF	.6500
*			39000608	AHF	.6500
*		11	39000408	AHF	.6500
*			39000608	AHF	.6500

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	SHELL OIL CO	01	30600104	AHF	.0810
*		02	30600104	AHF	.0810
*		03	30600104	AHF	.0810
*		04	30600104	AHF	.0810
*		05	30600104	AHF	.0810
*		06	30600104	AHF	.0810
*		07	30600104	AHF	.0810
*		13	30600104	AHF	.0810
*		14	30600104	AHF	.0810
*		15	30600104	AHF	.0810
*		17	30600104	AHF	.0810
*		18	30600104	AHF	.0810
*		19	30600104	AHF	.0810
*		21	30600104	AHF	.0810
*		22	30600104	AHF	.0810
*		24	30600104	AHF	.0810
*		30	30600104	AHF	.0810
*		31	30600104	AHF	.0810
*		33	30600104	AHF	.0810
*		34	30600104	AHF	.0810
*		39	30600104	AHF	.0810
*		41	30600104	AHF	.0810
*		46	10200601	AHF	.0810
*			10200601	AHF	.0810
*		48	10200601	AHF	.0810
*			10200601	AHF	.0810
*		50	10200601	AHF	.0810
*		51	10200601	AHF	.0810
*		52	10200601	AHF	.0810
*		53	10200601	AHF	.0810
*		78	10200601	AHF	.0810
*		79	10200601	AHF	.0810

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	LACLEDE STEEL CO	01	10200401	AHF	.5200
*			10200601	AHF	.5200
*		02	10200401	AHF	.5200
*			10200601	AHF	.5200
*		03	30300905	AHF	1.0000
*		04	30300905	AHF	1.0000
*		06	39000499	AHF	.6500
*			39000699	AHF	.6500
*		08	39000499	AHF	.6500
*			39000699	AHF	.6500
*		11	39000699	AHF	.6500
*	GRANITE CITY ARMY DEPOT	02	10300402	AHF	.6400
*			10300502	AHF	.6400
*		03	10300402	AHF	.6400
*			10300502	AHF	.6400
*	ALTON BOX BOARD CO	02	10200401	AHF	.1380
*		03	10200202	AHF	.1420
*			10200601	AHF	.1420
*		04	10200202	AHF	.1420
*			10200601	AHF	.1420
*	DUNCAN FOUNDRY	01	10200502	AHF	.6400
*		02	10200602	AHF	.6400
*			10200502	AHF	.6400
*	HIGHLAND ELECTRIC PLT	01	10100208	AHF	.1590
*		03	10100208	AHF	.1590
*	FINLEY PLATING CO	01	10200603	AHF	.6400

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	CONSOLIDATED ALUMINUM CO	02	10200602	AHF	.6400
*	MOSS AMERICAN INC	01	10200502	AHF	.6400
*	ST JOSEPHS HOSPITAL	01	10300213	AHF	.6400
*			10300213	AHF	.6400
*	REILLY TAR & CHEM	01	10200402	AHF	.6400
*			10200602	AHF	.6400
*		02	10200402	AHF	.6400
*			10200602	AHF	.6400
*	A O SMITH	01	10200602	AHF	.6400
*	COLUMBIA QUARRY PLT #3	05	39000609	AHF	.6400
*	ILLINOIS POWER CO	01	10100203	AHF	.1280
*		02	10100203	AHF	.1280
*		03	10100202	AHF	.1280
*	MENARD BR. ILL. PEN.	01	10300209	AHF	.6400
*			10300209	AHF	.6400
*			10300602	AHF	.6400
*	STOTZ QUARRY	04	20200401	AHF	.6400
*	CARLING/STAG BREWING CO	01	10200205	AHF	.1400
*			10200205	AHF	.1400
*	SWIFT & CO NATIONAL CITY	01	10200401	AHF	.6400
*			10200601	AHF	.6400
*			10200401	AHF	.6400
*			10200601	AHF	.6400

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	MONSANTO CO	05	10200401	AHF	.1390
*			10200601	AHF	.1390
*		06	10200401	AHF	.1390
*			10200601	AHF	.1390
*		07	10200204	AHF	.1390
*		08	10200204	AHF	.1390
*		09	10200204	AHF	.1390
*		10	10200204	AHF	.1390
*	SCOTT AIR FORCE BASE	01	10300402	AHF	.6400
*		02	10300402	AHF	.6400
*		03	10300402	AHF	.6400
*		04	10300402	AHF	.6400
*	MASCOUTAH CITY POWER	01	10100208	AHF	.1600
*			10100502	AHF	.1600
*			10100602	AHF	.1600
*		02	10100208	AHF	.1600
*			10100502	AHF	.1600
*			10100602	AHF	.1600
*	R FOX LTD	01	10200212	AHF	.6400
*	HUNTER PACKING CO	01	10200502	AHF	.6400
*			10200602	AHF	.6400
*		02	10200502	AHF	.6400
*			10200602	AHF	.6400
*		03	39000631	AHF	.6400
*	ST.ELIZABETHS HOSPITAL	01	10300402	AHF	.6400
*	AUTOCRAT CORP	01	10200213	AHF	.6400

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	CERRO COPPER PRODUCTS	01	10200603	AHF	.6400
*		02	10200603	AHF	.6400
*		03	10200603	AHF	.6400
*		05	39000605	AHF	.9500
*		06	39000605	AHF	.9500
*		07	39000605	AHF	.9500
*		09	39000605	AHF	.9500
*		10	39000605	AHF	.9500
*		12	39000605	AHF	.9500
*		13	39000605	AHF	.9500
*		14	39000605	AHF	.9500
*	CERTAIN-TEED	01	10200602	AHF	.6400
*			10200502	AHF	.6400
*	OBEAR NESTER GLASS	01	10200602	AHF	.6400
*		09	39000608	AHF	.6500
*		10	39000608	AHF	.6500
*		11	39000608	AHF	.6500
*	CENTREVILLE TWP HOSPITAL	01	10300401	AHF	.6400
*	ALLIED CHEMICAL CORP	01	10200602	AHF	.6400
*	COVINGTON STONE CO	01	20200401	AHF	.6400
*	P.P.G. GLASS	01	10200601	AHF	.6400
*	USS AGRI-CHEM	08	10200402	AHF	.1300

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	PENNSYLVANIA GLASS SAND	02	39000599	AHF	.6500
*			39001099	AHF	.6500
*			30504033	AHF	.6500
*			39000599	AHF	.6500
*	AMERICAN CAN CO	01	39000699	AHF	.7000
*	ANHEUSER BUSCH INC	01	10200202	AHF	.1320
*			10200202	AHF	.1320
*		02	10200202	AHF	.1320
*			10200202	AHF	.1320
*		03	10200202	AHF	.1420
*			10200601	AHF	.1420
*		04	10200601	AHF	.1420
*		05	10200601	AHF	.1420
*		06	39000630	AHF	.7000
*	GENERAL MOTORS ASSEMBLY	01	10200209	AHF	.6400
*			10200208	AHF	.1180
*			10200202	AHF	.6400
*		101	10200204	AHF	.6400
*			10200209	AHF	.6400
*			10200208	AHF	.6400
*			10200202	AHF	.6400
*	GREAT LAKES CARBON	01	30300301	AHF	.7000
*		02	30300301	AHF	.7000
*		03	10200708	AHF	.6400

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	MALLINCKRODT CHEM	01	10200601	AHF	.6400
*			10200401	AHF	.6400
*		04	10200204	AHF	.6400
*		05	10200601	AHF	.6400
*			10200401	AHF	.6400
*	MONSANTO CO	02	10200602	AHF	.1440
*		03	10200602	AHF	.1440
*		04	10200402	AHF	.1440
*			10200602	AHF	.1440
*		05	10200402	AHF	.1440
*			10200602	AHF	.1440
*		06	10200209	AHF	.1360
*	MUNICIPAL INCINERATOR N.	01	50100101	AHF	.4800
*		02	50100101	AHF	.4800
*	MUNICIPAL INCINERATOR S.	01	50100101	AHF	.4800
*		02	50100101	AHF	.4800
*	WASH. UNIV. EUCLID PWR P	01	10300209	AHF	.6400
*			10300602	AHF	.6400
*	VA HOSPITAL COCHRAN	01	10300401	AHF	.6400
*			10300601	AHF	.6400
*	PROCTER AND GAMBLE	02	10200602	AHF	.6400
*	PVO INTERNATIONAL	01	10200205	AHF	.1120
*			10200602	AHF	.1120
*		02	10200205	AHF	.1120
*		03	10200205	AHF	.1120
*			10200602	AHF	.1120

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	ALPHA PORTLAND CEMENT	01	39000201	AHF	.7000
*	CHRYSLER ASSEMBLY PLANT	08	10200601	AHF	.6400
*		09	10200601	AHF	.6400
*	CONTINENTAL CAN CO	01	10200402	AHF	.6400
*	EMERSON ELECTRIC	01	10200402	AHF	.6400
*			10200602	AHF	.6400
*	MCDONNELL DOUGLAS CORP	01	10200601	AHF	.6400
*		04	10200602	AHF	.6400
*		05	10200602	AHF	.6400
*		06	10200602	AHF	.6400
*		07	10200602	AHF	.6400
*		08	10200602	AHF	.6400
*		09	10200602	AHF	.6400
*		10	10200602	AHF	.6400
*		11	10200602	AHF	.6400
*		12	10200602	AHF	.6400
*		13	10200602	AHF	.6400
*		14	10200602	AHF	.6400
*	MISSOURI PORTLAND CEMENT	01	39000201	AHF	.7000
*	N L INDUSTRIES	01	10200209	AHF	.0680
*		02	10200209	AHF	.0680
*		03	10200601	AHF	.0680
*			10200701	AHF	.0680
*		04	10200601	AHF	.0680
*			10200701	AHF	.0680

(continued)

TABLE 8 (continued)

	PLANT	STKID	SCC	PLUTNT	EMFACT
*	N L INDUSTRIES (cont'd)	05	10200401	AHF	.0680
*		06	10200204	AHF	.0680
*		10	39000699	AHF	.4750
*		11	39000699	AHF	.4750
*		13	39000699	AHF	.4750
*		18	10200209	AHF	.0680
*	VA HOSPITAL JEFF BARRACK	01	10300602	AHF	.6400
*			10300502	AHF	.6400
*	WASH. UNIV. CAMPUS PWR.	01	10300209	AHF	.6400
*			10300602	AHF	.6400
*	PENNA GLASS Z SAND CORP	02	39099998	AHF	.7000
*	CHRYSLER TRUCK ASSEMBLY	01	39000699	AHF	.6400

The location of some 235 substations was plotted on county maps, and the power consumption for those counties served exclusively by Union Electric was determined. Power consumption for areas not included in the Union Electric network was estimated using the number of housing units and an average power consumption per household (8333 kwh), then multiplying by 100/35 to get total power consumption. As a check, power consumption calculated by this method was compared with actual consumption of the network. The respective totals differed by only 0.6 percent (Table 9). This holds true only for the network totals. Individual counties show large discrepancies, since some are rural, others urban and industrial. Fortunately, the counties for which estimates had to be made (Bond, Clinton, Monroe, Randolph and Washington) cumulatively account only for less than 5 percent of the electrical power used in the AQCR. Thus, any errors in the estimation of their power consumption are relatively small.

TABLE 9 - COMPARISON OF ACTUAL VS. CALCULATED POWER CONSUMPTION

	Power Consumption, kwh x 10^6	
County	Actual*	Calculated**
Madison	1,684	2,472
St. Clair	1,145	2,175
Franklin	383	461
Jefferson	989	792
St. Charles	566	665
St. Louis (City)	9,806	5,677
St. Louis (County)	4,597	6,942
TOTAL	19,170	19,184

* Determined from substation loads

** Based on number of housing units x 100/35

Since all electric power consumed is converted to heat, heat emission from residential usage can be obtained quite accurately by multiplying the number of housing units per grid square by 8333 kwh, the average power consumption per household. The number of housing units per grid square is available from Reference 4. Table 10 indicates that the residential power consumption for AQCR 70 calculated by this method amounts to 6827.0 X 10^6 kwh, about 34 percent of the total consumption. This is in good agreement with the rough breakdown shown on page 26.

Heat emissions from commercial usage of electric power can be calculated by assigning each grid square a factor corresponding to its commercial land usage as a fraction of county commercial land usage, and multiplying this by the commercial power consumption per county (10 percent of the total) and by 3413, the thermal equivalent of a kilowatt hour. Commercial land usage per grid square (CLUG) as well as commercial land usage per county (CLUC) is again available from Reference 4.

The remainder of the power usage is ascribed to industrial power consumption in only those grid squares in which industrial plants are located (Table 11).

Thus, the calculations for heat emissions resulting from electric power consumption on a grid square basis become:

1) Heat emission from residential power usage per grid square, Btu's per hour = number of housing units per grid square X 8333 X $\frac{3413}{8760}$.

2) Heat emission from commercial power usage per grid square, Btu's per hour - power usage per county X 10% X $\frac{CLUG}{CLUC}$ X $\frac{3413}{8760}$.

3) Heat emissions from industrial power usage, Btu's per hour for grid squares containing industrial plants = [power consumption per county - (residential + commercial consumption)] X $\frac{3413}{8760}$ X $\frac{\text{no. of plants per grid}}{\text{no. of plants per county}}$.

4.2.2 Temporal Distribution of Electric Power Consumption

The temporal distribution of power production for the Union Electric network was ascertained from RAPS data. It can be safely assumed that these

TABLE 10 - DISTRIBUTION OF ELECTRIC POWER USAGE BY COUNTIES

County	Housing Units(1)	Res. Power @ 8333 kwh kwh x 10^6	Commercial Power kwh x 10^6	Total (3) Power/Co. kwh x 10^6	Industrial Total-(Comm.+Res.) kwh x 10^6
(Illinois)					
Bond	5,099	42.5	19.5	195	133.8
Clinton	8,830	73.6	21.1	211	116.3
Madison	82,225	685.2	168.4	1,684	830.5
Monroe	6,152	51.3	14.8	148	81.9
Randolph	10,254	85.4	24.5	245	135.1
St. Clair	91,327	761.0	114.5	1,145	269.5
Washington	5,310	44.2	12.7	127	70.1
(Missouri)					
Franklin	19,345	161.2	38.3	383	183.5
Jefferson	33,285	277.4	98.9	989	612.8
St. Charles	27,911	232.6	56.6	566	276.8
St. Louis (City)	238,436	1,986.9	980.6	9,806	6,838.5
St. Louis	291,577	2,425.7	459.7	4,597	1,711.6
TOTAL AQCR	819,751	6,827.0	2,009.6	20,096	11,259.6

(1) County and City Data Book, U. S. Department of Commerce, Bureau of Census (1972)

(2) Table 2

TABLE 11 - GRID SQUARES IN WHICH INDUSTRIAL PLANTS ARE LOCATED

Bond	Clinton	Madison	Monroe	Randolph	St. Clair	Washington	Franklin	Jefferson	St. Clarles	St. Louis County	St. Louis City
1 (1)	2 (4)	3 (33)	4 (6)	5 (9)	6 (40)	7 (3)	8 (16)	9 (10)	10 (12)	11 (22)	12 (32)
1795	1759	1020	528	1203	886	1790	3	292	60	281	759
	1761	1049	697	1203	997	1829	39	349	106	404	787
	1768	1074	1058	1203	998	1838	40	355	110	525	789
	1818	1077	1059	1579	998		40	355	110	561	794
		1105	1146	1633	1062		47	467	245	586	795
		1107	2237	1633	1063		56	497	2034	614	826
		1110		2414	1063		59	502	2034	641	816
		1110		2430	1067		2002	527	2054	643	815
		1127		2448	1071		2011	2050	2085	725	831
		1127			1072		2011	2082	2234	744	849
		1128			1095		2015		2287	766	849
		1128			1095		2015		2302	942	850
		1128			1095		2015			2044	852
		1134			1096		2022			2126	858
		1135			1096		2022			2141	925
		1135			1097		2030			2147	925
		1157			1118					2147	933
		1161			1123					2169	935
		1167			1152					2229	938
		1200			1152					2245	956
		1224			1152					2250	957
		1240			1152					2254	957
		1241			1252						957
		1300			1252						958
		1332			1283						972
		1332			1484						1001
		1332			1511						1003
		1333			1518						1008
		1354			1540						1008
		1392			1561						1008
		1624			1583						1031
		1709			1584						1037
		2281			1618						
					1621						
					1637						
					1637						
					1637						
					1701						
					2286						
					2337						

( ) Number of grids per county.

patterns also hold for the areas served by other utilities.

The diurnal and seasonal variations are shown in Figure 2. There are two basic patterns: a summer pattern, which holds from mid-June through mid-September; and a spring-fall-winter pattern, applicable to the rest of the year. The latter shows two plateaus with only minor peaks, a daytime level from about 8 AM to 10 PM and a night level from 10 PM to 8 AM. The night level corresponds to about 70-75 percent of the daytime level. The summer pattern has a sinusoidal shape, peaking at 4 PM and dropping to a minimum at 6 AM. It would appear that the pattern is directly related to air conditioning. There is also a marked difference between summer and winter in total consumption, with summer usage beint 60-70 percent higher than winter usage.

Normalized factors describing these patterns are given in Table 12. These are applied to obtain hourly average values for commercial and residential usage to correct for diurnal variations. Industrial power consumption is assumed to be uniformly distributed.

4.3 HEAT EMISSIONS FROM MOBILE SOURCES

Mobile sources comprise several categories. By far the largest are highway vehicles which consume well over a billion gallons of gasoline and diesel fuel, giving off about 150 X 10^{12} Btu's in the AQCR, an amount almost as large as the heat given off by the use of natural gas, and equal to about 32 percent of all area heat emissions.

Railroads, vessels and off-highway mobile equipment contribute two percent, one percent and one percent of all area sources, respectively.

4.3.1 Highway Vehicles

Heat emissions from highway vehicles are based on the "Line and Area Source Emission from Motor Vehicles" methodology developed for RAPS (6). The methodology provides an output of "Vehicle-Kilometers-Traveled" (VKT) for four classes of roads (freeway, principal arterials, minor arterials and feeder roads) for each grid square on a daily basis. A sample of this output is shown in Figure 3. The daily figure is apportioned to hourly values using either a weekday or weekend traffic pattern shown in Table 13. The percentages shown in Table 13 are normalized over a week, since on a weekday

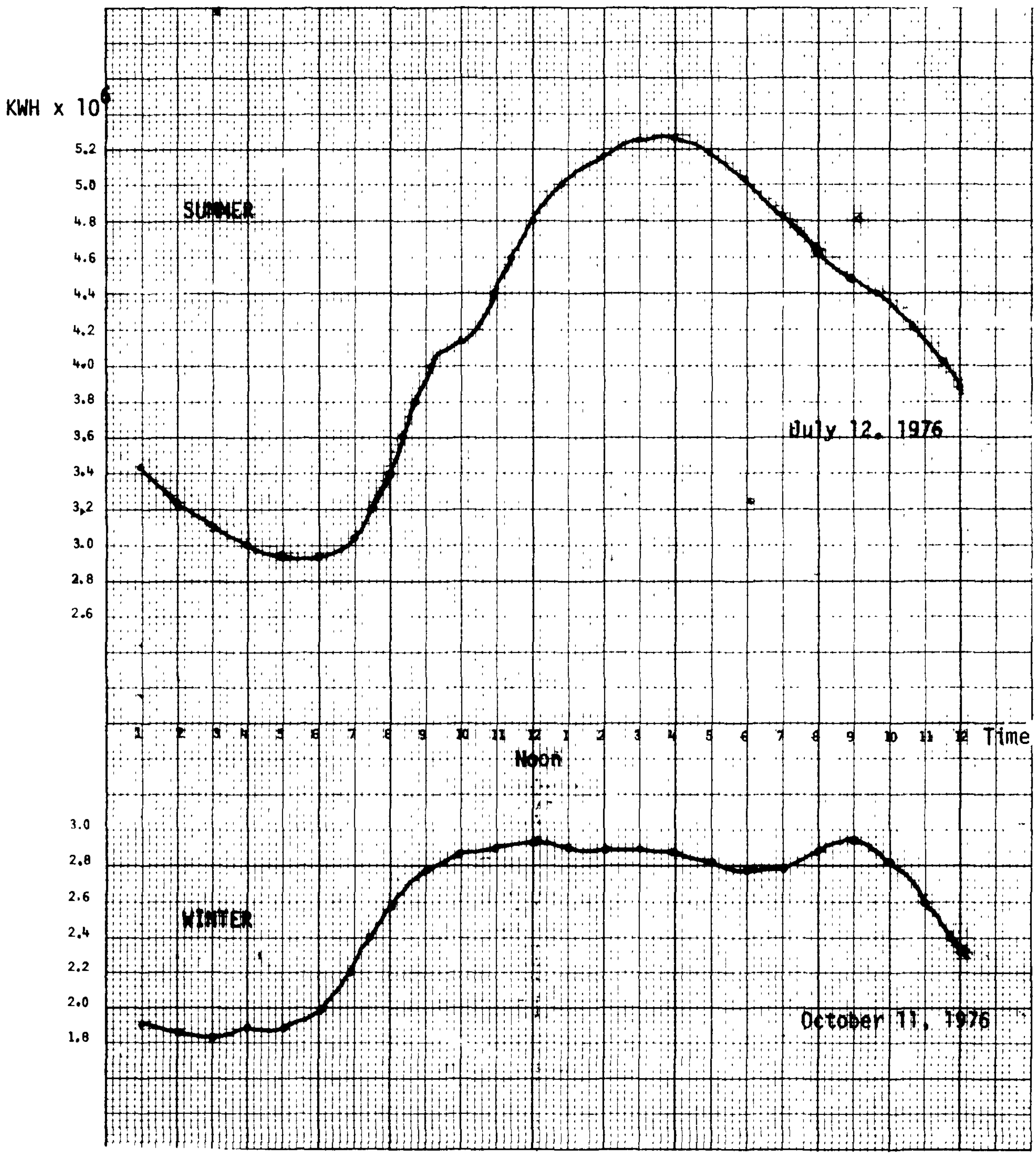

FIGURE 2 - TYPICAL DIURNAL DISTRIBUTION PATTERNS
OF ELECTRIC POWER PRODUCTION

TABLE 12 - ELECTRIC POWER CONSUMPTION - DIURNAL VARIATION

	SUMMER CONDITIONS (July 12, 1976)	WINTER CONDITIONS (October 11, 1976)
Hour	Coefficient	Coefficient
1	0.83	0.75
2	0.78	0.73
3	0.75	0.72
4	0.72	0.73
5	0.70	0.73
6	0.70	0.78
7	0.74	0.91
8	0.86	1.03
9	0.98	1.10
10	0.99	1.12
11	1.09	1.14
12	1.18	1.15
13	1.21	1.13
14	1.25	1.13
15	1.26	1.13
16	1.26	1.11
17	1.24	1.10
18	1.20	1.09
19	1.15	1.10
20	1.10	1.16
21	1.07	1.15
22	1.05	1.10
23	0.98	1.01
24	0.88	0.90

FIGURE 3 - "VEHICLE-KILOMETER-TRAVELED" (VKT) OUTPUT

GRID	FREEWAY	PRIN ARTERIAL	MIN ARTERIAL	AREA	TOTAL
135	42362.39	4308.86	5490.88	1818.83	53980.96
136	45384.67	45663.40	.00	8475.13	99523.20
140	.00	16325.55	.00	3030.02	19355.57
144	.00	15643.18	.00	2903.37	18546.55
145	.00	5375.67	.00	997.72	6373.39
150	.00	23627.79	.00	4385.32	28013.11
151	.00	20218.37	.00	3752.53	23970.90
156	.00	.00	29747.90	5521.21	35269.11
159	.00	.00	16192.99	3005.42	19198.41
160	59056.01	7993.71	7683.68	2909.72	77643.12
163	.00	44460.10	.00	8251.80	52711.90
180	.00	24440.09	.00	4536.08	28976.17
181	.00	25234.28	.00	4683.48	29917.76
182	.00	22519.17	.00	4179.56	26698.73
185	.00	23932.98	.00	4441.96	28374.94
189	89186.57	.00	.00	.00	89186.57
190	.00	115733.07	13709.92	24024.62	153467.61
191	.00	52924.72	74883.22	23721.15	151529.09
192	101290.01	40816.99	1734.11	7897.48	151738.59
195	.00	119128.27	.00	22110.21	141238.48
196	132406.42	.00	32775.06	6083.05	171264.53
213	.00	3050.37	.00	566.15	3616.52
215	.00	4246.32	.00	788.12	5034.44
216	.00	26411.23	.00	4901.92	31313.15
226	.00	8445.00	14410.99	4242.07	27098.06
227	.00	7500.00	14623.99	4106.21	26230.20
228	.00	94107.02	2150.91	17865.47	114123.40
229	.00	28313.22	27254.06	10313.29	65880.57
230	32242.96	38696.78	3742.72	7876.77	82559.23

TABLE 13 - HOURLY PERCENTAGES OF AVERAGE DAILY HIGHWAY VKT NORMALIZED TO ONE WEEK

Hour	Weekdays	Saturday	Sunday
1	2.02	3.48	3.48
2	1.35	3.48	2.90
3	.63	2.55	2.09
4	.34	.93	.58
5	.28	.93	.46
6	.77	1.16	.58
7	3.22	1.62	.70
8	6.78	2.43	.93
9	6.12	3.48	1.16
10	5.09	3.84	1.39
11	5.35	4.41	1.86
12	5.90	4.63	2.32
13	6.47	4.63	2.32
14	6.13	4.16	2.78
15	6.41	4.05	2.78
16	7.71	4.05	2.67
17	9.09	4.30	2.55
18	9.12	3.94	2.55
19	7.46	3.25	2.32
20	7.11	3.13	2.20
21	5.87	3.48	2.09
22	5.03	3.94	2.09
23	3.78	3.94	1.87
24	2.71	3.73	2.09
% Average Daily VKT	114.74	79.54	46.75

the VKT averages about 115% of the average value, on a Saturday 80% and a Sunday only 47%. A further breakdown into light duty gasoline engined vehicles, heavy duty gasoline engined vehicles and diesel engined vehicles is then applied. The ratio of these three types in the St. Louis AQCR is 93.4 percent light duty, 3.9 percent heavy duty gasoline and 2.7 percent heavy duty diesel (these ratios apply to VKT, not the number of vehicles). Thus, the final output is hourly VKT for three vehicle types. This number can be converted to hourly heat emissions:

$$\text{Heat emissions, } \left(\frac{\text{Btu}}{\text{hr}}\right) = \text{VKT} \left(\frac{\text{km}}{\text{hr}}\right) \times \frac{1}{\text{FC}\left(\frac{\text{km}}{\text{gal}}\right)} \times \text{HC} \left(\frac{\text{Btu}}{\text{gal}}\right)$$

where FC is fuel consumption in gallons per kilometer.

The average values for FC are: 21.9 km/gal - light duty
9.7 km/gal - heavy duty
7.4 km/gal - diesel

HC is the heat content of the fuel, which amounts to 125 x 10^3 Btu's per gallon of gasoline, 140 x 10^3 Btu's per gallon of diesel fuel.

4.3.2 Off-Highway Mobile Sources

This category includes a wide variety of sources powered by internal combustion engines. The following groups are considered: off-highway motorcycles, lawn and garden equipment, construction equipment, industrial equipment, farm equipment and outboard motorboats.

An inventory of pollutant emissions from these sources has been compiled as part of the RAPS emission inventory (7,8). County fuel consumption data are included in the referenced reports. These were converted to heat emissions, using 125 x 10^3 Btu/gal for gasoline and 140 x 10^3 Btu/gal for diesel fuel and are shown in Table 14.

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

TABLE 14 - HEAT EMISSIONS - OFF-HIGHWAY MOBILE SOURCES, BTU/YEAR

	MOTORCYCLES	LAWN & GARDEN	CONSTRUCTION	INDUSTRIAL	FARM	OUTBOARDS
St. Louis (County)	6.70×10^{9}	3.47×10^{11}	3.86×10^{12}	1.65×10^{12}	1.34×10^{11}	8.37×10^{11}
St. Louis (City)	3.13×10^{9}	1.21×10^{11}	2.53×10^{12}	2.39×10^{12}	0	2.13×10^{11}
St. Clair	2.18×10^{9}	1.02×10^{11}	9.83×10^{11}	2.97×10^{11}	4.44×10^{11}	1.06×10^{11}
Madison	2.64×10^{9}	9.71×10^{10}	8.62×10^{11}	3.31×10^{11}	5.28×10^{11}	1.13×10^{11}
Jefferson	1.30×10^{9}	4.09×10^{10}	4.28×10^{11}	3.17×10^{10}	1.50×10^{11}	1.55×10^{11}
St. Charles	1.41×10^{9}	2.34×10^{10}	3.78×10^{11}	2.95×10^{10}	3.16×10^{11}	1.43×10^{11}
Franklin	7.20×10^{8}	1.15×10^{10}	2.24×10^{11}	3.08×10^{10}	3.56×10^{11}	7.78×10^{10}
Clinton	3.10×10^{8}	7.96×10^{9}	9.77×10^{10}	1.31×10^{11}	3.62×10^{11}	1.56×10^{10}
Monroe	2.37×10^{8}	1.27×10^{10}	6.51×10^{10}	5.20×10^{10}	2.64×10^{11}	9.12×10^{10}
Randolph	4.30×10^{8}	6.65×10^{9}	1.08×10^{11}	2.39×10^{10}	3.47×10^{11}	2.03×10^{10}
Bond	2.17×10^{8}	6.65×10^{9}	4.83×10^{10}	1.05×10^{10}	2.35×10^{11}	6.74×10^{9}
Washington	1.29×10^{8}	7.18×10^{9}	4.75×10^{10}	7.87×10^{9}	3.62×10^{11}	6.44×10^{9}
AQCR TOTALS	0.02×10^{12}	0.78×10^{12}	9.63×10^{12}	4.99×10^{12}	3.50×10^{12}	1.79×10^{12}

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)	Outboard 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 obtain emissions per hour. County based emissions were distributed to the grid squares using factors worked out in Reference 8. The factors are shown in Table 15.

The total heat emissions for the AQCR from off-highway sources amounts to 20.7 X 12^{12} Btu per year, or about 12.9 percent of the emissions from all mobile sources.

4.3.3 Airport Emissions

The methodology and emission inventory for airport operations for the RAPS program are described in Reference 9.

Airport emissions result from aircraft operations, ground support vehicles, fuel storage and handling, and engine maintenance testing. Aircraft emissions depend on the operating modes (taxi, idle, loading, take-off, approach and climb-outs, the latter two limited to 3000 ft. altitutde), the time spent in each mode, and the emission rate for each mode. Emissions from ground vehicle operations are directly related to the landing and take-off volume and the aircraft mix. Engine testing emissions were not included in the inventory; fuel storage and handling are of no interest to the heat emission inventory.

The resultant emissions are calculated by a subprogram which calculates emissions for the criteria pollutants for each affected grid square on an hourly basis. The sulfur dioxide (SO_2) emissions are directly proportional to the amount of fuel burned and hence to heat emissions. Based on an

TABLE 15 - METHODS OF APPORTIONING COUNTY HEAT EMISSIONS TO GRID SQUARES

Motorcycles

$$\text{Grid Element Emissions} = \text{County Emissions} \times \frac{\text{Grid Population}}{\text{County Population}}$$

Lawn and Garden

$$\text{Grid Element Emissions} = \text{County Emissions} \times \frac{\text{Grid One-Unit Structures}}{\text{County One-Unit Structures}}$$

Construction

$$\text{Grid Element Emissions} = \text{County Emissions} \times \frac{\text{Grid Construction Acreage}}{\text{County Construction Acreage}}$$

Industrial

$$\text{Grid Element Emissions} = \text{County Emissions} \times \frac{\text{Grid Industrial Plants}}{\text{County Industrial Plants}}$$

Farm

$$\text{Grid Element Emissions} = \text{County Emissions} \times \frac{\text{Grid Farm Acreage}}{\text{County Farm Acreage}}$$

Outboards

$$\text{Grid Element Emissions} = \text{County Emissions} \times \frac{\text{Grid Surface Water}}{\text{County Surface Water}}$$

assumed sulfur content of 0.05 percent, a heat content of 140 x 10^3 Btu/gal, and a volume to weight factor of 2.8 kg/gal, the calculation becomes:

Heat emissions, Btu x 10^6 = 50 x SO_2 (kg)

Since the airport program calculates pollutant emissions on an hourly basis for the 48 grid squares affected by airport operations, heat emissions will also be available on an hourly basis.

The total annual heat emissions from airport operations were calculated to be about 2.2 x 10^{12} Btu, about 0.5 percent of all area heat emissions. In Table 16 these emissions are included under "gasoline".

4.3.4 Railroad Operations

The methodology and emission inventory from rail operations are described for the RAPS program in Reference 10. Based on calculated fuel usage for each engine type, emissions of the criteria pollutants are reported for each affected grid square. Total fuel used per grid square is also reported, making it possible to calculate heat emissions per grid square:

Heat emissions, Btu x 10^6 = fuel usage (gal) x 0.140

The total amount of fuel used by railroads has been calculated to be 70,070,000 gal annually, corresponding to 9.8 x 10^{12} Btu, or about 2.4 percent of the total area heat emissions.

4.3.5 River Vessels

A methodology and inventory of air pollution from river vessels was developed for RAPS (11). This study gives an estimate of river towboat air pollution emissions for the St. Louis Air Pollution Study area. No emissions from secondary sources or from recreational boating on the river of other areas are considered. The emission estimate is based primarily on river traffic data taken by the Corps of Engineers at Lock 27 near St. Louis and on exhaust emission factors of similar engines of the Coast Guard fleet and railroad locomotives. Emissions are assigned to appropriate grid squares. River traffic on the Mississippi was considered on a year-round basis, on the Missouri for March through November, as this river is normally closed to navigation from the beginning of December to the first of March.

Fuel consumption values are not given in this report, but can be back-calculated from SO_2 emissions, which are reported as grams per day per grid square.

At an assumed sulfur content of 0.20 percent and a density of 7.12 pounds per gallon for diesel fuel, each gram of SO_2 corresponds to 0.077 gallons or 10.84×10^3 Btu.

Total annual heat emissions from river vessel traffic is estimated at 4.54×10^{12} Btu, or about one percent of all area sources.

5.0 SUMMARY

Heat emissions from an urban area, such as the St. Louis AQCR, are associated with fuel and power consumption and occur in two forms: concentrated plumes from point sources (stacks) and diffuse emission from area sources. Point source data are located geographically by UTM coordinates, while area sources are distributed over 1989 grid squares. Since the primary end use of heat emission data is modeling and most models require hourly inputs, all data are reported on hourly values. These values are based either on measured parameters, as is the case with most major combustion sources, or on a calculated distribution based on appropriate parameters, such as work patterns, traffic patterns, diurnal temperature changes, etc.

Heat emissions from point sources are relatively straightforward to deal with. They consist of that fraction of the heat content of the fuel which is not transferred to the process or product and is carried off by the stack gases. They can be calculated by applying a heat emission factor (HEM) to the amount of fuel consumed. Since the RAPS point source emission inventory is based on hourly fuel consumption records, heat emission calculations parallel those for other pollutants; e.g., SO_2. Point source heat emissions account for only a small fraction of the total heat emissions for the area, about 12 percent.

Heat emissions from stationary area sources include the heat released by residential and commercial space heating, industrial process heat, and the heat resulting from the use of electric power. Basic data for these categories are available only on an annual basis. The annual values were broken down to hourly data by the application of appropriate distribution patterns. Distribution to grid squares was achieved on the basis of applicable parameters, such as population density, number of single dwellings, average power consumption per household, etc. This category accounts for a large fraction of the total heat release--57 percent.

Heat emissions from highway vehicles were calculated from traffic distribution patterns. The pattern expressed in vehicle miles per grid squares is generated by the Mobile Source Emissions inventory program developed for the RAPS program. Using average fuel consumption values for each class of vehicle, heat emissions were calculated directly. Table 16 presents an overall summary of heat emissions in the St. Louis area (AQCR 70).

TABLE 16 - SUMMARY OF HEAT EMISSIONS IN AQCR 70, 10^{12} BTU

	Coal	Res. Oil	Dist. Oil	Nat. Gas	Electricity	Gasoline	Diesel Fuel	LPG	Totals
Point Sources	42	4	3	12	--	--	--	--	61
Stationary Area Sources									
Residential	2	--	13	87	24	--	--	38	
Commercial	2	--	11	44	7	--	--	--	
Industrial	8	4	6	31	37	--	--	--	
TOTAL									314
Mobile Sources									
Highway Vehicles	--	--	--	--	--	115	8	--	
Off-Highway Vehicles	--	--	--	--	--	7	14	--	
Airport	--	--	--	--	--	2	--	--	
Railroads	--	--	--	--	--	--	9	--	
Vessels	--	--	--	--	--	--	5	--	
TOTAL									160
GRAND TOTAL	54	8	33	174	68	124	36	38	535

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16. ABSTRACT

As part of the St. Louis Regional Air Pollution Study (RAPS), a heat emission inventory has been assembled. Heat emissions to the atmosphere originate, directly or indirectly, from the combustion of fossil fuels (there are no nuclear plants in the St. Louis AQCR). With the exception of a small amount of energy radiated into space as light, and the energy carried out of the AQCR by cooling water (primarily the Mississippi River), all of the energy released by the combustion of fuels is sooner or later released to the atmosphere as heat, either at the point of production (the power stations) or where it is consumed.

This report deals with heat emsssions from point sources as well as area sources. Heat emissions from point sources account for about 11 percent in the AQCR. Point source emissions are, however, in the form of concentrated plumes, while other heat emissions are diffused. Thus, the meteorological dispersion behavior of these sources is likely to be quite different.

17. KEY WORDS AND DOCUMENT ANALYSIS

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