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AIR POLLUTANT EMISSION FACTORS

April 1970

Prepared for

Department of Health, Education and Welfare
Public Health Service
Environmental Health Service
National Air Pollution Control Administration
Washington, D. C.

TRW
SYSTEMS GROUP OF TRW INC.

This report contains an updating of selected existing emission factors in addition to twenty new factors compiled for the National Air Pollution Control Administration, Division of Air Quality and Emission Data, under contract CPA-22-69-119.

1. INTRODUCTION

This report represents a compilation of the latest atmospheric emission data available for a wide variety of selected processes. One-half of the 40 processes discussed in this report involve an updating or review of existing emission factors presented in Public Health Service Publication 999-AP-42, "A Compilation of Air Pollutant Emission Factors" by R.L. Duprey. The remaining factors represent new processes for which emission factors were not previously reported. All emission factors refer to uncontrolled processes unless otherwise stated.

Information for emission factors was gathered primarily from the technical literature up to November 1969, state and local air pollution control agencies, trade and professional associations, releasable portions of data obtained by TRW in various past studies, and individual companies and persons within the various industries under study. In all cases, attempts were made to obtain some idea of the validity of the information obtained, and thus place each bit of data relative to other data in the same area. Greatest weight was given to actual measured emission data, i.e., source tests, especially when the measuring technique was known. Estimates of emissions were also made when feasible by making material balances and process loss or yield calculations.

In general, it was found that except for the combustion and incineration fields, very little new emission factor data has been made public since Duprey's work in 1967. In the metallurgical and mineral industries, additional emission data has been obtained by various companies and control equipment manufacturers. This information has not been made public, however. Some emission data was available for most of the new factors developed in this report. Frequently, however, these data were in the form of concentrations only, not quantitative emission rates. Process weight rates were also frequently not given or reported. Considerable engineering calculations were thus required in order to put these data into a form usable for emission factors. These calculations, based on material balances, combustion reactions, humidity balances, and comparisons with similar processes with available emission data, allowed one to relate the reported data with process throughputs and develop a factor which is usable until better data are made available.

Detailed information used to obtain the emission factors is generally presented in an appendix to each section. Selection of a final emission factor depended on the amount and range of data available. Where considerable data existed a direct arithmetic average was used. Values on order of magnitude greater or less than the bulk of the data were not considered in determining the arithmetic average. Where limited data were available (1 to 5 values) and the values covered a wide range, the selected factor was based on our best judgment considering the factors affecting emissions. Whenever possible, the range or variation in emission factors was reported and shown in parenthesis following the factor. This range represents the range of values used in obtaining the factor and represents the expected variation in emissions. A lack of information sometimes prevented the reporting of a reasonable factor range.

Standard statistical deviations of the emission factors were not generally reported since insufficient or only widely scattered data were available and a significant deviation could not be calculated.

All emission factors in this report were ranked according to the available data upon which they were based. A system which weighted various information categories was used to rank the final factors. These categories were: measured emission data with a total possible weight of 20, process data with a weight of 10, and engineering analysis with a weight of 10. The highest possible score for any factor was thus 40. Any factor ranking less than 20 was considered questionable and those ranked 20 or greater were considered reliable.

The emission data category rated the amount of measured emission data, i.e., stack test data available with which to develop an emission factor.

The process data category included such factors as the variability of the process and its effect on emissions, and available data on the variables. The engineering analysis category included the data available upon which a material balance or related emission calculation could be based.

The range of values for many emission factors is large. However, when the factors are applied to a large number of sources, the calculated overall emissions should approximate the true value. When applied to a single isolated source, an emission factor may yield emissions that differ considerably from the true value. Measured emission data should therefore be used, if possible, for single sources.

2. STATIONARY FUEL COMBUSTION

Particulate emissions from most types of stationary fuel combustion sources have been the subject of considerable research. However, emissions from the combustion of some of the less common fuels have not been determined to any great extent, nor have gaseous emissions been studied in any great depth. This section concentrates on some of these areas, and further quantifies some of these emissions.

Emissions from all types of fuel combustion are highly dependent on the efficiency of combustion and type of fuel. The resulting emission factors therefore cover a wide range.

Data used to determine the emission factors presented in this section were largely based on measured values or by comparison with similar combustion processes.

Anthracite coal combustion yielded the following approximate particle size breakdown (% by weight, size by microns).

Particle Size	>44	20-44	10-20	5-10	<5
% in Range	45	7	8	5	35

No particle size data was found for wood combustion emissions, the only other particulate source investigated in this section.

2.2 BITUMINOUS COAL COMBUSTION - GASEOUS EMISSIONS

General

Coal is the most plentiful fuel in the United States, and is burned in a wide variety of furnaces to produce heat and steam. Coal-fired furnaces range in size from small hand-fired units with capacities of 10-20 pounds of coal per hour to large pulverized coal-fired units which burn 300-400 tons of coal per hour.

Although predominantly carbon, coal contains many compounds in varying amounts. The exact nature and quantity of these compounds is determined by the source of the coal and will usually affect the final use of the coal.

Particulate and sulfur oxide emissions from coal combustion have received considerable attention, but the other gaseous emissions which are less noticeable have not been the subject of intensive investigations.

Emissions of gaseous hydrocarbons, carbon monoxide and nitrogen oxides are currently not reduced by using control equipment. They can, however, be reduced by optimum adjustment of combustion conditions as discussed in the next section.

Factors Affecting Emissions

The carbon monoxide and hydrocarbon content of the gases emitted from bituminous coal combustion depend mainly on the efficiency of combustion. Complete combustion and a low level of gaseous carbon and organic emissions involves a high degree of turbulence, high temperatures, and sufficient time for the combustion reaction to take place. Thus, careful control of excess air rates, high combustion temperature, and intimate fuel-air contact will minimize these emissions.

Since the larger furnaces are usually better equipped to control air and fuel feed rates, they have lower gaseous emission rates. Smaller furnaces, both manual and stoker-fired, have less control over air and fuel rates and combustion temperatures, and produce higher emissions. Composition of the bituminous coal does not apparently have any significant effect on these emissions.

Emissions of nitrogen oxides result primarily from the high temperature reaction of atmospheric nitrogen and oxygen in the combustion zone. The main factors affecting these emissions are furnace temperature, residence time in the furnace, and the rate of gas cooling. Generally, larger more efficient combustion units yield higher nitrogen oxide emissions. The practice of preheating combustion air at large boilers is considered a significant reason for the resultant higher NO_x release.

Since some of the factors affecting gaseous emissions such as combustion temperatures or excess air rates are frequently not readily apparent to the operator, the emissions of these compounds tend to vary over a wide range. Reported CO and hydrocarbon emissions vary 3 to 4 orders of magnitude among smaller combustion sources. (See Appendix).

Emissions

Selected gaseous emissions from bituminous coal combustion are presented in Table 2.2-1. The size range in Btu per hour for the various categories is shown only as a guide in applying these factors and cannot be used as a clear demarcation between furnace applications. The actual values selected are based on engineering judgment and on knowledge and involvement with most of the tests.

Due to their higher firebox temperatures, cyclone-fired furnaces and other types of wet bottom burnaces produce greater concentrations of nitrogen oxides. However, longer residence time in the conventional wet bottom furnace appears to reduce concentrations again by causing decomposition of the oxide.[4]

Table 2.2-1. Selected Gaseous Emissions from Bituminous Coal Combustion.

Lbs/ton of Coal Burned

Furnace Size, 10^6 Btu/hr heat input	NO_x[a]	CO	HC[b]
1. Greater than 100 - utility and large industrial boilers			
General-dry bottom	18	1 (0.1-3)	0.25 (.11-1)
Cyclone Furnaces	55	1 (0.1-3)	0.25 (.11-1)
2. 10 to 100			
large commercial and general industrial boilers, stoker-fired	15	1.5 (1-3)	1 (0.2-20)
3. Less than 10			
stoker-fired commercial and domestic furnaces	6	10 (4.5-31)	2.5 (1-3.3)
4. Hand-fired Units	3	90	20

a) Expressed as NO_2. The equation, log NO_x = 1.165 log (hourly heat input) - 7.6081, represents NO_x emissions from dry bottom pulverized and stoker fired units and can be used to estimate hourly NO_x emissions.

b) Expressed as methane.

Carbon monoxide and hydrocarbons are generally emitted at concentrations of 5-50 ppm under normal combustion conditions in stoker-fired units.

Nitrogen oxides are mainly emitted as nitric oxide (NO) at concentrations of about 100 to 500 ppm, except for the large cyclone-fired units which emit concentrations in the range of 700 to 1200 ppm.[4] Relationships between Btu input and hourly emission of NO_x may be found in the literature.[9, 10] For larger combustion sources, an empirical relationship which expresses NO_x emissions in terms of heat input would probably be more accurate than using a general emission factor. Based on emission data available for this review (excluding cyclone furnaces), the equation:

$$\log NO_x = 1.165 (\log \text{heat input}) - 7.608$$

was derived. This equation gives the NO_x emissions in lbs/hr when the hourly heat input is known. Figure 2.2-1 shows this relationship.

Reliability of Emission Factors

Gaseous emissions from bituminous coal combustion vary widely since they are affected by many variables some of which are not easily controlled. Thus, emissions even from the same furnace will vary from day to day since only a small change in the efficiency of combustion can greatly affect carbon monoxide and hydrocarbon emissions. It must be realized, that these pollutants are only emitted in ppm quantities, and they are not easily measured with a great degree of accuracy.

Nitrogen oxide emissions are also affected by many variables and thus cover a wide range. However, these emission data correlate well with furnace size and are representative of the true emission.

Table 2.2-2 ranks the emission factors and indicates that they are fairly reliable.

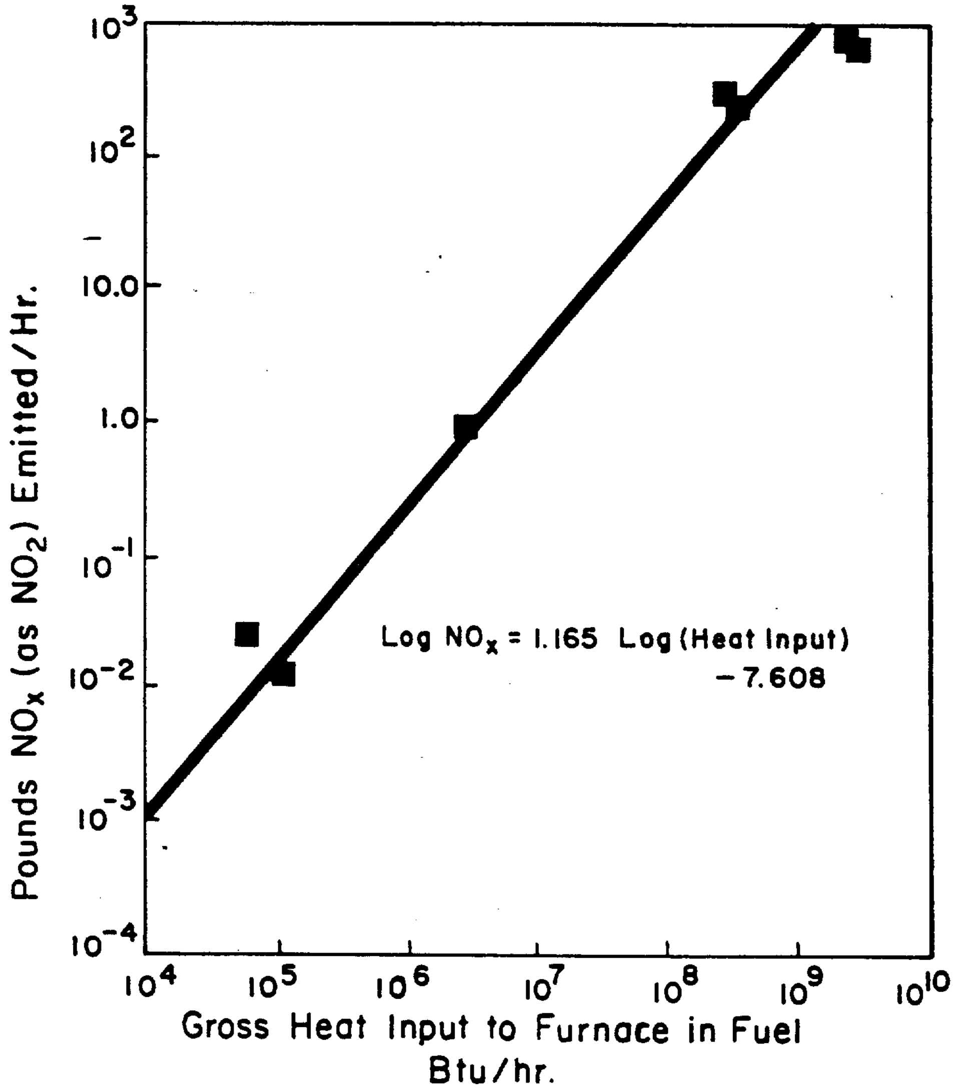

Figure 2.2-1. Nitrogen Oxide Emissions from Dry Bottom Pulverized, and Stoker-Fired Bituminous Coal Burning Furnaces.

Table 2.2-2. Gaseous Emission Factor Ranking for Bituminous Coal

	Emission Data 0-20	Process Data 0-10	Engineering Analysis 0-10	Total
NO_x	12	7	8	27
CO	10	7	5	22
HC	10	7	5	22

APPENDIX 2.2

A. NITROGEN OXIDE EMISSIONS

1. Furnaces larger than 100 x 10^6 Btu/hr heat input
   Large Industrial and Public Utility Sizes

Full Load Tests

Pulverized Coal - Dry bottom

	lbs/10^6Btu	lbs/ton Coal	Reference
	0.55	13.0	4
	0.71	17.1	4
	0.95	24.8	4
Avg.	0.74	18.3	

Cyclone-Fired

2.2	61	4

Other Firing Methods, Stokers, etc.

0.76	19.2	4
0.59	15.6 - wet bottom furnace	4

Partial Load Tests

Pulverized Coal - Dry bottom

	lbs/10^6Btu	lbs/ton Coal	
	0.31	7.3	4
	0.51	13.7	4
	0.74	19.3	4
Avg.	0.52	13.4	

$lbs/10^6$ Btu	lbs/ton	Reference
Cyclone-Fired		
1.8	55	4
Other Firing Methods		
0.68	17.2	4
0.56	14.8 - wet bottom furnace	4
Data not designating load or type of unit		
0.17 to 2.5	4.1 - 60	5
0.12 to 2.4[a]	3 - 20	1
2.3[a]	19.2	2,3

A value of 18 lbs/ton was chosen for dry bottom units, and 55 for cyclone units.

2. Furnaces in the 10 to 100 x 10^6 Btu/hr heat input range.
Large Commercial and General Industrial Sizes; Underfeed or Overfeed Stokers

$lb/10^6$Btu	lbs/ton	Reference
-	20 (estimate)	6,7
0.8	19.2	2,3

Note, Oil-fired units in this size range emit 12-17 lbs NO_x/ton.

Factor chosen based on data for both larger and smaller sized units and on relationship in Figure 2.2-1, was 15 lbs. NO_x/ton coal.

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a) Based on 25 million Btu per ton of coal.

3. Furnaces less than 10 x 10^6 Btu/hr heat input stoker-fired including residential.

lbs/10^6Btu	lbs/ton fuel	Reference
0.30	8.3	9
0.36	9.8	9
	0.4	7
–	0.5	8
Hand-Fired Units		
0.11	3.2	9

Factor chosen was 6 and 3 lbs/ton of fuel respectively for small stokers and hand-fired units.

B. CARBON MONOXIDE AND HYDROCARBON EMISSIONS

1. Furnaces larger than 100 x 10^6 Btu/hr heat input

	CO		HC^a		Reference
	lbs/10^6Btu	lbs/ton	lbs/10^6Btu	lbs/ton	
	PULVERIZED COAL				
	0.017	0.41	0.013	0.32	3,4
	0.011	0.26	0.005	0.13	3,4
	0.005	0.13	0.013	0.35	3,4
	0.10	2.8	0.004	0.11	9
	0.044	1.16	0.001	0.35	3,4
Avg.	0.035	0.95	0.007	0.25	
Other Data	-	0.1 - 0.6	-	0.34 - 1.25	1[c]
	STOKER-FIRED				
	0.029	0.73	0.012	0.31	3,4
	0.51	12	0.005	0.11	9[b]
Value chosen for factor					
		1		0.25	

a) Expressed as methane. Data from reference 3 & 4 converted from carbon to methane by multiplying by 16/12.

b) Old unit without modern combustion controls.

c) Data from reference one converted from hexane to methane.

2. Furnaces in the 10 x 10^6 to 100 x 10^6 Btu/hr heat input range.

CO		HC		Reference
lbs/10^6Btu	lbs/ton	lbs/10^6Btu	lbs/ton	
0.1	3	0.0045	0.16	9
-	1	-	20	6
-	-	-	14 - 26	7

Since very limited and scattered data are available for furnaces in the 10 x 10^6 to 100 x 10^6 Btu/hr heat input range, the final CO and HC factor was chosen by picking values between the factors for the larger and smaller stoker-fired units and not on the values reported above. Values chosen were 1.5 lbs/ton for CO and 1 for HC.

3. Furnaces less than 10 x 10^6 Btu/hr heat input.

	CO		HC		Reference
	lbs/10^6Btu	lbs/ton	lbs/10^6Btu	lbs/ton	
	STOKER-FIRED				
	0.16	4.5	0.116	3.2	9
	0.14	3.9	0.036	1.0	9
	1.1	31	0.12	3.3	9
Avg.	0.47	13.1	0.095	2.5	
Value chosen		10		2.5	
	HAND-FIRED				
	3.5	99	0.73	21	9

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