EPA-450/3-76-018-a

April 1977

DETERMINING INPUT VARIABLES FOR CALCULATION OF IMPACT OF NEW SOURCE PERFORMANCE STANDARDS: WORKSHEETS FOR STATIONARY COMBUSTION SOURCES

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

EPA-450/3-76-018-a

DETERMINING INPUT VARIABLES FOR CALCULATION OF IMPACT OF NEW SOURCE PERFORMANCE STANDARDS: WORKSHEETS FOR STATIONARY COMBUSTION SOURCES

by

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
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FOREWORD

During 1974, two studies were initiated that ultimately resulted in the establishment of priorities for developing and promulgating New Source Performance Standards (NSPS). The procedures used to determine these priorities produced a great deal of information that is believed to be useful in the industries involved and, accordingly, is being published in this series of reports (EPA-450/3-76-017, EPA-450/3-76-018, EPA-450/3-76-019, and EPA-450/3-76-020). This information is organized as follows:

EPA-450/3-76-017 discusses (1) the mathematical model (Model IV) used to determine NSPS impacts over a 10-year period; (2) the methods used to attain input variables; and (3) the summary tables which are the heart of this study. Included in the summary tables are data related to (1) emission, growth, and replacement rates; (2) present and future production and capacity; (3) nationwide emissions; and (4) NSPS impact. These tables include information on 13 pollutants and nearly 200 stationary source categories.

EPA-450/3-3-76-018-a, -b, -c, -d, -e, and -f are the calculation sheets, showing how the input variables reported in EPA-450/3-76-017 were derived. All information sources, assumptions, and calculations are documented and explained. The appropriate worksheets are arranged alphabetically in the following volumes:

018-a - Stationary Combustion Sources

018-b - Chemical Processing Industries

018-c - Food and Agricultural Industries

018-d - Mineral Products Industries

018-e - Metallurgical Industries

018-f - Miscellaneous Sources (Evaporation Losses, Petroleum Industry, Wood Products Industry, and Assembly Plants

The 018-a -f series is of interest only to those concerned with the detailed calculations used to determine the Model IV input variables.

EPA-450/3-76-019-a provides additional results and information produced during the priority study. Its major purpose is to describe the computer program used to rank all the Model IV input and output variables by pollutant (these rankings are reported in 019-b and -c). In addition, it contains (1) summaries of the control systems considered "best" for each source, (2) equipment retirement ages, and (3) emission trends for each source category.

EPA-450/3-76-019-b and c present the computer-generated ranked data for each pollutant. Ranking is from highest to lowest for each of the 21 variables, e.g., A (nationwide capacity) and Eu (uncontrolled emission rate). Volume 019-b contains ranked data for particulate, nitrogen oxide (NO_x), and sulfur oxide (SO_x) sources. In Volume 019-c, the remaining pollutant sources are ranked: hydrocarbons, carbon monoxide (CO), fluorides, hazardous material, acid mist, lead, ammonia, sulfides, chlorine, and trace metals.

EPA-450/3-76-020, the final document in this series, takes the objective impact values from EPA-450/3-76-017, adds subjective judgements, and uses these combined criteria to produce a priority list for NSPS development. The report then calculates nationwide emission trends over the next 15 years for each criteria pollutant (particulate, SO_x, NO_x, hydrocarbons, and CO) based on a series of scenarios (e.g., no NSPS, 20 NSPS per year, etc.)

In summary, documents EPA-450/3-76-017 and 020 present the results of this study. Each stands alone, but they also complement each other, with 020 building on the results of 017. The remaining documents (018-a -f and 019-a -c) present additional and/or more detailed information derived from the impact and priority studies.

DETERMINATION OF INPUT VARIABLES
FOR
STATIONARY COMBUSTION SOURCES

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Industrial Factors

Calculations Done By HOARER Date 9/19/74

Source Fossil Fuel Boilers

Boiler Type	Typical Rated Capacity Range #steam/hr	Source Class 10^6 BTU	Total Capacity 10^6 #steam/hr (1)		
			1967	1975	1985
Residential		<0.3	2117	2877	3844
Cast Iron	650 - 8000 (3)	0.3 - 10.0	757	985	1330
Firetube	420 - 25000 (3)	0.3 - 10.0	813	1365	2255
Watertube-1	10,000 - 100,000 (2)	10 - 250	921	1045	1201
Watertube-2	100,001 - 250,000 (2)	10 - 250	658	700	810
Watertube-3	250,001 - 500,000 (2)	>250	259	286	276
Watertube-4	>500,000 (2)	0	?	2564	4663

(1) Ref (73) p16 Tab 1-5.
(2) Ref (73) p16 Tab 1-5
(3) Ref (22) p1-1

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/19/74

Source Fossil Fuel Boilers

DETERMINATION OF K

"K" WILL BE DEFINED AS FOLLOWS

$$K = \sum_{\text{various fuels}} \frac{\left[\text{HEAT INPUT (BTU)}\right]}{\left[\frac{\text{BTU}}{\text{\# STEAM}}\right]} \times \frac{1}{\left[\text{CAPACITY}\right] \frac{\text{\# STEAM}}{\text{HR}} \times \left[8760 \frac{\text{HRS}}{\text{YR}}\right]}$$

for EACH BOILER type

$$\left(\frac{\text{BTU}}{\text{\# STEAM}}\right) = \frac{975 \frac{\text{BTU}}{\#}}{\eta_{\text{BOILER}}}$$

① The value of BTU/# steam will differ for each fuel type within A given BOILER CATEGORY.

② REF (73) p A-4, A-5 for 975 value

RESIDENTIAL

REF (73) p 5 TAB 1-1 gives 1967 Capacity & Fuel Usage data. Capacity is presented on p, of this analysis.

355×10^6 BBls DISTILLATE OIL
3.15×10^{12} FT^3 GAS

$\eta_{\text{RESIDENTIAL}} = 100\%$ BECAUSE CAPACITY DATA IS BASED ON INPUT, NOT OUTPUT REF (73) pA-15

HEATING VALUES - REF (22) p4-2 TAB 4-1

DISTILLATE oil - 5.817×10^6 BTU/BBL
GAS - 1040 BTU/FT^3

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Computation Sheet For Industrial Factors

Calculations Done By Hoaker Date 9/19/74

Source Fossil Fuel Boilers

$$K_{RES} = \frac{(355\times10^6)(5.817\times10^6) + (3.15\times10^{12})(1040)}{(2117\times10^6)(975)(8760)} = \frac{(20.65 + 32.76)\times10^{14}}{(2117\times10^6)(975)(8760)}$$

$$K_{\text{RESI-DENTAL}} = 0.30$$

CAST IRON

REF (73) p 5 TAB 1-1 gives 1967 capacity & fuel usage data. Capacity is presented on p1 of this analysis.

11×10^6 tons coal	EFFICIENCIES PER REF (73) p A-16 TAB A-3
56×10^6 BBLS RES. OIL	COAL - 70%
37×10^6 BBLS DIST OIL	RO - 80%
1.03×10^{12} FT3 GAS	DO - 80%
	GAS - 77%

Heating values - REF (22) p4-2 TAB 4-1

Dist oil & Gas have already been stated

Res. oil - 6.384×10^6 BTU/BBL

Coal - 26.2×10^6 BTU/TON

$$K_{\text{CAST IRON}} = \frac{\frac{(11\times10^6)(26.2\times10^6)}{\frac{(975)}{0.7}} + \frac{(56\times10^6)(6.384\times10^6)}{\frac{(975)}{0.8}} + \frac{(37\times10^6)(5.817\times10^6)}{\frac{(975)}{0.80}} + \frac{(1.03\times10^{12})(1040)}{\frac{(975)}{0.77}}}{(757\times10^6)(8760)}$$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/19/74

Source Fossil Fuel Boilers

$$K = \frac{2.069\times10^{11} + 2.933\times10^{11} + 1.766\times10^{11} + 8.460\times10^{11}}{(757\times10^{6})(8760)} = 0.23$$

$$K_{\substack{CAST\\IRON}} = 0.23$$

Firetube

From Ref (73) p5 Tab 1-1

11×10^{6} tons coal
98×10^{6} BBLS RO
69×10^{6} BBLS DO
1.12×10^{2} FT^3 gas

Efficiencies per Ref (73) PA-16, Tab A-3

Coal - 70%
RO - 77%
DO - 77%
Gas - 75%

$$K_{\substack{FIRE\\TUBE}} = \frac{\dfrac{(11\times10^{6})(26.2\times10^{6})/(975)}{0.7} + \dfrac{(98\times10^{6})(6.384\times10^{6})/(975)}{0.77} + \dfrac{(69\times10^{6})(5.817\times10^{6})/(975)}{0.77} + \dfrac{(1.12\times10^{12})(1040)/(975)}{0.75}}{(813\times10^{6})(8760)}$$

$$= \frac{2.069\times10^{11} + 4.941\times10^{11} + 3.170\times10^{11} + 8.96\times10^{11}}{(813\times10^{6})(8760)} = 0.27$$

$$K_{\substack{FIRE\\TUBE}} = 0.27$$

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Computation Sheet For Industrial Factors

Calculations Done By Hagar Date 9/20/74

Source Boilers

WATERTUBE - TYPES 1,2,3

FROM REF (73) p5 TAB A-1

132×10^6 TONS COAL
194×10^6 BBLS RO
14×10^6 BBLS DO
1.72×10^{12} FT³ GAS

EFFICIENCIES PER REF (73) p A-16 TAB A-3

	(1)	(2)	(3)
COAL –	77%	83%	89%
RO –	75%	80%	87%
DO –	75%	80%	87%
GAS –	70%	76%	81%

IF ALL UNITS WERE TYPE 1, THEN

$$K_{WT_1} = \frac{\dfrac{\frac{(132\times10^6)(26.2\times10^6)}{(975)}}{.77} + \dfrac{\frac{(194\times10^6)(6.384\times10^6)}{(975)}}{.75} + \dfrac{\frac{(14\times10^6)(5.817\times10^6)}{(975)}}{.75} + \dfrac{\frac{(1.72\times10^{12})(1040)}{(975)}}{.70}}{(1838\times10^6)(8760)}$$

$$K_{WT_1} = \frac{2.731\times10^{12} + .9527\times10^{12} + 6.264\times10^{10} + 1.28\times10^{12}}{(1838)\times10^6\,(8760)} = 0.31$$

$$K_{WT_1} = 0.31$$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/20/74

Source Boilers

IF ALL UNITS WERE TYPE 2, THEN

$$K_{WT_2} = \frac{\dfrac{\frac{(132\times10^6)(26.2\times10^6)}{(975)}}{.83} + \dfrac{\frac{(194\times10^6)(6.384\times10^6)}{(975)}}{.80} + \dfrac{\frac{(14\times10^6)(5.817\times10^6)}{(975)}}{.80} + \dfrac{\frac{(1.72\times10^{12})(1040)}{(975)}}{.76}}{(1838\times10^6)(8760)}$$

$$= \frac{2.944\times10^{12} + 1.016\times10^{12} + 6.682\times10^{10} + 1.394\times10^{12}}{(1838\times10^6)(8760)} = 0.34$$

$$K_{WT_2} = 0.34$$

IF ALL UNITS WERE TYPE 3, THEN

$$K_{WT_3} = \frac{\dfrac{\frac{(132\times10^6)(26.2\times10^6)}{(975)}}{(.89)} + \dfrac{\frac{(194\times10^6)(6.384\times10^6)}{(975)}}{.87} + \dfrac{\frac{(14\times10^6)(5.817\times10^6)}{(975)}}{.87} + \dfrac{\frac{(1.72\times10^{12})(1040)}{(975)}}{.81}}{(1838\times10^6)(8760)}$$

$$= \frac{3.157\times10^{12} + 1.105\times10^{12} + 7.267\times10^{10} + 1.486\times10^{12}}{(1838\times10^6)(8760)} = 0.36$$

$$K_{WT_3} = .36$$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/20/74

Source Boilers

To determine K for type 4 units, use data from ref (73) p5 Tab 1-1 for utility boilers, which, as a general rule, are in this size category

COAL - 271×10^6 TONS
RO - 156×10^6 BBLS
DO - 2×10^6 BBLS
GAS - 2.76×10^{12} FT^3

CAP 1967 = 1800×10^6 PPH STEAM

Efficiencies per ref (73) pA-16 TAB A-3

COAL — 90%
RO — 88%
DO — 88%
GAS — 81%

$$K_{WT_4} = \frac{\dfrac{(271\times10^6)(26.2\times10^6)}{\frac{(975)}{.90}} + \dfrac{(156\times10^6)(6.384\times10^6)}{\frac{(975)}{.88}} + \dfrac{(2\times10^6)(5.817\times10^6)}{\frac{(975)}{.88}} + \dfrac{(2.76\times10^{12})(1040)}{\frac{(975)}{.81}}}{(1800\times10^6)(8760)}$$

$$= \frac{6.55\times10^{12} + (8.989\times10^{11}) + 1.050\times10^{10} + 2.385\times10^{12}}{(1800\times10^6)(8760)} = 0.62$$

$$K_{WT_4} = 0.62$$

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Computation Sheet For Industrial Factors

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Source Fossil Fuel Boilers

$$K_{<0.3} = 0.30$$

$$K_{0.3-10.0} = \left(\frac{757}{757+813}\right)(0.23) + \left(\frac{813}{757+813}\right)(0.27)$$

$$= 0.1109 + 0.1398 = 0.251$$

$$K_{0.3-10.0} = 0.25$$

$$K_{10-250} = \frac{(921)}{(921+658)}(0.31) + \frac{(658)}{(658+921)}(0.34)$$

$$= 0.1808 + 0.1417 = 0.3225$$

$$K_{10-250} = 0.32$$

$$K_{>250} = \frac{(259)}{(259+1248)}(0.36) + \frac{(1248)}{(259+1248)}(0.62)$$

$$= 0.0619 + 0.5134 = 0.575$$

$$K_{>250} = 0.58$$

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Source Fossil Fuel Boilers

We have 1975 capacity (P1 of these calc's) in #/hr steam. Since emission factors will be on a per BTU basis, it is necessary to convert.

$$1975\,CAP.\ (10^{12}\,BTU) = 1975\,CAP\left(\#/HR\ STEAM\right)\left(8760\ \frac{HR}{YR}\right)\left(\frac{BTU}{\#\ STEAM}\right)$$

$$\frac{BTU}{\#\ STEAM} = \frac{975\ \frac{BTU}{\#}}{\eta_{BOILER}}$$ (see P2 of these calcs)

For the sake of minimizing extensive calc's as to weight efficiencies, we will assume a linear av's

Residential

$$A = \frac{(2877\times10^{6})(8760)(975)}{1.0} = 24{,}572\times10^{12}\ \frac{BTU}{YR}$$

$$A_{RESIDENTIAL} = 24{,}572\times10^{12}\ \frac{BTU}{YR}$$

Cast Iron

70
80
80
77
77 = AVG

$$A = \frac{(985)(8760)(975)(10^{6})}{0.77} = 10{,}926\times10^{12}$$

$$A_{CAST\ IRON} = 10{,}926\times10^{12}\ \frac{BTU}{YR}$$

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Computation Sheet For Industrial Factors

Calculations Done By Homer Date 9/23/74

Source Fossil Fuel Boilers

Firetube

70
77
77
75
75 = AVG

$$A = \frac{(1365\times10^6)(8760)(975)}{0.75} = 15,545\times10^{12}\ BTU$$

$$A_{FIRETUBE} = 15,545\times10^{12}\ BTU/YR$$

Watertube - Type #1

.77
.75
.75
.70
74 = AVG

$$A = \frac{(1045\times10^6)(8760)(975)}{0.74} = 12,061\times10^{12}$$

$$A_{WT.1} = 12,061\times10^{12}\ BTU/YR$$

Watertube - Type #2

83
80
80
76
80 = AVG

$$A = \frac{(700\times10^6)(8760)(975)}{.80} = 7,473\times10^{12}$$

$$A_{WT-2} = 7,473\times10^{12}\ BTU/YR$$

Watertube - Type #3

89
87
87
81
86

$$A = \frac{(286\times10^6)(8760)(975)}{.86} = 2840\times10^{12}\ BTU/YR$$

$$A_{WT-3} = 2840\times10^{12}\ BTU/YR$$

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Computation Sheet For Industrial Factors

Calculations Done By HAPER Date 9/23/74

Source Fossil Fuel Boilers

WATERTUBE - TYPE #4

$$A = \frac{(9564 \times 10^6)(8760)(975)}{0.87} = 25,171 \times 10^{12}$$

90
88
88
81
87 = AVG

$$A_{WT-4} = 25,171 \times 10^{12} \text{ BTU/YR}$$

$$A_{<0.3} = 24,572 \times 10^{12} \text{ BTU/YR}$$

$$A_{0.3-10.0} = (10,926 + 15,545)\, 10^{12} = 26,471 \times 10^{12}$$

$$A_{0.3-10.0} = 26,471 \times 10^{12} \text{ BTU/YR}$$

$$A_{10.0-250} = (12,061 + 7,473)(10^{12}) = 19,534 \times 10^{12} \text{ BTU/HR}$$

$$A_{10.0-250} = 19,534 \times 10^{12} \text{ BTU/HR}$$

$$A_{>250} = (2840 \times 10^{12} + 25,171 \times 10^{12}) = 28,011 \times 10^{12}$$

$$A_{>250} = 28,011 \times 10^{12} \text{ BTU/YR}$$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/23/74

Source Fossil Fuel Boilers

P_B DETERMINATION

CAST IRON REF (22) p 2-1 life = 50 years

$\frac{100\%}{50 yrs} = 2\%$ s

$P_{B_{CAST\ IRON}} = 2\%$ simple

FIRETUBE REF (22) p-2-1 Life = 20 yrs

$\frac{100\%}{20 yrs} = 5\%$ s

$P_{B_{FIRETUBE}} = 5\%$ simple

WATERTUBE REF (22) p 2-3

"....longevity may be comparable to firetube units ...."

$P_{B_{WT}} = 5\%$ simple

Assume Residential equal to the av'g of cast iron } REF 73 p 50

$P_{B_{<0.3}} = 2\%$ simple

$$P_{B_{0.3-10.0}} = (2\%)\left(\frac{985}{985+1365}\right) + (5\%)\left(\frac{1365}{985+1365}\right) = 0.838 + 2.904 = 3.74\%$$

1975 capacities (see P1 of these calcs)

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Source Fossil Fuel Boilers

$$P_{B_{0.3-10.0}} = 3.7\%$$ simple

$$P_{B_{10-250}} = P_{B_{WT}} = 5\%$$

$$P_{B_{10-250}} = 5\%$$ simple

$$P_{B_{>250}} = P_{B_{WT}} = 5\%$$

$$P_{B_{>250}} = 5\%$$ simple

P_C DETERMINATION

REF (73) p16 TAB 1-5 gives 1975-1985 Capacities
Assume cmpd growth

$$P_{C_{RES.}} = \sqrt[10]{\frac{3844}{2877}} - 1.0 = 2.9\%$$

$$P_{C_{CI}} = \sqrt[10]{\frac{1330}{985}} - 1.0 = 3.05\%$$

$$P_{C_{FT}} = \sqrt[10]{\frac{2255}{1365}} - 1.0 = 5.15\%$$

$$P_{C_{WT-1}} = \sqrt[10]{\frac{1201}{1045}} - 1.0 = 1.40\%$$

$$P_{C_{WT-2}} = \sqrt[10]{\frac{810}{700}} - 1.0 = 1.47\%$$

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Computation Sheet For Industrial Factors

Calculations Done By [illegible] Date 9/23/74

Source Boilers

$$Pc_{WT-3} = \sqrt[10]{\frac{276}{286}} - 1.0 = -0.36\%$$

$$Pc_{WT-4} = \sqrt[10]{\frac{4663}{2564}} - 1.0 = 6.16\%$$

$$Pc_{<0.3} = 2.9\% \text{ cmpd}$$

$$Pc_{0.3-10.0} = \left(\frac{985}{985+1365}\right)(3.05) + \left(\frac{1365}{985+1365}\right)(5.15) = 1.278 \cdot 2.991 = 4.27$$

1975 Capacities (see p1 of these calcs)

$$Pc_{0.3-10.0} = 4.3\% \text{ cmpd}$$

$$Pc_{10-250} = 1.4\%$$

$$Pc_{10-250} = 1.4\% \text{ cmpd}$$

$$Pc_{>250} = (-.36)\left(\frac{286}{286+2564}\right) + 6.16\left(\frac{2564}{286+2564}\right) = -.03[illegible] \quad 5.54$$

$$Pc_{>250} = 5.5\% \text{ cmpd}$$

1975 Capacities (see p1 of these calcs)

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 7/23/74

Source Boilers

Summary Of Industrial Factors

	K	A (10^{12})	P_c (%)	P_B
< 0.3	0.3	24,572	2.9 c	2.0 s
0.3 - 10.0	0.25	26,471	4.3 c	3.7 s
10.0 - 250	0.32	19,534	1.4 c	5.0 s
> 250	0.58	28,011	5.5 c	5.0 s

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 9/23/74

Source Fossil Fuel Boilers

RESIDENTIAL

CONVERSION FACTORS, FUEL USAGE RATES & CAPACITIES HAVE ALL BEEN PRESENTED IN "INDUSTRIAL FACTORS" CALC'N SHEETS

PART. REF (75) p 1.3-2 TAB 1.3-1

$$Eu_{P_{DO}} = 10^{\#}/1000\,GAL$$

$$\frac{\frac{0.010\,\#}{GAL} \times \frac{42\,GAL}{BBL}}{5.817 \times 10^6\ BTU/BBL} = 0.0722\ \frac{\#}{10^6\,BTU}\ \left(\text{DIST. OIL}\right)$$

REF (75) p 1.4-2 TAB 1.4-1

$$Eu_{P_{GAS}} = 19^{\#}/10^6\,FT^3$$

$$\frac{\left(19 \times 10^{-6}\,\frac{\#}{FT^3}\right)}{1040\,\frac{BTU}{FT^3}} \times 10^6 = 0.0183\ \frac{\#}{10^6\,BTU}\ (GAS)$$

$$\frac{(355 \times 10^6)(5.817 \times 10^6)}{(355 \times 10^6)(5.817 \times 10^6) + (3.15 \times 10^{12})(1040)} = 38.7\ \%\ \text{DIST. OIL}$$

2.065×10^{15} 3.276×10^{15}

∴ % GAS = 61.3%

$$(0.387)(.0722) + (.613)(.0183) = .0279 + .0112 = .0391$$

$$Eu_{\substack{RES\\PART}} = 0.0391\ \frac{\#}{10^6\,BTU}$$

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Computation Sheet For Emission Factors

Calculations Done By Hepper Date 9/23/74

Source Fossil Fuel Boilers

NOx

Ref (75) p1.3-2 TAB 1.3-1

$$EU_{NO_x, DO} = 12\ \#/1000\,gal$$

Ref (75) p1.4-2 TAB 1.4-1

$$EU_{NO_x, gas} = 80\ \#/10^6\,FT^3$$

$$\frac{(.012)(42)}{5.817} = 0.0866\ \#/10^6 BTU\ (D.O.)$$

$$\frac{(80\times10^{-6})(10^6)}{1040} = 0.0769\ \#/10^6 BTU\ (GAS.)$$

$$(0.0866)(.387) + (.0769)(.613) = .0335 + .0471 = .0.0806$$

$$EU_{RES, NO_x} = 0.0806\ \#/10^6\ BTU$$ *

HC

Same Refs & pp As above

$$EU_{RES, DO, HC} = 3+2\ \#/1000\,gal = 5$$

$$EU_{gas, HC} = 8\ \#/10^6 FT^3$$

$$\frac{(.005)(42)}{5.817} = .0361\ \#/10^6 BTU\ (DO) \qquad \frac{(8\times10^{-6})(10^6)}{1040} = .0077$$

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Computation Sheet For Emission Factors

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Source

$.0361(.387) + .0077(.613) = .0140 + .0047 = 0.0187$

$EU_{RES\ HC} = 0.0187$ #/10^6 BTU *

SOx

REF (97) P19 TAB 29 % S in #2 FUEL = 0.265%
(ARITHMETIC AVG OF TAB 49)

REF (75) P 1.3-2 TAB 1.3-1 → $EU_{SOx} = (142+2)S = (144)(.265) = 38.16$ #/1000 gal

$$\frac{(.03816)(12)}{5.817} = 0.2755 \text{ \#}/10^6 \text{BTU (DO)}$$

REF (75) P 1.4-2 TAB 1.4-1

0.6 #/10^6 FT³

$$\frac{(0.6\times10^{-6})(10^6)}{1040} = 0.00058 \text{ \#}/10^6 \text{BTU (GAS)}$$

$(.2755)(.387) + (.00058)(.613) = .1066 + .00036 = 0.1070$

$EU_{SOx\ RES} = 0.1070$ #/10^6 BTU *

CO Same refs as above

$EU_{RES\ DO\ CO} = 5$ #/1000 gal $EU_{RES\ GAS\ CO} = 20$ #/10^6 FT³

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Source Boilers

$$\frac{(.005)(42)}{(5.817)} = 0.0361 \ \#/10^6 \text{ BTU} \ (\text{DO}) \qquad \frac{(20 \times 10^{-6})(10^6)}{1040} = 0.0192 \ \#/10^6 \text{ BTU} \ (\text{GAS})$$

$$(.0361)(.387) + (0.0192)(.613) = .0140 + .0118 = 0.0258$$

$$E_{U_{RES}} \ (\text{CO}) = 0.0258 \ \#/10^6 \text{ BTU} \qquad *$$

FIRETUBE

PARTICULATE

% BREAKDOWN OF FUEL USAGE TYPES ARE NECESSARY TO SYNTHESIZE EMISSION FACTORS SINCE THESE FACTORS ARE DIFFERENT FOR DIFFERENT FUELS. DATA FOR THE FOLLOWING CALCS HAS BEEN PREVIOUSLY PRESENTED IN THE "INDUSTRIAL FACTORS" CALC'N SHEETS.

$$\text{TOTAL HEAT LOAD} = (11 \times 10^6)(26.2 \times 10^6) + (75 \times 10^6)(8.384 \times 10^6) + (69 \times 10^6)(5.817 \times 10^6) + (1.12 \times 10^{12})(1040)$$

$$= (2.882 \times 10^{14} + 6.256 \times 10^{14} + 4.014 \times 10^{14} + 11.648 \times 10^{14})$$

$$= 24.8 \times 10^{14} \text{ BTU/YR}$$

$$\% \text{ COAL} = \frac{2.882}{24.8} = 11.6\% \qquad \% \text{ GAS} = \frac{11.648}{24.8} = 47.0\%$$

$$\% \text{ RO} = \frac{6.256}{24.8} = 25.2\%$$

$$\% \text{ DO} = \frac{4.014}{24.8} = 16.2\%$$

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Source Boilers

Ref (22) p 1-2 TAB 1-1 gives emission factors

$$EU_{FT_{GAS\,P}} = \left(18/.1040 \times 10^{10}\right) \times 10^{6} = 0.0173 \quad \text{gas}$$

$$EU_{FT_{RO\,P}} = \left(\frac{966}{.6384 \times 10^{10}}\right)\left(10^{6}\right) = 0.1029 \quad \text{RO}$$

$$EU_{FT_{DO\,P}} = \left(\frac{630}{.5817 \times 10^{10}}\right)\left(10^{6}\right) = 0.1083 \quad \text{DO}$$

$$EU_{FT_{C\,P}} = \frac{(5000)(8.1)(10^{6})}{2.62 \times 10^{10}} = 1.5458 \quad \text{coal}$$

{ Ref (22) p 1-1 gives ash content of coal = 8.1%
Ref (73) p A-14 states ALL cast iron units are underfired stoker type }

$$EU_{FT_P} = (.0173)(.47) + (0.1029)(.252) + (.1083)(.162) + (1.5458)(.116)$$

$$= 0.0081 + .0259 + .0175 + .1793 = 0.2308$$

$$EU_P = 0.2308$$ *

NOx

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Source Boilers

Ref (22) p4-2 TAB 4-1 gives emission factors #/10^6 BTU

$$EU_{NO_x, FT} = \left(\frac{118}{.1040 \times 10^{10}}\right)(10^6) = 0.1135 \quad \text{gas}$$

$$= \left(\frac{1529}{.6384 \times 10^{10}}\right)(10^6) = 0.2395 \quad \text{RO}$$

$$= \left(\frac{1391}{.5817 \times 10^{10}}\right)(10^6) = 0.2391 \quad \text{DO}$$

$$= \left(\frac{10,000}{2.62 \times 10^{10}}\right)(10^6) = 0.3817 \quad \text{COAL}$$

$$EU_{NO_x, FT} = (.1135)(.47) + (.2395)(.252) + (.2391)(.162) + (.3817)(.116)$$

$$= .0533 + .0604 + .0387 + .0443 = 0.1967$$

$$EU_{NO_x, FT} = 0.1967 \ \#/10^6 \text{ BTU}$$ *

H/C Same ref as above

$$EU_{H/C, FT} = \left(\frac{40}{.1040 \times 10^{10}}\right)(10^6) = .0385 \quad \text{gas}$$

$$= \left(\frac{126}{.6384 \times 10^{10}}\right)(10^6) = .0197 \quad \text{RO}$$

$$= \left(\frac{126}{.5817 \times 10^{10}}\right)(10^6) = .0217 \quad \text{DO}$$

$$= \left(\frac{3000}{2.62 \times 10^{10}}\right)(10^6) = 0.1145 \quad \text{COAL}$$

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Source Boilers

$$(.0385)(.47) + (.0197)(.252) + (.0217)(.162) + (.1145)(.116) =$$

$$.0181 + .00496 + .0035 + .0133 = .0399$$

$$EU_{\frac{HC}{FT}} = 0.0399 \ \#/10^6 BTU$$ *

CO

Same Refs as above

$$EU_{\frac{CO}{FT}} = \left(\frac{.4}{.1090 \times 10^{10}}\right)(10^6) = .00038 \quad \text{gas}$$

$$= \left(\frac{8.4}{.6384 \times 10^{10}}\right)(10^6) = .0013 \quad \text{RO}$$

$$= \left(\frac{8.4}{.5817 \times 10^{10}}\right)(10^6) = .0014 \quad \text{DO}$$

$$= \left(\frac{10{,}000}{2.62 \times 10^{10}}\right)(10^6) = 0.3817 \quad \text{coal}$$

$$(.00038)(.47) + (.0013)(.252) + (.0014)(.162) + (.3817)(.116) =$$

$$= .00018 + .00023 + .00023 + .0443 = .0449$$

$$EU_{\frac{CO}{FT}} = 0.0449 \ \#/10^6 BTU$$ *

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Computation Sheet For Emission Factors

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Source Boilers

SO_2

SAME REFS AS ABOVE FOR EMISSION FACTORS

% S_{GAS} = .0006 % REF (22) p4-4 TAB 4-2

% S_{RO} = 1.5 % " " "

% S_{DO} = 0.265 % (PREVIOUSLY QUOTED)

% S_{COAL} = 2.00 % REF (22) p4-4 TAB 4-2

$$EU_{SO_2/FT} = \frac{(0.6)(.0006)(10^6)}{(.1040 \times 10^{10})} \cong 0.0 \quad \text{GAS}$$

$$= \frac{(6804)(1.5)(10^6)}{(.6384 \times 10^{10})} = 1.5987 \quad \text{RO}$$

$$= \frac{(5838)(.265)(10^6)}{(.5817 \times 10^{10})} = 0.2660 \quad \text{DO}$$

$$= \frac{(38,000)/(2.0)(10^6)}{(2.62 \times 10^{10})} = 2.9008 \quad \text{COAL}$$

$$(0.0)(.47) + (1.5987)(.252) + (.266)(.162) + (2.9008)(.116) =$$

$$0 + .4029 + .0431 + .3365 = 0.7825$$

$$EU_{SO_x/FT} = 0.7825$$ *

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Computation Sheet For Emission Factors

Calculations Done By Hyper Date 9/23/74

Source Boilers

CAST IRON

Emission factors for each fuel are the same as for firetube boilers. However, the distribution is different. Data for following calc's previously presented on "INDUSTRIAL FACTORS" calc'n sheet.

$$\text{TOTAL HEAT INPUT} = (11\times10^{6})(26.2\times10^{6}) + (56\times10^{6})(6.384\times10^{6}) + (37\times10^{6})(5.817\times10^{6}) + (1.03\times10^{12})(1040)$$

$$= 2.882\times10^{14} + 3.5750\times10^{14} + 2.1523\times10^{14} + 10.712\times10^{14}$$

$$= 19.321\times10^{14}\ \text{BTU}$$

$$\%\ \text{COAL} = \frac{2.882}{19.321} = 14.9\% \qquad \%\ \text{DO} = \frac{2.152}{19.321} = 11.1\%$$

$$\%\ \text{RO} = \frac{3.575}{19.321} = 18.5\% \qquad \%\ \text{GAS} = \frac{10.712}{19.321} = 55.4\%$$

PARTICULATE.

$$EU_{CI_P} = (.0173)(.554) + (.1029)(.185) + (.1083)(.111) + (1.5458)(.149)$$

$$= .00958 + .0190 + .0120 + .2303 = .2709$$

$$EU_{CI_P} = 0.2709\ \#/10^{6}\ \text{BTU} \quad *$$

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Source Boilers

NO_x

$(.1135)(.554) + (.2395)(.185) + (.2391)(.111) + (.3817)(.149) =$

$.0629 + .0443 + .0265 + .0569 = .1906$

$EU_{NO_x, CI} = 0.1906$ #/10^6 BTU *

H/C

$(.0385)(.554) + (.0197)(.185) + (.0217)(.111) + (.1145)(.149) =$

$.0213 + .0036 + .0024 + .0171 = 0.0444$

$EU_{HC, CI} = .0444$ #/10^6 BTU *

CO

$(.00038)(.554) + (.0013)(.185) + (.0014)(.111) + (.3817)(.149) =$

$0.00021 + .00024 + .00016 + .0569 = .0575$

$EU_{CO, CI} = 0.0575$ #/10^6 BTU *

SO_2

$(0) + (1.5987)(.185) + (.266)(.111) + (2.901)(.149) =$

$= 0.2958 + .0295 + .4322 = .7575$

$EU_{SO_2, CI} = 0.7575$ #/10^6 BTU *

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Computation Sheet For Emission Factors

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Source Boilers

Watertube -1

Particulate

Emission factors for RO, DO & Gas are the same. Coal must be broken down dependant upon feed mechanism.

Ref (73) pA-14 Tab A-2 gives feed breakdown & def'ns

PV = .194 OF = .474 UF = .129
CY = 0.0 SS = .203

$E_{U_{WT1,P}}$ = .0173 gas
= .1029 RO
= .1083 DO

For coal, Ref (22) p1-2 Tab 1-1

$$(.194)(16000) + (.474)(13{,}000) + (.129)(5000) + (.203)(5000) =$$
$$3104 + 6162 + 645 + 1015 = 10{,}926\ A$$

$$\frac{(10{,}926)(8.1)(10^6)}{2.62\times10^{10}} = 3.378\ \#/10^6\text{BTU coal}$$

Fuel usage breakdown has been previously presented for WT-1 boilers

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Source Boilers

$$\text{TOTAL HEAT INPUT} = (132\times10^6)(26.2\times10^6) + (194\times10^6)(6.384\times10^6) + (14\times10^6)(5.817\times10^6) + (1.72\times10^{12})(1040)$$

$$= 34.584\times10^{14} + 12.385\times10^{14} + 0.814\times10^{14} + 17.888\times10^{14}$$

$$= 65.671\times10^{14}$$

$$\%\ \text{COAL} = \frac{34.584}{65.671} = 52.7\% \qquad \%\ \text{DO} = \frac{.814}{65.671} = 1.2\%$$

$$\%\ \text{RO} = \frac{12.385}{65.671} = 18.9\% \qquad \%\ \text{GAS} = \frac{17.888}{65.671} = 27.2\%$$

$$EU_{WT_1,\,PART} = (3.378)(.527) + (.1029)(.189) + (.1083)(.012) + (.0173)(.272)$$

$$= 1.780 + .0194 + .0013 + .0047 = 1.8054$$

$$EU_{WT\text{-}1,\,P} = 1.8054\ \#/10^6\ \text{BTU}$$ *

NOx

Ref (22) p 4-2 TAB 4-1 gives emission factors

$$EU_{WT\text{-}1,\,gas} = \frac{(167.6)(10^6)}{.1040\times10^{10}} = 0.1612 \qquad \text{gas}$$

$$EU_{WT1,\,RO} = \frac{(218)(10^6)}{0.6384\times10^{10}} = .0341 \qquad \text{RO}$$

$$EU_{WT1,\,DO} = \frac{(2017)(10^6)}{.5817\times10^{10}} = .3467 \qquad \text{DO}$$

Using the coal feed breakdowns previously presented for WT-1 boilers,

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Computation Sheet For Emission Factors

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Source Boilers

$$EU_{WT-1,\ COAL} = (.194)(20,000) + (.474)(15,000) + (.129)(10,000) + (.203)(10,000)$$

$$= 3880 + 7110 + 1290 + 2030 = 14,310$$

$$EU_{WT-1,\ COAL,\ NOx} = \frac{(14,310)(10^6)}{2.62 \times 10^{10}} = .5462 \qquad \text{COAL}$$

$$(.5462)(.527) + (.189)(.0341) + (.012)(.3467) + (.272)(.1612) =$$

$$.2878 + .0064 + .0042 + .0438 = .3422$$

$$EU_{WT-1,\ NOx} = 0.3422\ \#/10^6 BTU \qquad *$$

H/C

Ref (22) p 1-2 TAB 4-1 gives emission factors

$$EU_{HC,\ WT-1,\ gas} = \frac{(20)(10^6)}{.1040 \times 10^{10}} = .0192 \qquad \text{gas}$$

$$EU_{WT-1,\ DO} = \frac{(126)(10^6)}{.6384 \times 10^{10}} = .0197 \qquad \text{DO}$$

$$EU_{WT-1,\ RO} = \frac{(126)(10^6)}{.5817 \times 10^{10}} = .0217 \qquad \text{RO}$$

Using coal feed breakdowns as previously presented

$$EU_{WT-1,\ Coal} = (.194)(300) + (.474 + .129 + .203)(3000) = 58.2 + 2418 = 2476 \qquad \text{COAL}$$

$$= (2476)(10^6)/(2.62 \times 10^{10}) = .0945$$

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Source Boilers

$(.0192)(.272) + (.0197)(.012) + (.0217)(.189) + (.0945)(.527) =$

$.00522 + .00024 + .0041 + .0498 = .0594$

$EU_{WT-1, HC} = .0594$ #/10^6 BTU *

SOx

Emission factors for gas, RO & DO & coal same as Firetube

gas - 0.0
RO - 1.5987
DO - .2660
coal - 2.901

$(.012)(.2660) + (.189)(1.5987) + (.527)(2.901) = .0032 + .3022 + 1.5288$
$= 1.8342$

$EU_{WT-1, SOx} = 1.8342$ #/10^6 BTU *

CO

Ref (22) p 4-2 TAB 4-1 for emission factors

$EU_{WT-1, CO, g} = \frac{(8)(10^6)}{.1040 \times 10^{10}} = .0077$ gas

$EU_{WT1, RO} = \frac{(8.4)(10^6)}{.6384 \times 10^{10}} = .0013$ RO

$EU_{WT1, DO} = \frac{(8.4)(10^6)}{.5817 \times 10^{10}} = .0014$ DO

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Source Boilers

$$EU_{WT-1,\ coal} = (.194)(1000) + (.474 + .129 + .203)(10{,}000) = 194 + 8060 = 8254$$

$$EU_{WT-1,\ raw} = \frac{(8254)(10^6)}{2.62 \times 10^{10}} = .3150$$

$$(.012)(.0014) + (.189)(.0013) + (.527)(.3150) + (.272)(.0077) =$$

$$0 + .00025 + .1660 + .0021 = .1684$$

$$EU_{WT-1,\ CO} = 0.1684\ \#/10^6 BTU \quad *$$

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Source Boilers

WATERTUBE -2

PARTICULATE Emission factors Ref (22) p 1-2 TAB 1-1

$$EU_{WT-2 \atop gas} = \frac{(15)(10^6)}{.1040 \times 10^{10}} = .0144 \quad gas$$

$$EU_{WT-2 \atop RO} = \frac{(420)(10^6)}{.6384 \times 10^{10}} = .0658 \quad RO$$

$$EU_{WT-2 \atop DO} = \frac{(630)(10^6)}{.5817 \times 10^{10}} = .1083 \quad DO$$

Coal Feed breakdowns per Ref (73) p A-14 TAB A-2

PV = .593 OF = .293 UF = .021
CY = .016 SS = .077

$$(.593)(16000) + (.016)(20,000) + (.293)(13000) + (.077)(5000) + (.021)(5000) =$$
$$9488 + 320 + 3809 + 385 + 105 = 14,107 A$$

$$EU_{WT-2 \atop coal} = \frac{(14,107)(8.1)(10^6)}{2.62 \times 10^{10}} = 4.3613 \quad coal$$

Fuel usage & distribution is same as WT-1

gas = 27.2%
RO = 18.9%
DO = 1.2%
Coal = 52.7%

$$EU_{WT-2 \atop P} = (.0144)(.272) + (.0658)(.189) + (.1083)(.012) + (4.3613)(.527) =$$
$$.0039 + .0124 + .0013 + 2.2984 = 2.316$$

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Source Boilers

$$EU_{WT-Z_{P}} = 2.316 \text{ \#}/10^6 \text{ BTU}$$ *

NOx

$$EU_{WT-Z_{g}} = \frac{(228)(10^6)}{.1040 \times 10^{10}} = .2192 \quad \text{gas}$$

$$EU_{WT-Z_{RO}} = \frac{(3072)(10^6)}{.6384 \times 10^{10}} = .4812 \quad \text{RO}$$

$$EU_{WT-Z_{DO}} = \frac{(2794)(10^6)}{.5817 \times 10^{10}} = .4803 \quad \text{DO}$$

COAL

$$(.593)(20{,}000) + (.016)(60{,}000) + (.293)(15000) + (.077 + .021)(10{,}000) =$$

$$11{,}860 + 960 + 4395 + 980 = 18{,}195$$

$$EU_{WT-Z_{COAL}} = \frac{(18{,}195)(10^6)}{2.62 \times 10^{10}} = 0.6945$$

$$EU_{WT-Z_{NOx}} = (.272)(.2192) + (.189)(.4812) + (.012)(.4803) + (.527)(.6945) =$$

$$= .0596 + .0909 + .0058 + .3660 = 0.5223$$

$$EU_{WT-Z_{NOx}} = 0.5223 \text{ \#}/10^6 \text{ BTU}$$ *

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Source Boilers

H/C Ref (22) p 4-2 TAB 4-1 : Emission factors

$$EU_{WT-2,\ gas} = \frac{(40)(10^6)}{.104 \times 10^{10}} = .0385 \quad \text{gas}$$

$$EU_{WT-2,\ RO} = \frac{(126)(10^6)}{.6384 \times 10^{10}} = .0197 \quad \text{RO}$$

$$EU_{WT-2,\ DO} = \frac{(126)(10^6)}{.5817 \times 10^{10}} = 0.0217 \quad \text{DO}$$

COAL

$$(.593)(300) + (.016)(300) + (.293 + .077 + .021)(1000) = 182.7 + 391 = 574$$

$$EU_{WT-2,\ COAL} = \frac{(574)(10^6)}{2.62 \times 10^{10}} = .0219$$

$$(.0385)(.272) + (.0197)(.189) + (.0217)(.012) + (.0219)(.527) =$$

$$.0105 + .0037 + .00026 + .0115 = 0.026$$

$$EU_{WT-2,\ HC} = 0.026 \ \#/10^6 \text{ BTU} \quad *$$

SO_x Emission factors same as for firetube

gas ≈ 0.0

RO = 1.5987

DO = .2660

COAL = 2.901

$$EU_{WT-2,\ SOX} = (1.5987)(.189) + (.2660)(.012) + (2.901)(.527) = .3022 + .0032 + 1.5288 =$$

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Source Boiler

$$EU_{WT-2, SO_x} = 1.8342 \ \#/10^6 \ BTU$$ *

CO Emission factor Ref (22) p 4-2 TAB 4-1

$$EU_{WT-2, g} = \frac{(6.4)(10^6)}{.104 \times 10^{10}} = 0 \quad \text{gas}$$

$$EU_{WT-2, RO} = \frac{(8.4)(10^6)}{.6384 \times 10^{10}} = .0013 \quad \text{RO}$$

$$EU_{WT-2, DO} = \frac{(8.4)(10^6)}{.5817 \times 10^{10}} = .0014 \quad \text{DO}$$

COAL

$$(.593+.016)(1000) + (.343+.077+.021)(2000) = 609 + 782 = 1391$$

$$EU_{WT-2, coal} = \frac{(1391)(10^6)}{2.62 \times 10^{10}} = .0531$$

$$EU_{WT-2, CO} = (.189)(.0013) + (.012)(.0014) + (.527)(.0531)$$

$$= .00025 + 0 + .0280 = .0283$$

$$EU_{WT-2, CO} = 0.0283 \ \#/10^6 \ BTU$$ *

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Computation Sheet For Emission Factors

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Source Boilers

WATERTUBE-3

PARTICULATE Ref (22) p 4-2 TAB 4-1 for emissions

Assuming a misprint for CY coal emissions (2000 instead of 20,000), emission factors are the same as for WT-2 boilers

Coal emission factors must be redefined since the feed mechanism is different than WT-2

Ref (73) p A-14 TAB A-2 states 92.1% PV & the remaining % being distributed between the other feed mechanisms. We will assume 100% PV.

$$EU_{WT-3,gas} = .0144 \quad gas$$

$$EU_{WT-3,RO} = .0658 \quad RO$$

$$EU_{WT-3,DO} = .1083 \quad DO$$

$$EU_{WT-3,coal} = \frac{(16,000)(8.1)(10^6)}{2.62 \times 10^{10}} = 4.9466 \quad coal$$

Fuel usage & distribution same as WT-1

$$EU_{WT-3,P} = (.0144)(.272) + (.0658)(.189) + (.1083)(.012) + (4.9466)(.527)$$

$$= .0039 + .0124 + .0013 + 2.6069 = 2.6245$$

$$EU_{WT-3,P} = 2.6245 \ \#/10^6 BTU$$ *

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Source Boilers

NOx Ref (22) p 4-2 TAB 4-1 for emission factors

$$EU_{WT-3,g} = \frac{(249)(10^6)}{.104 \times 10^{10}} = .2394 \quad \text{gas}$$

$$EU_{WT-3,RO} = \frac{(3372)(10^6)}{.6384 \times 10^{10}} = .5282 \quad \text{RO}$$

$$EU_{WT-3,DO} = \frac{(3067)(10^6)}{.5817 \times 10^{10}} = .5272 \quad \text{DO}$$

coal $$EU_{WT-3,coal} = \frac{(20{,}000)(10^6)}{2.62 \times 10^{10}} = .7634 \quad \text{coal}$$

$$EU_{NOx,WT-3} = (.2394)(.272) + (.5282)(.189) + (.5272)(.012) + (.7634)(.527)$$

$$= .0651 + .0998 + .0063 + .4023 = .5735$$

$$EU_{WT-3,NOx} = 0.5735 \ \#/10^6 \ BTU$$ *

H/C Emission factors for gas, DO, RO same as WT-2

$$EU_{WT-3,g} = .0385$$

$$EU_{WT-3,RO} = .0197$$

$$EU_{WT-3,DO} = .0217$$

coal $$EU_{WT-3,coal} = \frac{(300)(10^6)}{2.62 \times 10^{10}} = .0115$$

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Computation Sheet For Emission Factors

Calculations Done By Hoggx Date 9/22/74

Source Boilers

$$EU_{HC\,WT\text{-}3} = (.0385)(.272) + (.0197)(.189) + (.0217)(.012) + (.0115)(.527)$$

$$= .0105 + .0037 + .00026 + .0061 = .0206$$

$$EU_{HC\,WT\text{-}3} = .0206\ \#/10^6\,BTU$$ *

SO_x

Same emission factors as for WT-2

gas ≈ 0.0
RO = 1.5987
DO = .2660
coal = 2.901

$$EU_{WT\text{-}3\,SO_x} = (1.5987)(.189) + (.2660)(.012) + (2.901)(.527) =$$

$$= .3022 + .0032 + 1.5288 = 1.8342$$

$$EU_{WT\text{-}3\,SO_x} = 1.8342\ \#/10^6\,BTU$$ *

CO

Eu for GAS, RO, DO same as WT-2

$$EU_{WT\text{-}3\,gas} = 0$$

$$EU_{WT\text{-}3\,RO} = .0013$$

$$EU_{WT\text{-}3\,DO} = .0014$$

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Calculations Done By Hoffer Date 9/28/74

Source Boilers

COAL $$EU_{WT-3,\ coal} = \frac{(1000)(10^6)}{2.62\times10^{10}} = .0382$$

$$EU_{WT-3,\ CO} = (.0013)(.189) + (.0014)(.012) + (.0382)(.527)$$

$$= 0.00025 + 0 + .02013 = .0204$$

$$EU_{WT-3,\ CO} = 0.0204 \ \#/10^6\ BTU$$ *

WT-4

Assume emission factors for GAS, RO, DO to be the same as for WT-3 units. Coal is 100% PV (Ref (73) p-A14 Tab A-2) ∴ Emission factor for coal is same also. Fuel usage for WT-4 units has been previously presented as:

$$\text{TOTAL HEAT INPUT} = (271\times10^6)(26.2\times10^6) + (156\times10^6)(6.384\times10^6) + (2\times10^6)(5.8\times10^6) + (2.76\times10^{12})(1040)$$

$$= 7.100\times10^{15} + .996\times10^{15} + .0116\times10^{15} + 2.870\times10^{15} = 10.978\times10^{15}$$

$$\%\ COAL = \frac{7.100}{10.978} = 64.7\%$$

$$\%\ RO = \frac{.996}{10.978} = 9.1\%$$

$$\%\ DO = \frac{.0116}{10.978} = 0.1\% \approx 0.0\%$$

$$\%\ GAS = \frac{2.870}{10.978} = 26.1\%$$

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Calculations Done By Hopper Date 9/27/74

Source Boilers

Particulates

$$(.0144)(.261) + (.0658)(.091) + 0 + (4.9466)(.647) = EU_{WT-4_P}$$

$$EU_{WT-4_P} = .0038 + .0060 + 3.2004 = 3.2102$$

$$EU_{WT-4_P} = 3.2102 \text{ \#}/10^6 \text{ BTU}$$ *

NOx

$$(0.2394)(.261) + (.5282)(.091) + (.5272)(0) + (.7634)(.647)$$

$$= .0625 + .0481 + .4939 = .6045$$

$$EU_{WT-3_{NO_x}} = .6045$$ *

H/C

$$(.0385)(.261) + (.0197)(.091) + (.0115)(.647) = .0100 + .0018 + .0074$$

$$EU_{WT-3_{H/C}} = 0.0192 \text{ \#}/10^6 \text{ BTU}$$ *

SOx

$$(1.5987)(.091) + (2.901)(.647) = .1455 + 1.8769 = 2.0224$$

$$EU_{WT-3_{SO_x}} = 2.0224 \text{ \#}/10^6 \text{ BTU}$$ *

CO

$$(.0013)(.091) + (.0382)(.647) = .00012 + .0247 = .0248 \quad EU_{WT-3_{CO}} = .0248 \text{ \#}/10^6 \text{ BTU}$$ *

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Calculations Done By Hopper Date 9/27/74

Source Boilers

INTERMEDIATE SUMMARY

		PART	NOx	HC	SOx	CO	
	RESIDENTIAL	.0391	.0806	.0187	.1070	.0258	<0.3
.5178	FIRETUBE	.2308	.1967	.0399	.7825	.0449	0.3-10.0
.4822	CAST IRON	.2709	.1906	.0444	.7575	.0575	0.3-10.0
.5833	WT-1	1.8054	.3422	.0594	1.8342	.1684	10-250
.4167	WT-2	2.316	.5223	.0260	1.8342	.0283	10-250
.1718	WT-3	2.6245	.5735	.0206	1.8342	.0204	>250
.8282	WT-4	3.2102	.6045	.0192	2.0224	.0248	>250

These values will be weighted for each category based upon DATA from TABLE 1-5 p16 Ref (73)

0.3-10.0

$$E_{U_{P\,0.3-10}} = \left(\frac{757}{757+813}\right)(.2709) + \left(\frac{813}{757+813}\right)(.2308)$$

$$= (0.4822)(.2709) + (0.5178)(.2308)$$

$$= 0.1306 + .1195$$

$$E_{U_{P\,0.3-10.0}} = 0.2501 \ \#/10^6 \text{ BTU}$$

$$E_{U_{NOx\,0.3-10.0}} = (0.4822)(.1906) + (.5178)(.1967) = .0919 + .1019$$

$$E_{U_{NOx\,0.3-10.0}} = 0.1938 \ \#/10^6 \text{ BTU}$$

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Source Boilers

$$EU_{HC} = (0.4822)(.0444) + (.5178)(.0399) = .0214 + .0207$$

$$EU_{HC\ 0.3-10.0} = 0.0421 \text{ \#}/10^6 \text{BTU}$$

$$EU_{SOx} = (.4822)(.7575) + (.5178)(.7825) = .3653 + .4052$$

$$EU_{SOx\ 0.3-10.0} = 0.7705 \text{ \#}/10^6 \text{BTU}$$

$$EU_{CO} = (.4822)(.0575) + (.5178)(.0449) = .0277 + .0232$$

$$EU_{CO\ 0.3-10.0} = 0.0509 \text{ \#}/10^6 \text{BTU}$$

10.0-250

1579

$$WT\text{-}1 = \frac{921}{921+658} = .5833$$

$$WT\text{-}2 = \frac{658}{921+658} = 0.4167$$

$$EU_{P} = (1.8054)(.5833) + (2.316)(.4167) = 1.0531 + .9651$$

$$EU_{P\ 10-250} = 2.0182 \text{ \#}/10^6 \text{BTU}$$

$$EU_{NOx} = (.5833)(.3422) + (.4167)(.5223) = .1996 + .2176$$

42

$$EU_{NOx\ 10-250} = 0.4172 \text{ \#}/10^6 \text{BTU}$$

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Source Boilers

$$E_{U_{HC}} = (0.5833)(.0594) + (.4167)(.0260) = .0346 + .0108 =$$

$$E_{U_{HC\ 10-250}} = 0.0454 \ \#/10^6 BTU$$

$$E_{U_{SOx}} = (.5833)(1.8342) + (.4167)(1.8342)$$

$$E_{U_{SOx\ 10-250}} = 1.8342 \ \#/10^6 BTU$$

$$E_{U_{CO}} = (.5833)(.1684) + (.4167)(.0283) = .0982 + .0118$$

$$E_{U_{CO\ 10-250}} = 0.11 \ \#/10^6 BTU$$

>250

$$WT\text{-}3 = \frac{259}{259 + 1248} = .1718$$

$$WT\text{-}4 = \frac{1248+}{1248 + 259} = .8282$$

$$E_{U_P} = (.1718)(2.6245) + (.8282)(3.2102) = .4509 + 2.6589$$

$$E_{U_{P>250}} = 3.1098 \ \#/10^6 BTU$$

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Source Boilers

$$E_{U_{NOx}} = (.1718)(.5735) + (.8282)(.6045) = 0.0985 + .5006$$

$$E_{U_{NOx,\ >250}} = 0.5991 \ \#/10^6 \text{ BTU}$$

$$E_{U_{HC}} = (.1718)(.0206) + (.8282)(.0192) = .0035 + .0159$$

$$E_{U_{HC,\ >250}} = 0.0194 \ \#/10^6 \text{ BTU}$$

$$E_{U_{SOx}} = (.1718)(1.8342) + (.8282)(2.0224) = .3151 + 1.6750$$

$$E_{U_{SOx,\ >250}} = 1.9901 \ \#/10^6 \text{ BTU}$$

$$E_{U_{CO}} = (.1718)(.0204) + (.8282)(.0248) = .0035 + .0205$$

$$E_{U_{CO,\ >250}} = 0.0240 \ \#/10^6 \text{ BTU}$$

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Source Boilers

Summary Of Eu:

	Part	NO_x	H/C	SO_x	CO
Residential	.039	.081	.019	.107	.026
0.3-10.0	.250	.194	.042	.771	.051
10.0-250	2.018	.417	.045	1.834	.110
>250	3.110	.599	.019	1.990	.024

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Source Boilers

DETERMINATION OF E_N

RESIDENTIAL UNITS

Nothing could be found in the literature regarding specific control methods for residential units. Some mention was made of work being done but no concrete values [Ref (73) p196].

It would appear @ the present time that residential units are not amenable to control.

In order to determine the extent of uncontrolled emissions & to ascertain maximum impact, we will use the methodology used previously in our study which sets $E_N = 0.0$ so that max impact can be quantified. If the result is extremely high, we will have "flagged" an "industry" which requires a substantial R&D effort on control technology before NSPS could be set.

∴ $E_{N\ \text{ALL POLLUTANTS RES}} = 0.0$

2/5/75 Ref (202) p 7-13 indicates the potential for a 50% NO_x reduction.
So, instead of $E_N = 0.0$, we will use $E_N = (0.5)(E_U) = (.5)(.081) = 0.04$

$E_{N\ NO_x} = 0.04$ 2.3

FIRETUBE & CAST IRON

Ref (28) p 4-19 "Fuel switching is the most cost-effective strategy for reducing emissions from intermediate boilers."

Ref (28) p 4-14 "However, for steam-electric plants [>50 MW] a complete switch from high sulfur coal and oil to low sulfur oil is not feasible....."

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Source Boilers

REF (73) p214 TAB 6-3 & p 225 TAB 6-9

PARTICULATES

0.549 x 10^6 TONS/YR (UNCONTROLLED)

REDUCTION DUE TO FUEL SWITCHING = 0.349 x 10^6 TPY
REDUCTION DUE TO FUEL ADDITIVES = 0.094 x 10^6 TPY
TOTAL REDUCTION = 0.443 x 10^6 TPY

$$\eta_{\text{REDUCTION PART. FT \& CI}} = \frac{0.443}{0.549} = 80.7\%$$ *

SO_x

1.983 x 10^6 TPY (UNCONTROLLED)

REDUCTION DUE TO FUEL SWITCHING = 1.452 x 10^6 TPY
NO REDUCTION BY SUPPLEMENTAL MEANS

$$\frac{1.452}{1.983} = 73.2\%$$

$$\eta_{\text{REDUCTION } SO_x \text{ FT \& CI}} = 73.2\%$$ *

NO_x

0.574 x 10^6 TPY (UNCONTROLLED)

0.057 x 10^6 TPY REDUCTION DUE TO FUEL SWITCHING

NO REDUCTION BY SUPPLEMENTAL MEANS

$$\eta = .057/.574 = 9.9\%$$

$$\eta_{\text{REDUCTION}, NO_x \text{ FT + CI}} = 9.9\%$$ *

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Source Boilers

WATERTUBE - 1

REF (73) p 214 TAB 6-3 & p 225 TAB 6-9

PARTICULATES

1.421 x10^6 TPY (UNCONTROLLED)
1.287x10^6 TPY REDUCTION DUE TO FUEL SWITCHING
0.057x10^6 TPY REDUCTION DUE TO FUEL ADDITIVES & COMBUSTION MODIFICATION

1.344 TPY = TOTAL REDUCTION

$$\eta = \frac{1.339}{1.421} = 94.6\%$$

$\eta_{\text{REDUCTION PART WT-1}}$ = 94.6% *

SOx

2.410x10^6 TPY (UNCONTROLLED)
2.023x10^6 TPY REDUCTION DUE TO FUEL SWITCHING
NO REDUCTION BY SUPPLEMENTAL METHODS

$$\eta = \frac{2.023}{2.410} = 83.9\%$$

$\eta_{\text{REDUCTION SOx WT-1}}$ = 83.9 % *

NOx

0.620 x10^6 TPY UNCONTROLLED
0.133x10^6 TPY REDUCTION BY FUEL SWITCHING
0.268x10^6 TPY REDUCTION DUE TO COMBUSTION MODIFICATION

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Source Boilers

TOTAL REDUCTION = 0.401×10^6 TPY

$$\eta = \frac{.401}{.620} = 64.7\%$$

$$\eta_{\substack{REDUCTION \\ NOx \\ WT-1}} = 64.7\%$$ *

WATERTUBE 2 & 3

PARTICULATE

0.561×10^6 TPY (UNCONTROLLED)
0.496×10^6 TPY BY FUEL SWITCHING
0.023×10^6 TPY BY FUEL ADDITIVES & COMBUSTION MODIFICATION

TOTAL REDUCTION = 0.519×10^6 TPY

$$\eta = \frac{.519}{.561} = 92.5\%$$

$$\eta_{\substack{REDUCTION \\ PART \\ WT-2,3}} = 92.5\%$$ *

SO_x

3.239×10^6 TPY (UNCONTROLLED)
2.876×10^6 TPY REDUCTION BY FUEL SWITCHING
NO REDUCTION BY SUPPLEMENTAL METHODS

$$\eta = \frac{2.876}{3.239} = 88.8\%$$

$$\eta_{\substack{REDUCTION \\ SOx \\ WT2,3}} = 88.8\%$$ *

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Source Boilers

NOx

0.885×10^6 TPY (UNCONTROLLED)
0.271×10^6 TPY BY FUEL SWITCHING
0.350×10^6 TPY BY COMBUSTION MODIFICATION
REDUCTION

TOTAL REDUCTION = 0.621×10^6 TPY

$$\eta = \frac{.621}{.885} = 70.2\%$$

$$\eta_{\text{REDUCTION NOx WT 2,3}} = 70.2\%$$ *

WT-4 As mentioned on p 30 of these calcs, fuel switching in the large units is not feasible. Ref (73) p 28 states "only simple alkaline scrubbing was considered as practically feasible for intermediate size boilers."

Ref (73) p 212 Tab 6-2 gives control from wet scrubbing employing a sodium carbonate solution

Assume data for WT-2,3 size

Particulate

0.561×10^6 TPY (UNCONTROLLED)
0.539×10^6 TPY BY SCRUBBING
REDUCTION

$$\eta = .539/.561 = 96.1\% = \eta_{\text{REDUCTION PART WT-4}}$$ *

SOx

3.239×10^6 TPY (UNCONTROLLED)
3.072×10^6 TPY REDUCTION BY SCRUBBING

$$\eta = 3.072/3.239 = 94.8\%$$

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Calculations Done By Hoppe Date 10/2/74

Source Boilers

$$\eta_{\substack{\text{REDUCTION}\\ SO_x\\ \text{WT-4}}} = 94.8\%$$ *

NO_x

0.885 x 10^6 TPY (UNCONTROLLED)
0.177 x 10^6 TPY REDUCTION FROM WET SCRUBBING

$$\eta = \frac{.177}{.885} = 20\%$$

$$\eta_{\substack{\text{REDUCTION}\\ NO_x\\ \text{WT-4}}} = 20\%$$ *

Summary Of Effiencies:

	PART	SO_x	NO_x
CAST IRON	80.7	73.2	9.9
FIRETUBE	80.7	73.2	9.9
WT-1	94.6	83.9	64.7
WT-2	92.5	88.8	70.2
WT-3	92.5	88.8	70.2
WT-4	96.1	94.8	20.0

No information could be found regarding control of CO & H/C

We will weight these efficiencies by the fraction of capacity of that type (REF (73) p16 TAB 1-5) to det'n the avg η for each source category. This avg efficiency will then be applied to E_U to derive E_N.

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 10/18/84

Source Boilers

RESIDENTIAL

$E_N = 0.0$ #/10^6 BTU
ALL POLLUTANTS <0.3

REASONING has been PREVIOUSLY DISCUSSED

*

0.3 - 10.0

$\eta_{part} = 80.7\%$

$E_N = (1-.807)(.250) =$

$E_{N\,0.3-10.0\,PART} = 0.048$ #/10^6 BTU *

$\eta_{SO_x} = 73.2\%$

$E_N = (1-.732)(.771) = 0.207$

$E_{N\,0.3-10.0\,SO_x} = 0.207$ #/10^6 BTU *

$\eta_{NO_x} = 9.9\%$

$E_N = (1-.099)(.194) = 0.175$

$E_{N\,0.3-10.0\,NO_x} = 0.175$ #/10^6 BTU *

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 10/4/74

Source Boilers

IN A EFFORT TO DET'N THE MAX $(T_S - T_N)$ FOR REASONS PREVIOUSLY DISCUSSED:

$E_{N\,0.3-10.0\,H/C} = 0.0$ #/10^6 BTU *

$E_{N\,0.3-10.0\,CO} = 0.0$ #/10^6 BTU *

10.0 – 250 (WT1 + WT2)

PART

$$WT\text{-}1 = \frac{921}{921+658} = 0.5833$$

$$WT\text{-}2 = \frac{658}{921+658} = 0.4167$$

$$\bar{\eta}_p = (94.6)(.5833) + (92.5)(.4167) = 55.18 + 38.54$$

$$\bar{\eta}_p = 93.7\%$$

$$E_{N\,10-250\,PART} = (1-.937)(2.018) = 0.127$$

$E_{N\,10-250\,PART} = 0.127$ #/10^6 BTU *

SO_x

$$\bar{\eta}_{SO_x} = (.5833)(83.9) + (.4167)(88.8) = 48.94 + 37.00 = 85.9\%$$

$$E_{N\,10-250\,SO_x} = (1-.859)(1.834) = 0.259 \text{ #}/10^6 \text{ BTU}$$

$E_{N\,10-250\,SO_x} = 0.259$ #/10^6 BTU

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Calculations Done By Hopper Date 10/2/74

Source Boilers

NOx

$$\bar{R}_{NO_x} = (.5833)(64.7) + (.4167)(70.2) = 37.74 + 29.25$$

$$\bar{R}_{NO_x} = 67.0\%$$

$$E_{N_{10\text{-}250,\,NO_x}} = (1 - .67)(0.417) = 0.138$$

$$E_{N_{10\text{-}250,\,NO_x}} = 0.138 \ \#/10^6 \text{ BTU}$$

For reasons previously discussed

$$E_{N_{10\text{-}250,\,CO}} = 0.0 \ \#/10^6 \text{ BTU}$$

$$E_{N_{10\text{-}250,\,HC}} = 0.0 \ \#/10^6 \text{ BTU}$$

>250 (WT-3, 4)

The Reg'd NSPS for particulate is 0.1 #/10⁶BTU (Ref 273). Ref 147 p9 states that new full-scale scrubbers are being installed @ large steam generators which have been designed to meet this st'd.

Particulate

However, Ref 279 indicates that 5/8/75 a level of 0.05 could be attained using an ESP. If we assume that the cost is not prohibitive.

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Calculations Done By Hopper Date 10/2/74

Source Boilers

$$E_{N_{P>250}} = 0.05 \text{ LB}/10^6 \text{ BTU}$$

SOx

$$\bar{\eta}_{SO_x} = (.1718)(88.8) + (.8282)(94.8) = 15.26 + 78.51$$

$$\bar{\eta}_{SO_x} = 93.87\%$$

$$E_N = (1-.938)(1.990) = 0.123 \text{ \#}/10^6 \text{ BTU}$$

$$E_{N_{>250} \, SO_x} = 0.123 \text{ \#}/10^6 \text{ BTU}$$

NOx

$$\bar{\eta}_{NO_x} = (70.2)(.1718) + (20.0)(.8282) = 12.06 + 16.56$$

$$\bar{\eta}_{NO_x} = 28.6\%$$

$$E_N = (1-.286)(.599) = 0.428$$

$$E_{N_{>250} \, NO_x} = 0.428 \text{ \#}/10^6 \text{ BTU}$$

For reasons previously discussed,

$$E_{N_{>250} \, CO} = 0.0 \text{ \#}/10^6 \text{ BTU}$$

$$E_{N_{>250} \, HC} = 0.0 \text{ \#}/10^6 \text{ BTU}$$

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Computation Sheet For Emission Factors

Calculations Done By Hoppe Date 10/2/74

Source Boilers

SUMMARY OF EN: (EU SUMMARY ON P29)

	PART	NO_x	H/C	SO_x	CO
RESIDENTIAL	0.0	0.0	0.0	0.0	0.0
0.3-10.0	.048	.175	0.0	.207	0.0
10.0-250	.127	.138	0.0	.259	0.0
>250	.05	.428	0.0	.123	0.0

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 10/3/74

Source Boilers

Es DETERMINATION

PARTICULATE

THERE ARE ONLY THREE STATES (ONE IS D.C.) WITH Es FOR BOILERS LESS THAN 1×10^6 BTU/HR. THEREFORE ASSUME

$$Es_{<0.3 \text{ PART.}} = EU_{<0.3 \text{ PART.}} = 0.039 \text{ \#}/10^6 \text{ BTU}$$

REF (84) p 20-23 INCL. TAB 1 & THE ENVIRONMENTAL RPTR (UP TO & INCLUDING AUGUST '74 ADDITIONS) WERE USED AS THE REFERENCES.

SINCE VALUES OF Es FOR EACH SIZE CATEGORY WERE OF THE SAME GENERAL ORDER OF MAGNITUDE, A STRAIGHT LINEAR AVERAGE WAS ASSUMED AS OPPOSED TO AN AVERAGE WEIGHTED BY FUEL USAGE.

The attached tables give the specific STATE AVG'S for EACH SIZE CATEGORY + THE METHODOLOGY USED IN THEIR DETERMINATION IF UNIQUE.

IT WAS NECESSARY to determine AN Es for both NEW & EXISTING SOURCES.

$$Es_{0.3\text{-}10.0 \text{ PART EXISTING}} = 0.48 \text{ \#}/10^6 \text{ BTU}$$

HOWEVER,

$$E_{U\ 0.3\text{-}10.0 \text{ PART}} = 0.250 \text{ \#}/10^6 \text{ BTU}$$

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Source Boilers

$E_{S_{0.3-10.0}}$ PART NEW $= 0.428$ #/10^6 BTU

$E_U = .250$ #/10^6 BTU

$E_{S_{10-250}}$ PART EXIST $= 0.383$ #/10^6 BTU

$E_{S_{10-250}}$ PART NEW $= 0.334$ #/10^6 BTU

$E_{S_{>250}}$ PART EXIST $= 0.277$ #/10^6 BTU

$E_{S_{>250}}$ PART NEW $= 0.100$ #/10^6 BTU

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Source Boilers

REF (81) P 58-63 TAB XVIII & THE ENVIRONMENTAL REPORTER REF (148) (UP TO & INCLUDING AUGUST '74 ADDITIONS)

SO_2

$$\frac{5.817 \times 10^6 \frac{BTU}{BBL}}{42 \frac{GAL}{BBL} \times 7.309 \text{ \#/GAL}} = 18,949 \text{ BTU/\#}$$

↑ REF (101) P 9-6 AVG OF DATA FOR #2 OIL, TAB 9-9

$$\frac{\left(0.005 \frac{\#S}{\#OIL}\right)\left(2 \frac{\#SO_2}{\#S}\right)\left(10^6\right)}{18,949 \text{ BTU/\#oil}} = 0.53 \text{ \#}SO_2/10^6 BTU$$

1.06 #/BTU PER %

$$\frac{26.2 \times 10^6 \frac{BTU}{TON}}{2000 \text{ \#/TON}} = 13,100 \text{ BTU/\#}$$

$$\frac{\left(.0200 \frac{\#S}{\#COAL}\right)\left(2 \frac{\#SO_2}{\#S}\right)\left(10^6\right)}{13,100} = 3.05 \text{ \#}SO_2/10^6 BTU$$

1.53 #/10⁶ BTU PER %

Results were broken down into the following categories

Existing & New

$>250 \times 10^6$ & $<250 \times 10^6$

Coal & Oil

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Source Boilers

INDIVIDUAL WORK IS FOUND ON ATTACHED tables

FOR EXISTING SOURCES

COAL 1.971 #/10^6 BTU }
OIL 1.589 #/10^6 BTU } < 250

COAL 1.845 #/10^6 BTU }
OIL 1.451 #/10^6 BTU } > 250

FOR NEW SOURCES

COAL 1.722 #/10^6 BTU }
OIL 1.303 #/10^6 BTU } < 250

COAL 1.013 #/10^6 BTU }
OIL 0.662 #/10^6 BTU } > 250

BECAUSE of NSPS, THE REGULATIONS of those STATES WHICH were GREATER THAN 1.2 (COAL) & 0.8 (OIL) WERE considered TO BE 1.2 & 0.8, NOT THE STATED VALUES

IT IS NECESSARY to synthesize the Es values for coal & oil USING FUEL DISTRIBUTION

REF (13) p 5 TAB 1-1

Assume DATA for COMMERCIAL & INDUSTRIAL to REPRESENT BOILER CAPACITIES < 250×10^6 & UTILITY to REPRESENT BOILER CAPACITIES > 250×10^6

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HEATING VALUES HAVE BEEN PREVIOUSLY PRESENTED.
FOR < 250×10^6 BTU/HR

$$\text{TOTAL HEAT VALUE} = \underset{\text{COAL}}{(26+84)}(26.2\times10^6)(10^6) + \underset{\text{RO}}{(106+192)}(10^6)(6.384\times10^6)$$

$$+ \underset{\text{DO}}{(58+60)}(10^6)(5.817\times10^6) + \text{ GAS NOT TO BE INCLUDED}$$

$$= \underset{\text{COAL}}{2.882\times10^{15}} + \underset{\text{RO}}{1.902\times10^{15}} + \underset{\text{DO}}{.686\times10^{15}} = 5.47\times10^{15}$$

% COAL = 53%
% OIL = 47%
} For boilers < 250×10^6 USING COAL OR OIL

$$E_{S_{<250, SO_x, EXIST.}} = (1.971)(.53) + (1.589)(.47) = 1.0446 + .7468$$

$$E_{S_{SO_x, <250, EXISTING}} = 1.791 \text{ \#}/10^6 \text{BTU}$$

$E_{U_{.3-10}} = .771$

$E_{U_{10-250}} = 1.834$

$$E_{S_{<250, SO_x, EXIST}} = (1.722)(.53) + (1.305)(.47) = .9127 + .6124$$

$$E_{S_{<250, SO_x, NEW}} = 1.525 \text{ \#}/10^6 \text{BTU}$$

$E_{U_{.3-10}} = .771$

$E_{U_{10-250}} = 1.834$

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Source Boilers

FOR >250x10^6 BTU/HR

TOTAL HEATING VALUE $= (271\times10^6)(26.2\times10^6) + (156\times10^6)(6.384\times10^6) + (2\times10^6)(5.817\times10^6)$

+ GAS NOT INCLUDED

$= 7.100\times10^{15} + .9959\times10^{15} + .0116\times10^{15} = 8.108\times10^{15}$

COAL RO DO

% COAL = 87.6 %

% OIL = 12.4 %

$Es_{>250\ SO_x\ EXIST} = 1.845(.876) + 1.451(.124) = 1.6162 + .1799$

$Es_{>250\ SO_x\ EXIST} = 1.796$ #/10^6 BTU

$Es_{>250\ SO_x\ NEW} = (1.013)(.876) + (.662)(.124) = .8874 + .0821 = .9695$

$Es_{>250\ SO_x\ NEW} = 0.970$ #/10^6 BTU

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Source Boilers

NOx

Ref (84) p64-65 TAB XIX
&
Ref (148) (up to & including August '74 additions)

See attached Table for summary

Not all states have NO_x regs for all fuels for all sizes for both new & existing

Regs for those that do have been synthesized using fuel distribution data from Ref (73) p5 Tab 1-1. These in turn are added to the previously det'd value of Eu by weighting on a straight line basis as a function of # of states w & w/o regs

For <250x10⁶ BTU/HR

$$\text{Total Heat Value} = (26+84)(10^6)(26.2\times10^6) + (106+92)(10^6)(6.384\times10^6) + (58+60)(10^6)(5.817\times10^6) + (1.33+1.99)(10^{12})(1040)$$

$$= \underset{\text{Coal}}{2.882\times10^{15}} + \underset{\text{RO}}{1.902\times10^{15}} + \underset{\text{DO}}{.686\times10^{15}} + \underset{\text{Gas}}{3.453\times10^{15}} = 8.923\times10^{15}$$

% Coal = 32%
% Oil = 29%
% Gas = 39%

For existing <250 $E'_{S_{NO_x}} = (.39)(.2182) + (.29)(.3) + (.32)(.7333)$
$= .0851 + .0871 + .2347 = .4069$

$E'_{S_{NO_x}} = 0.4069$ #/10⁶ BTU (28 categories out of 153)

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Source Boilers

VALUES OF E_U FOR EACH SIZE CLASS HAVE PREVIOUSLY BEEN DET'D & SUMMARIZED ON P 29 OF THESE CALCS

$(0.3-10)\times10^6$ BTU/HR

$$E_{S_{NO_x,\,0.3-10}} = \frac{(0.194)(153-28)}{153} + \frac{(.4069)(28)}{153} = 0.1585 + .0745 = .233$$

$$E_{S_{NO_x,\,0.3-10.0\ \text{EXISTING}}} = 0.233\ \#/10^6\ \text{BTU}$$

$E_U = 0.194\ \frac{\#}{10^6\ \text{BTU}}$

$$E_{S_{NO_x,\,10-250}} = \frac{(.417)(153-28)}{153} + \frac{(.4069)(28)}{153} = .3407 + .0745 = .4152$$

$$E_{S_{NO_x,\,10-250\ \text{EXISTING}}} = 0.415\ \#/10^6\ \text{BTU}$$

FOR EXISTING $>250\times10^6$

$$\text{TOTAL HEAT VALUE} = (271\times10^6)(26.2\times10^6) + (156\times10^6)(6.384\times10^6) + (2\times10^6)(5.817\times10^6) + (2.76\times10^{12})(1040)$$

$$= 7.100\times10^{15}\ (\text{COAL}) + .9959\times10^{15}\ (\text{RO}) + .0116\times10^{15}\ (\text{DO}) + 2.8704\times10^{15}\ (\text{GAS}) = 10.9779\times10^{15}$$

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Source Boilers

% Coal = 65%

% Oil = 9%

% Gas = 26%

For existing > 250

$$E'_{S_{NO_x}} = (.2333)(.26) + (.3158)(.09) + (.7)(.65)$$

$$= .0607 + .0284 + .455 = .5441$$

$$E'_{S_{NO_x}} = .5441 \quad (49 \text{ out of } 153 \text{ categories})$$

$$E_{S_{NO_x}} {}_{>250} = (.5441)\left(\frac{49}{153}\right) + (.599)\left(\frac{153-49}{153}\right) = .1743 + .4072 = .5815$$

$$E_{S_{NO_x}} {}_{>250 \text{ exist}} = 0.582 \ \#/10^6 \text{BTU}$$

For new < 250

$$E'_{S_{NO_x}} = (.2133)(.39) + (.3000)(.29) + (.6950)(.32)$$

$$= .0832 + .087 + .2224 = .3926$$

$$E'_{S_{NO_x}} {}_{<250 \text{ new}} = .3926 \quad (40 \text{ out of } 153 \text{ categories})$$

$$E_{S_{NO_x}} {}_{.3-10.0 \text{ new}} = (.3926)\left(40/153\right) + (.194)\left(\frac{153-40}{153}\right) = .1026 + .1433 = .2459$$

$$E_{S_{NO_x}} {}_{.3-10.0 \text{ new}} = 0.246 \ \#/10^6 \text{BTU} \qquad E_U = .194 \ \#/10^6 \text{BTU}$$

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$$Es_{NOx_{10-250}} = (0.3926)\left(\frac{40}{153}\right) + (.417)\left(\frac{153-40}{153}\right) = .1026 + .3079 = .4106$$

$$Es_{NOx_{10-250 \text{ NEW}}} = 0.411 \ \#/10^6 \text{ BTU}$$

IN ALL CASES, FOR NEW UNITS GREATER than 250×10^6 BTU/HR, NSPS will be IN ~~EFFECT~~.

From Ref (147) p 4

$Es_{gas} = 0.2$

$Es_{oil} = 0.3$

$Es_{coal} = 0.7$

From p 49 of these calcs

% Coal = 65

% oil = 9

% Gas = 26

$$Es_{NOx_{>250 \text{ NEW}}} = (.65)(.7) + (.09)(.3) + (.26)(.2) = .455 + .027 + .052 = .534$$

$$Es_{NOx_{>250 \text{ NEW}}} = 0.534 \ \#/10^6 \text{ BTU}$$

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Source Boilers

There are no state regs applicable to boilers for CO & H/C.

Assume, therefore, that Es = Eu

	Particulate		NO_x		H/C		SO_x		CO	
	Exist	New	Exist	New	Exist	New	Exist	New	Exist	New
Resid.	.039	.039	.081	.081	.019	.019	.107	.107	.026	.026
0.3-10.0	.480*	.428*	.233*	.246*	.042	.042	1.791*	1.525*	.051	.051
10-250	.383	.334	.415	.411	.045	.045	1.791	1.525	.110	.110
>250	.277	.100	.582	.534	.019	.019	1.796	.970	.024	.024

* These values of Es are greater than the values of Eu. This difference is probably due to the relative breakdowns of fuel types. This size category uses a substantial percentage of natural gas which generally results in lower uncontrolled emissions of part., NO_x & SO_x than do oil & coal. It is oil & coal that most fuel burning regs apply to. Therefore, the summary below will replace the values within the 0.3-10.0 MMBTU/HR category. They are the Eu values.

	Part.		NO_x		HC		SO_x		CO	
0.3-10.0	.250	.250	.194	.194	.042	.042	.771	.771	.051	.051

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Source Boilers

FLUORIDES – EU

Although coal contains only 0.01% (wt) Fluorine (Ref (234) p 3-130), its use in large quantities results in an appreciable annual emission.

Ref (234) p 3-131 gives an emission factor of 0.16 LB F/ton coal

For a heating value of 26.2x10⁶ BTU/ton

$$EU_{F^-}\Big]_{COAL} = \frac{0.16\ LB/ton}{26.2\times10^6\ \frac{BTU}{TON}} = 0.00611\ LB/10^6\,BTU$$

For small units <0.3 x10⁶ BTU/HR, no coal is used; ∴ no F⁻ emissions

From p4 of these calcs, the % coal for firetube boilers is 11.6%

$$EU_{F^-_{FT}} = (.116)(.00611) = 0.000709\ LB/10^6\,BTU \quad *$$

From p 9, the % coal for cast iron boilers = 14.9%

$$EU_{F^-_{CI}} = (.149)(.00611) = 0.000910\ LB/10^6\,BTU \quad *$$

From p 12, 16, 20, 23 the following % coal were shown

WT-1, 2, 3, – 52.7%

WT-4 — 64.7%

$$EU_{F^-_{WT-1,2,3}} = (.527)(.00611) = 0.00322\ LB/10^6\,BTU \quad *$$

$$EU_{F^-_{WT-4}} = (.647)(.00611) = 0.00395\ LB/10^6\,BTU \quad *$$

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Source Boilers

The breakdown of boiler types & heat input ranges are from pages 25-27 of these calcs.

$$E_{UF^-_{.3-10}} = (.4822)(.000910) + (.5178)(.000709)$$
$$= .0004388 + .0003671 = 0.000806$$

$$E_{UF^-_{.3-10}} = 0.000806 \ LB/10^6 BTU$$

$$E_{UF^-_{10-250}} = (.5833)(.00322) + (.4167)(.00322)$$

$$E_{UF^-_{10-250}} = 0.00322 \ LB/10^6 BTU$$

$$E_{UF^-_{>250}} = (.1718)(.00322) + (.8282)(.00395)$$
$$= .0005531 + .0032713 = 0.00382$$

$$E_{UF^-_{>250}} = 0.00382 \ LB/10^6 BTU$$

E_N From pages 36-39 of these calc's, the synthesized "η" for control for each boiler size is given for SOx control from fuel switching (<250) & alkaline scrubbing (>250). We will use these same η's for HF (gaseous) control, since the fluoride

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Source Boilers

emission is gaseous.

$$E_{NF^-_{.3-10}} = (1-.732)(0.000806) = 0.000216$$

$$E_{NF^-_{.3-10}} = 0.000216 \text{ LB}/10^6\text{BTU}$$

$$E_{NF^-_{10-250}} = (1-.859)(.00322) = 0.000454$$

$$E_{NF^-_{10-250}} = 0.000454 \text{ LB}/10^6\text{BTU}$$

$$E_{NF^-_{>250}} = (1-.938)(0.00382) = 0.000237$$

$$E_{NF^-_{>250}} = 0.000237 \text{ LB}/10^6\text{BTU}$$

E_S Since there are no regs for fluoride emissions from boilers $E_S \equiv E_U$.

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Source Boilers

Summary Of Fluoride Emission Factors

	E_U	E_N	E_S
0.3-10	.000806	.000216	.000806
10-250	.00322	.000454	.00322
>250	.00382	.000237	.00382

Trace Metals

Trace metals will include
Arsenic, Beryllium, Cadmium, Manganese, Mercury, Nickel & Vanadium
All emission factors (E_U) are from Ref (230). They are summarized as follows:

	Coal (#/1000 tons)	Oil (#/1000 gals)
Arsenic	3.0	.001
Beryllium	.03	.2
Cadmium	1.0	.03
Manganese	80.0	.001
Mercury	.40	.0004
Nickel	3.0	.3
Vanadium	.50	.2
TOTAL	87.93 #/1000 tons	0.7324 #/1000 gals

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Calculations Done By ______________ Date ______________

Source ______________

For a coal HV = 26.2×10^6 BTU/ton & an oil (Avg of RO & DO) of

$$\frac{\left(6.384 \times 10^6 \frac{BTU}{BBL} + 5.817 \times 10^6 \frac{BTU}{BBL}\right)}{(2)(42 \text{ gal/BBL})} = 145,250 \text{ BTU/gal}$$

$$E_{U_{TM}\,COAL} = \frac{87.93 \times 10^{-3}}{26.2 \times 10^6} = 0.00336 \text{ LB}/10^6\text{BTU} \quad *$$

$$E_{U_{TM}\,OIL} = \frac{0.7324 \times 10^{-3}}{145,250} = 0.00504 \text{ LB}/10^6\text{BTU} \quad *$$

We will go thru an analysis similar to that for fluorides using info previously developed in these calcs.

Residential ($<.3 \times 10^6$ BTU/HR)

38.7% oil

$$E_{U_{TM}\,<.3} = (.387)(.00504) = 0.00195$$

$$E_{U_{TM}\,<.3} = 0.00195 \text{ LB}/10^6\text{BTU} \quad *$$

Firetube

11.6% coal
41.4% oil

$$E_{U_{TM}\,FT} = (.116)(.00336) + (.414)(.00504) = .00039 + .00209$$

$$E_{U_{TM}\,FT} = 0.00248 \quad *$$

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Cast Iron

14.9% coal
29.6% oil

$$E_{U_{TM}\,CI} = (.149)(.00336) + (.296)(.00504) = .000501 + .00149$$

$$E_{U_{TM}\,CI} = 0.00199 \text{ LB}/10^6 \text{ BTU}$$ *

WT-1,2,3

% coal = 52.7%
% oil = 20.1%

$$E_{U_{WT-1}\,TM} = (.527)(.00336) + (.201)(.00504)$$
$$= .00177 + .00101 =$$

$$E_{U_{TM}\,WT-1,2,3} = .00278 \text{ LB}/10^6 \text{ BTU}$$ *

WT-4

64.7% coal
9.2% oil

$$E_{U_{WT-4}\,TM} = (.647)(.00336) + (.092)(.00504) = .002174 + .000464$$

$$E_{U_{TM}\,WT-4} = 0.00264 \text{ LB}/10^6 \text{ BTU}$$ *

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$$E_{U_{TM}\,.3-10} = (.4822)(.00199) + (.5178)(.00248) = .00096 + .00128$$

$$E_{U_{TM}\,.3-10} = 0.00224 \text{ LB}/10^6\text{BTU}$$

$$E_{U_{TM}\,10-250} = 0.00278 \text{ LB}/10^6\text{BTU}$$

$$E_{U_{TM}\,>250} = (.1718)(.00278) + (.8282)(.00264) = .000478 + .00219$$

$$E_{U_{TM}\,>250} = 0.00267 \text{ LB}/10^6\text{BTU}$$

$\underline{E_N}$

Since there are no particulate control methods demonstrated for residential units, we will assume (as for particulates)

$$E_{N_{TM}\,<.3} = 0.0$$

For units 0.3-10.0, fuel switching was the control method. The effective control "η" for units this size (part.), is 80.7%

$$E_{N_{TM}\,.3-10} = (1-.807)(.00224) = 0.00043 \text{ LB}/10^6\text{BTU}$$

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$$E_{N_{TM}\ .3-10} = 0.00043 \ LB/10^6 BTU$$

$$E_{N\ 10-250} = (1-.937)(.00278) = 0.000175 \quad \text{(fuel switching)}$$

$$E_{N_{TM}\ 10-250} = 0.00018 \ LB/$$

For units >250, an ESP was used to control particulate which would also control trace metals.

$$\left(\frac{.05}{3.11}\right)(.00267) = .00004 \qquad E_{N_{TM}\ >250} = 0.00004$$

E_S

Although there are no regs for trace metals, the control of particulate will control TM's defacto. We will, ∴, use the E_S for particulate & its relationship to E_U to get an E_S for TM's.

Since there are essentially no regs for residential units, $E_S = E_U$

$$E_{S_{TM}\ <.3} = 0.00195 \ LB/10^6 BTU$$

For units 0.3-10, E_S was greater than E_U; ∴, $E_S = E_U$

$$E_{S_{TM}\ .3-10} = 0.00224 \ LB/10^6 BTU$$

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E_{SP} (10-250, EXIST) = .383

E_{UP} (10-250) = 2.018

$$\frac{.383}{2.018} = \frac{X}{.00278} \qquad X = 0.00053$$

E_{STM} (10-250, EXIST) = 0.00053 LB/10^6 BTU

E_{SP} (10-250, NEW) = .334

$$\frac{.334}{2.018} = \frac{X}{.00278} \qquad X = 0.00046$$

E_{STM} (10-250, NEW) = 0.00046 LB/10^6 BTU

E_{SP} (>250, EXIST) = 0.277

E_{UP} (>250) = 3.110

$$\frac{.277}{3.110} = \frac{X}{.00267} \qquad X = 0.00024$$

E_{STM} (>250, EXIST) = 0.00024 LB/10^6 BTU

E_{SP} (>250, NEW) = 0.144

$$\frac{.100}{3.11} = \frac{X}{.00267} \qquad X = 0.00009$$

E_{STM} (>250, NEW) = 0.00009 LB/10^6 BTU

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Source Boilers

Summary Of Trace Metal Emission Factors

	E_U	E_N	$E_{S_{EXIST}}$	$E_{S_{NEW}}$
<0.3	.00195	0.0	.00195	—
.3 - 10.0	.00224	.00043	.00224	—
10.0-250	.00278	.00018	.00053	.00046
>250	.00267	.00004	.00024	.00009

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Source Boilers

$E_{111(d)}$

For units < 250 x 10^6 BTU/HR, the control technique was fuel switching which can be accomplished for existing sources. Therefore, E_{111d} for TM's & Fluorides is equal to E_N.

$$E_{111d_{TM, F^-}} = E_{N_{TM, F^-}} \quad \text{for} < 250 \times 10^6$$

However, for units > 250 x 10^6 BTU/HR, alkaline scrubbing was the control technique. This is non-amenable to retrofit on existing installations. Therefore, E_{111d} for fluorides is equal to $E_{S\,existing}$

$$E_{111d_{F^-}} = E_{S_{F^-\,existing}} \quad > 250 \times 10^6$$

An ESP could conceivably be retrofit to an existing installation; ∴ E_{111d} for TM's is equal to E_N for TM

$$E_{111d_{TM}} = E_{N_{TM}} \quad \text{for} > 250 \times 10^6$$

Particulate Reg's. Fuel Burning

#/10⁶ BTU

	0.3–10.0 MM BTU/HR	[illegible]–250 MMBTU/HR	>250 MM BTU/HR
Alabama	0.5 (AVG)	.27 (AVG [illegible]); .21 (AVG [illegible])	.12
Alaska	0.1 (ALL [illegible])	.1 (AVG)	.10
Arizona	0.6	[illegible] (AVG)	.28 (AVG)
Arkansas	0.25 (EX) no reg	2.0 (EX no reg)	3.1 (EX) no reg
Colorado			
California	0.30 (AVG)	.15	.10
Conn.	0.20 (EXIST); 0.1 (NEW)	[illegible] (EXIST); [illegible] (NEW)	.20 (EXIST); .10 (NEW)
Delaware	0.30	.30	.30
D.C.	0.12	[illegible]	[illegible]
Florida	[illegible] ([illegible])	[illegible]	.10
Georgia	0.7 (EXIST); 0.5 (NEW)	[illegible]	[illegible] (EXIST); .10 (NEW)
Hawaii	0.6	.6	.6
Idaho	0.6	[illegible]	.12
Illinois	0.1 ([illegible])	.1	.1
Indiana	0.6	.5 ([illegible]); [illegible]	.2
Iowa	0.8 (EXIST); 0.6 (NEW)	[illegible]	.8 (EXIST); .6 (NEW)
Kansas	0.6	[illegible] (AVG)	.16 (AVG)
Kentucky	0.75 (EXIST); 0.56 (NEW)	.44 (EXIST); .27 (NEW)	.15 (AVG EXIST); .10 (NEW)
Louisiana	0.6	.6	.6
Maine	0.6	.3	.3
Maryland	0.6	.35	.15 (AVG)
Mass.	0.15 (EXIST); 0.10 (NEW)	.16 (EXIST); .10 (NEW)	.21 (AVG); .1 (NEW)
Michigan			
Minn.	0.6 (EXIST); 0.4 (NEW)	.6 (EXIST); .4 (NEW)	.6 (EXIST); .4 (NEW)
Miss.	0.6	.41	.21 (AVG)
Missouri	0.6	.39 (AVG)	.16 (AVG)
Montana	0.6	.40 (EXIST); .35 (NEW)	.22 (AVG EXIST); .2 (NEW)
Nebraska	0.6	.35	.15 (AVG)
Nevada	0.6	.35	.11 (AVG)
N. Hampshire	0.6	.43 (EXIST); .37 ([illegible] AVG)	.23 (AVG)
N. Jersey	0.6	.24 (AVG)	.10
N. Mexico	.56	.40 (AVG)	.15
New York	.35 (EXIST); 0.1 (NEW)	.43 (EXIST); .1 (NEW)	.10
N. Carolina	.6	.33	.13
N. Dakota	.8 (EXIST); .6 (NEW)	.46	.25
Ohio	.5 (AVG)	.2	.10

Oklahoma	.6	.35	.13
Oregon	.33 (exist); .17 (new)	.33 (exist); .17 (new)	.33 (exist); .17 (new)
Penn.	0.4	.25 (avg)	.18 (avg)
R.I.	Consider not applicable	Same comment	Same comment
S. Carolina	.6	.6	not applicable
S. Dakota	.3	.3	.3
Tennessee	.6	.34 (exist); .2 (new)	.18 (existing); .1 (new)
Texas	.2 (avg)	.2 (avg)	.2 avg
Utah	Consider not applicable	Same comment	Same comment
Vermont	.5	.3	.1
Virginia	.4	.4	.1
Washington	.33 (exist); .17 (new)	.33 (exist); .17 (new)	.33 (exist); .17 (new)
W. Virginia	.10 (avg)	.10 avg	.10 (avg)
Wisconsin	.35 (exist avg); .15 (new)	.15	.10
Wyoming	.6 (exist); .1 (new)	.4 (exist); .1 (new)	.21 (exist); .1 (new)
	.420 (exist); .4?? (new)	.383 (exist); .334 (new)	.277 (exist); .248 (new)

① Where new installations are not specifically noted, max rate is the same as existing.

② Many states have $E_{s>210} > .200$. Therefore, E_{s} must be reevaluated assuming that 0.2 (NSPS) will exist for those states whose present reg is $> .2$. Those which are $< .200$ will remain in effect. $6.63/46 = 0.144$ #/10^6 BTU.

③ Avg = Avg of regs within given size category

④ Arkansas has no reg — assume uncontrolled

Summary of NO_x Regs – Fuel Burning #/10^6 BTU

	Existing						New					
	<250			>250			<250			>250		
	Gas	Oil	Coal	Gas	Oil	Coal	Gas	Oil	Coal	Gas	Oil	Coal
Ala										.2	.3	.7
Alask												
Ariz	.2	.3	.7	.7	.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ark												
Colo												
Cal												
Ct.	.2	.3	.9	.2	.3	.7	[illegible]	[illegible]	.7	[illegible]	[illegible]	.7
Del				[illegible]	[illegible]	[illegible]				.2	.3	.3
DC				.7	.3	[illegible]				.2	[illegible]	.7
Fla							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.7
GA							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hawi												
Idl												
Ill							.2	[illegible]	.7	[illegible]	[illegible]	[illegible]
Ind				.2	.3	.7				[illegible]	[illegible]	.7
Iowa	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
Kans							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.7
Ky										.2	.3	.7
LA												
Maine												
Md										[illegible]	.3	[illegible]
Mass										.3	.3	.3
Mich												
Minn				.2	.3					.2	.3	
Miss												
Mo												
Mont												
Neb				.2	.3					[illegible]	[illegible]	
Nev												
NH												
NJ												
NM	.3	.5	.7	[illegible]	.3	.7	.2	[illegible]	.95	.2	.3	.05
NY	.2	.3	.7	.2	[illegible]	.7	.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NC				.6	.4	1.7				.6	.6	1.3
ND												
Ohio												

NOx

	Existing						New					
	<200			>200			<200			>200		
	G	O	C	G	O	C	G	O	C	G	O	C
Orig.	.2	.3	.7	.2	.3	.7	.2	[illegible]	[illegible]	[illegible]	[illegible]	.7
Oper.												
Perm	.3	.3		.3	.3		[illegible]	[illegible]		.3	.3	
RI	.2	.3		.2	.3		[illegible]	[illegible]		[illegible]	.3	
S.C												
SD	.2	.3		.2	.3		[illegible]	[illegible]		[illegible]	[illegible]	
Tenn	.2	.3	.7	.2	.3	.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.7
Tex												
WaL												
Vt				[illegible]	.3	.7					[illegible]	[illegible]
VA				.2	.3	.7				[illegible]	[illegible]	[illegible]
Wash												
W. Va												
Misc										.7	[illegible]	.7
Oper.	.2	.3	[illegible]	.2	.3		[illegible]	[illegible]		[illegible]	[illegible]	
	2.4/11	3.3/11	4.4/6	4.2/13	[illegible]	6.4/12	[illegible]/12	4.5/[illegible]	6.75/10	[illegible]/27	2.7/23	12.35/21
	.2182	.3000	.7333	.2333	.3158	.7000	.2133	.3000	.6750	.2259	.3107	.5875

Summary of Regs – Fuel Burning
#/10^6 BTU

	Existing Eq				New Eq			
	<250		>250		<250		>250	
	Coal	Oil	Coal	Oil	Coal	Oil	Coal	Oil
Ala	1.35	1.35	1.35	1.35	1.2	1.2	1.2	1.2°
Alaska	1.0 →							° →
Ariz								
Ark								
Colorado	0.3 →							→
Cal	.							
Ct	.77	.53	.77	.53	.77	.53	.77	.53
Del	.46	.22	.46	.22	.46	.22	.46	[illegible]
DC	.77	.53	.77	.53	.77	.53	.77	.53
Fla	1.00	1.77	1.5	1.1	1.00	1.77	1.2	.8
Ga	3.82	2.65	4.49	3.18	1.2	.8	1.2	.8
Haw	3.05	3.05	.53	.53	3.05	3.05	.53	.53
Id								°
Ill	1.8	.65	1.8	.65	1.8	.65	1.2	.55
Ind.	1.2 →							° →
Iowa	5.0	1.5	6.0	1.5	6.0	1.5	5.0*	1.5°
Kans.	1.99	1.99	1.5	1.5	1.99	1.99	1.5*	1.5°
Ky	3.2	2.05	2.37	1.56	3.2	2.05	2.37*	1.56°
LA								
Maine	3.52	2.11	3.52	2.11	3.52	2.11	3.52*	2.11°
Md	1.53	.13	1.53	.13	1.53	.13	1.53*	.13
Mass.	.77	.38	.77	.38	.77	[illegible]	.77	[illegible]
Mich.	2.8	1.95	2.8	1.95	2.8	1.95	2.8*	[illegible]°
Minn	3.05	2.12	3.05	2.12	3.05	2.12	3.05*	[illegible]°
Miss	4.8 →				2.4 →		*	° →
Mo	2.15 →				1.4 →		*	° →
Mont	2.0 →						*	° →
Neb								
Nev	1.06 →		2.5 →		1.06 →		2.5* →	°
NH	2.0	.83	2.0	.83	1.0	.83	1.0	.83°
NJ	0.3 →							→
NM	1.99	1.99	.34	.34	1.99	1.99	.34	.34
NY	.4	.11	.4	.11	.4	.11	.4	.11°
NC	2.3 →				1.6 →			° →
ND	3.0 →						*	° →

Notes (right margin):
- Ariz / Ark: Ground level / Ground level
- Id: Not yet published
- LA: Incl't
- Neb: Ground level

Due to NSPS
* 1.2
° 0.8

SO_2

	Existing ES				New ES				
	<250		>250		<250		>250		
	Coal	Oil	Coal	Oil	Coal	Oil	Coal	Oil	
Ohio	2.0	2.0	1.1	1.1	1.0	→		o	
Okl					3.0	.8	[illegible]		[illegible]
Oreg	1.6	1.1	1.2	.8	1.0	1.0	1.2	.8	
Penn	.46	.27	.46	.27	.46	.27	.46	.27	
RI	1.53	1.06	1.53	1.06	1.53	1.06	1.53*	1.06°	
SC	2.0	→					*	→	
SD	3.0	→					*	→	
Tenn									I and F
Tex									Ground [illegible]
Utah	1.53	1.??	1.53	1.59	1.53	1.59	1.53*	1.59°	
Vt	1.53	1.06	1.53	1.06	1.53	1.06	1.53*	1.06°	
VA									Ground Coal
Wash	1.5	→					*	o	
W Va	1.53	.53	1.53	.53	1.53	.53	1.53*	.53	
Wisc	1.99	→			1.2	.8	1.2	.8	
Wyoming	1.09	→					*	o	
	80.83 / 41 =	65.16 / 41 =	75.66 / 41 =	59.49 / 41 =	72.32 / 42 =	54.73 / 42 =	42.56 / 42 =	[illegible] / 42 =	
	1.971	1.589	1.845	1.451	1.722	1.303	1.013	0.6??	

[illegible]:
* 1.2
o 0.8

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 1/3/75

Source MIXED FUEL Boilers

For the purpose of this study, we will define mixed fuel boilers as those which simultaneously fire fossil fuel & municipal refuse for the purpose of generating steam. This decision is made for the following reasons:

(1) This "industry" has the potential for rapid growth in the immediate future

(2) The analysis of "fossil fueled boilers" was based on fuel usage &, therefore, covers emissions from any combination of fuels.

(3) The combustion of process gas was covered under petroleum refineries + any combination with natural gas would have been covered under note (2) above.

(4) Any combination of wood waste and an auxiliary fuel is covered under wood waste boilers & note (2) above.

Ref (249) p 7ff Tab 1 Gives Existing & Projected 1980 capacity. Summarizing in TPD

	COAL + REF	OIL + REF
3000	200	550
1500	300	900
900	1500	1500
1000	2000	2500
1400	17	2200
1500	1150	1210
1400	1000	500
1000	1000	1250
(600)	700	1200
2000	1400	Σ = 11,810
6000	1000	
750	1350	
950	200	
1000	1250	
640	1100	
	1750	
Σ = 40,057	1100	

Where coal or oil were optional, coal was chosen

( ) = Existing

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 1/3/75

Source Mixed Fuel Boilers

Presently, there is only one combined-fired unit - St Louis (Meremac)
This is rated @ 600 TPD. The values are to be considered as "speculation only" (ref (249) p 7)

40,057 + 11,810 = 51,867 TPD in 1980

Assuming simple growth between 1975 & 1980

$$\frac{51,867}{5} = 10,373 \text{ TPD/YR}$$

If 1975 capacity is assumed to be 600 TPD, then

$$P_C = \frac{10,373}{600} = 17.29 \; !$$

The reason for this phenomenal value is due to the low baseline year capacity.

$$P_C = 17.29$$ simple

$$A = (600)(5)(52) = 156,000 \text{ TPY}$$

← Assumes that refuse is collected 5 days per week

$$A = 0.156 \times 10^6 \text{ tons refuse burned}$$ ← see page 3

Since these will all be new units, it is assumed that replacement will not occur before 1985.

$$P_B = 0$$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 1/3/75

Source Mixed Fuel Boilers

We will assume a K equal to that for boilers. Since most new units will exceed 1000 x10⁶ BTU/HR, we will use the K developed for boilers >250 x 10⁶ BTU/HR. (See "Industrial Factors - Fossil-Fueled Boilers")

$$K = 0.58$$

Since emissions/control/regs differ for coal & oil, A must be broken down

$$\% \text{ Coal} = \frac{40,057}{51867} = 77\%$$

$$\% \text{ oil} = \frac{11,810}{51867} = 23\%$$

Assuming that this same breakdown holds in 1985

$$A_{\text{coal refuse}} = (.77)(.156 \times 10^6) = 0.120 \times 10^6$$

$$A_{\text{coal refuse}} = 0.120 \times 10^6 \text{ tons refuse}$$

$$A_{\text{oil ref}} = (.23)(.156 \times 10^6) = 0.036 \times 10^6$$

$$A_{\text{oil refuse}} = 0.036 \times 10^6 \text{ tons refuse}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 1/3/75

Source Mixed Fuel Boilers

For the purpose of developing emission factors, we will assume that 20% of the heat input is supplied by refuse & the remaining 80% either coal or oil.

Particulate

Coal + Refuse

$$E_U = f\left(7.32\ \text{LB}/10^6\ \text{BTU}\right)$$ Ref (249) p 79 TAB 13

We must now convert this to LB/TON REFUSE

Ref (249) p 24

5000 BTU/LB REFUSE

$$\left(\frac{\text{LB}}{\text{BTU TOTAL}}\right)\left(\frac{\text{BTU TOTAL}}{\text{TON WASTE}}\right) = \text{LB}/\text{TON WASTE}$$

$$\left(\frac{\text{BTU TOTAL}}{\text{TON WASTE}}\right) =$$

$$5000\ \frac{\text{BTU}}{\text{LB REF}} \times 2000\ \frac{\text{LB REF}}{\text{TON REF}} = 10 \times 10^6\ \frac{\text{BTU}}{\text{TON REF}}$$

$$\frac{10 \times 10^6}{0.2} = \frac{\text{TOTAL BTU}}{\text{TON REF.}} = 50 \times 10^6\ \text{BTU TOTAL}/\text{TON REF}$$

$$\left(7.32 \times 10^{-6}\right)\left(50 \times 10^6\right) =$$

$$E_{U_{P_{COAL}}} = 366\ \text{LB}/\text{TON REFUSE}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 1/3/75

Source Mixed Fuel Boilers

Ref (249) p 94-112 indicates that ESP efficiencies =99% are possible by adding surface area to existing designs. With this assumption

$$E_{N_{P_{COAL}}} = (1-.99)(366) = 3.66 \text{ LB/TON REFUSE}$$

$$E_{N_{P_{COAL}}} = 3.66 \text{ LB/TON REFUSE}$$

Since all units will be new units & assuming that NSPS regs for boilers > 250×10⁶ BTU/HR apply (& not NSPS for incinerators)

$$E_S = f(0.1 \text{ LB}/10^6)$$

Converting

$$E_{S_{P_{COAL}}} = (0.1 \times 10^{-6})(50 \times 10^6) = 5.0$$

$$E_{S_{P_{COAL}}} = 5.0 \text{ LB/TON REFUSE}$$

Oil & Refuse

Ref (249) p 8 TAB 18

$$E_U = f(2.03 \text{ LB}/10^6 \text{ BTU})$$

Converting,

$$E_U = (2.03 \times 10^{-6})(50 \times 10^6) = 101.5$$

$$E_{U_{P_{OIL}}} = 101.5 \text{ LB/TON REFUSE}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 1/6/75

Source Mixed Fuel Boilers

Using the same ESP efficiency as for coal & refuse,

$$E_N = (1-.99)(101.5) = 1.02$$

$$E_{N_{P_{oil}}} = 1.02 \text{ LB/TON refuse}$$

The Es for oil from new boiler units >250x10^6 BTU/HR is

$$E_S = f(.1 \text{ \#}/10^6 \text{BTU}) \quad (\text{Same as coal})$$

$$E_{S.P_{oil}} = 5.0 \text{ LB/TON refuse}$$

NOx

Coal & Refuse

From Ref (249) p79 TAB 13

$$E_U = f(.75 \text{ LB}/10^6 \text{BTU})$$

Converting

$$E_U = (.75 \times 10^{-6})(50 \times 10^6) = 37.5 \text{ LB/TON refuse}$$

$$E_{U_{NOx\ coal}} = 37.5 \text{ LB/TON refuse}$$

Ref (249) p 115 TAB 24

$$E_{N_{NOx}} = f(\eta = 60\%)$$ Using flue gas recirculation & off stoichiometric combustion (oil + refuse)

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 1/6/75

Source Mixed Fuel Boilers

Assuming that a similar reduction can be realized for coal & refuse,

$$E_N = 37.5(1-.6) = 15.0$$

$$E_{N_{NOx}\,coal} = 15.0 \text{ LB/TON Refuse}$$

The NSPS, NOx reg for coal = 0.7 LB/10^6 BTU

Converting

$$E_S = (.7)(50) = 35.0$$

$$E_{S_{NOx}\,coal} = 35.0 \text{ LB/TON Refuse}$$

Oil & Refuse

Ref (249) p88 TAB 18

$$E_U = f(.69 \text{ LB}/10^6 \text{BTU})$$

Converting

$$E_U = (.69)(50) = 34.5$$

$$E_{U_{NOx}\,oil} = 34.5 \text{ LB/TON Refuse}$$

As mentioned on p3 of these calcs, $\eta = 60\%$

$$E_N = (1-.6)(34.5) = 13.8$$

$$E_{N_{NOx}\,oil} = 13.8 \text{ LB/TON Refuse}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 1/6/75

Source Mixed Fuel Boilers

The NO_x NSPS for oil is 0.3 LB/10^6 BTU

Converting

$$E_S = (.3)(50) = 15.0$$

$$E_{S_{NO_x, OIL}} = 15.0 \text{ LB/TON Refuse}$$

SO_x

Coal & Refuse

Ref (249) P 79 TAB 13

$$E_U = f(4.48 \text{ LB}/10^6 \text{BTU})$$

Converting

$$E_U = (4.48)(50) = 224$$

$$E_{U_{SO_x, COAL}} = 224 \text{ LB/TON Refuse}$$

If a lime/limestone scrubbing system is employed, efficiencies between 70% & 90% can be expected (Ref (249) p 106)

Assuming the avg of 80%

$$E_{N_{SO_x}} = (1-.80)(224) = 44.8$$

$$E_{N_{SO_x, COAL}} = 44.8 \text{ LB/TON Refuse}$$

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Computation Sheet For Emission Factors

Calculations Done By Hoger Date 1/6/75

Source Mixed Fuel Boilers

The NSPS reg for SO_x from coal-fired boilers = 1.2 LB/10^6 BTU

Converting

$$E_S = 1.2(50) = 60$$

$$E_{S_{SO_x \, coal}} = 60 \text{ LB/TON Refuse}$$

Oil & Refuse

Ref (249) p 88 TAB 18

$$E_U = f(.41 \text{ LB}/10^6 \text{BTU})$$

Converting,

$$E_U = (.41)(50) = 20.5$$

$$E_{U_{SO_x \, oil}} = 20.5 \text{ LB/TON Refuse}$$

The use of low sulfur oil will certainly reduce SO_x emissions. However, it is technically feasible to employ a lime/limestone scrubber. We will assume the same η as the one chosen for the coal analysis, 80%.

$$E_{N_{SO_x \, oil}} = 20.5(1-.8) = 4.1$$

$$E_{N_{SO_x \, oil}} = 4.1 \text{ LB/TON Refuse}$$

The NSPS reg for SO_x for oil-fired units = 0.8 LB/10^6 BTU

Converting,

$(0.8)(50) = 40$

Since this is greater than E_U, $E_S = E_U$

$$E_{S_{SO_x \, oil}} = 20.5 \text{ LB/TON Refuse}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 1/6/74

Source Mixed Fuel Boilers

Summary

	Coal & Refuse			Oil & Refuse		
	E_U	E_N	E_S	E_U	E_N	E_S
P_T	3660.0	3.66	5.0	101.5	1.02	5.0
NO_x	37.5	15.0	35.0	34.5	13.8	15.0
SO_x	224.0	44.8	60.0	20.5	4.1	20.5

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Computation Sheet For Industrial Factors

Calculations Done By K. Tower Date 1/29/75

Source Wood Boilers

Wood boilers are used for wood waste which is mainly associated with the pulp + paper industry where refuse results from the separation of bark from the logs and the lumber industry where it appears mainly as shavings, sawdust and bark. (Ref 236, p II-60).

From ref. 043, p. 321 we make the assumption that the average bark boiler size is 300,000 lb/hr steam. Ref 073, p A-4,5 states there are 975 BTU/lb steam/efficiency of boiler. From ref 073, p. A-15, Table A-3 we assume the average efficiency of a wood boiler is 80%.

From these data we can calculate the capacity of an average wood waste boiler as follows:

$$\text{Capacity} = \frac{\left(975\ \frac{BTU}{lb}\right)\left(300{,}000\ lb/hr\right)}{.8} = 365.6\ BTU/HR$$

From the Boiler Industrial Factors data sheets, p. 15 we find that this size boiler will have a fractional utilization rate of 0.58 and a $P_B = .05_{simple}$.

$K = .58$ $P_B = .05_{simple}$

We make the assumption that the growth rate of wood boilers to be the same as that of the wood pulping industry, which is $.012_{compound}$. However, it should be noted that this number may be slightly low since more industries may find it economically feasible to use wood wastes as a fuel source.

$P_c = .012_{compound}$

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Computation Sheet For Industrial Factors

Calculations Done By K. Tower Date 1/29/75

Source Wood Boilers

Ref 048, p. 280 gives the total process emissions from bark boilers of the pulp mill industry to be 734,400 TONS/YR. Ref 075, p. 1.6-2, Table 1.6-1 gives an emission factor of 25-30 lbs/TON for bark boilers. We will assume 27.5 lbs/TON. We will also assume that the pulp mill industry operates 60% of all wood boilers. Therefore production in 1970 can be calculated as follows:

$$\text{Production}_{1970} = \frac{\left(734{,}400 \frac{\text{TONS}}{\text{YR}}\right)\left(2000 \frac{\text{lbs}}{\text{TON}}\right)}{\left(27.5 \frac{\text{lbs}}{\text{TON}}\right)(0.60)} = 89.0 \times 10^{6} \frac{\text{TONS}}{\text{YR}}$$

From this information we can calculate 1975 Production as follows:

$$P_{75} = P_{73}(1 + P_c)^{1975-1970}$$

$$= \left(89.0 \times 10^{6} \frac{\text{TONS}}{\text{YR}}\right)(1 + .012)^{5}$$

$$P_{1975} = 94.5 \times 10^{6} \frac{\text{TONS}}{\text{YR}}$$

$$A = \frac{\text{Prod}_{1975}}{K} = \frac{94.5 \times 10^{6} \frac{\text{TONS}}{\text{YR}}}{.58} = 162.9 \times 10^{6} \frac{\text{TONS}}{\text{YR}}$$

$$\boxed{A = 162.9 \times 10^{6} \frac{\text{TONS}}{\text{YR}}}$$

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Computation Sheet For Emission Factors

Calculations Done By K. Tower Date 1/29/75

Source Wood Boilers

As previously mentioned ref 075, p. 1.6-2, Table 1.6-1 gives an uncontrolled emission factor of 25 to 30 lbs/TON. We assume a 27.5 lb/TON factor.

$$E_u = 27.5 \text{ lbs/TON}$$

The best method of controlling these emissions would be with a baghouse filter (Ref 236, p. II-60) We will assume a 99% efficiency.

$$E_N = 27.5 \text{ lbs/TON} \times .01 = .275 \text{ lbs/TON}$$

$$E_N = 0.28 \text{ lbs/TON}$$

Since we could not obtain an accurate geographical distribution of wood boiler we obtain E_s from the general process weight curve. (Ref 084, Ref 148) Assuming an average process weight rate of 300,000 lbs/hr (as previously referenced) the allowable emissions = 52 lbs/HR.

Ref 043, p. 341 gives a process weight bark feed lb/hr wet (45% moisture) for a 300,000 lbs/hr bark boiler as 63,000 lb/hr. This rating in units of $\frac{\text{TONS (DRY)}}{\text{HR}}$ can be calculated as follows.

$$\frac{\text{TONS}}{\text{HR}} = \frac{(63{,}000 \text{ lbs/HR})(.55)}{2000 \text{ lbs/TON}} = 17.3 \frac{\text{TONS}}{\text{HR}}$$

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Computation Sheet For Emission Factors

Calculations Done By K. Tower Date 1/29/75

Source Wood Boilers

E_s can now be calculated as follows

$$E_s = \frac{52 \text{ lbs/HR}}{17.3 \frac{\text{TONS}}{\text{HR}}} = 3.01 \frac{\text{lbs}}{\text{TON}}$$

$$\boxed{E_s = 3.01 \frac{\text{lbs Pt.}}{\text{TON}}}$$

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Computation Sheet For Industrial Factors

Calculations Done By HOPPER Date 8/13/74

Source STATIONARY GAS TURBINES

STATIONARY GAS TURBINES ARE USED PRIMARILY IN TWO DISTINCT AREAS:

1. GAS-PIPELINE
2. ELECTRIC POWER GENERATION

They will be treated separately due to the potential for differing K, P_c & emissions

I. ELECTRIC POWER GENERATION

CAPACITY 1971 = 19,313 MW REF (105) p 185

GROWTH BETWEEN 1970 & 1980 ESTIMATED @ 5,250 MW/YR (STRAIGHT LINE) REF (104) p 175 FIG 4

$$\frac{69{,}000\ (1980) - 16{,}500\ (1970)}{10} = 5{,}250\ \text{MW/YR}$$

P_c: $1975 = 1971\,(1 + 4 P_c)$

$$(5250)4 + 19{,}313 = 19313\,(1 + 4P_c)$$

$$\frac{2.087 - 1.0}{4} = P_c = 27\% \quad \text{(SIMPLE)}$$

$P_c = 27\%_s$

$P_c = .27$ simple

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Computation Sheet For Industrial Factors

Calculations Done By HOMER Date 8/13/74

Source STATIONARY GAS TURBINES

$$A = 19{,}313 + 4(5250) = 40{,}313$$

$$A = 40{,}313 \text{ MW} \qquad \frac{(40{,}313 \text{ MW})(1 \times 10^6 \frac{\text{WATTS}}{\text{MW}})}{745.7 \frac{\text{WATTS}}{\text{HP}}}$$

$$\boxed{A = 54.1 \times 10^6 \text{ HP}}$$

REF 105 p 185

① UTILIZATION VARIES from 10 HRS/YR to base load durations

REF 104 p 179

② DEMANDS ARE such that the units must be OPERATED MORE frequently THAN ORIGINALLY INTENDED

ⓐ "1950 hrs/yR"

ⓑ "1970 hrs/yR"

ⓒ "WELL ABOVE THE 1500 hour per year level

Assuming that this trend continues, assume

$$K = \frac{1950}{(365)(24)} = 22.3\%$$

$$\boxed{K_{\text{ELEC POWER}} = 0.223}$$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 8/14/74

Source STATIONARY GAS TURBINES

II. GAS PIPELINE SERVICE

REF (104) WAS FOUND TO CONTAIN THE MOST RECENT COMPILATION OF INFORMATION. HOWEVER, THE TEXT TENDED TO BE A BIT MISLEADING DUE TO THE LACK OF DETAILED DEF'N BETWEEN TURBINES & GAS TURBINES. ALSO, SOME CURVES & FIGURES ARE PRESENTED TO SHOW THE GROWTH OF GAS TURBINES IN THE INDUSTRY RELATIVE TO ALL TURBINES & THEREFORE, LACK SPECIFIC DATA. HOWEVER, THE FOLLOWING INFORMATION WAS ASCERTAINED

REF (104) P 206 TAB 1

1970 CAPACITY (GAS TURBINES) = 2.540×10^6 hp

1970 CAPACITY (ALL TURBINES) = 8.7×10^6 hP P208 TAB 2

REF (104) P 207 1 SHOWS GROWTH OF GAS TURBINES BETWEEN 1964 & 1970 IN TERMS OF CAPACITY ADDED PER YEAR. THE ATTACHED FIGURE IS THE INTEGRAL OF THIS CURVE DRAWN TO DETERMINE THE GROWTH TREND

BETWEEN 1968 & 1970, WE HAD $(1.325 - .585) \times 10^6$ HP INCREASE

$$\therefore \frac{(1.325 - .585)(10^6)}{2} = 0.37 \times 10^6 \text{ HP/YR}$$

IF WE ASSUME STRAIGHT LINE GROWTH

$$A = 2.54 \times 10^6 + (.37 \times 10^6)(5) = 4.39 \times 10^6$$

$$A = 4.39 \times 10^6 \text{ HP}$$

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Computation Sheet For Industrial Factors

Calculations Done By Hoppe Date 8/14/74

Source Stationary Gas Turbines

P_c:

$$(4.39 \times 10^6) = (2.54 \times 10^6)(1 + 5P_c)$$

P_c = 14.5% simple

① Very little info was found regarding K
② K would generally be high considering the increasing need for natural gas (or any other fuel for that matter)
③ K is not equal to 1.0 because demands change daily and annually.

The following is an effort to define K & is subject to modification if new data are made available:

Ref (104) p 206

Ⓐ 1st g/t installation "late 1940's" (Assume 1949) has accumulated 148,000 hrs "to date" (Assume 1970)

Ⓑ Ref (104) p 177 TBO = 1500 hrs

$$\frac{148,000}{21 \text{ yrs}} = 7048 \frac{\text{hrs}}{\text{yr}}$$

7048/1500 ≈ 4 overhauls/yr @ 240 manhours Ref 104 p208

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 8/14/74

Source Stationary Gas Turbines

(C) Assume 2 men or $\frac{240}{2}$ = 120 hrs/overhaul

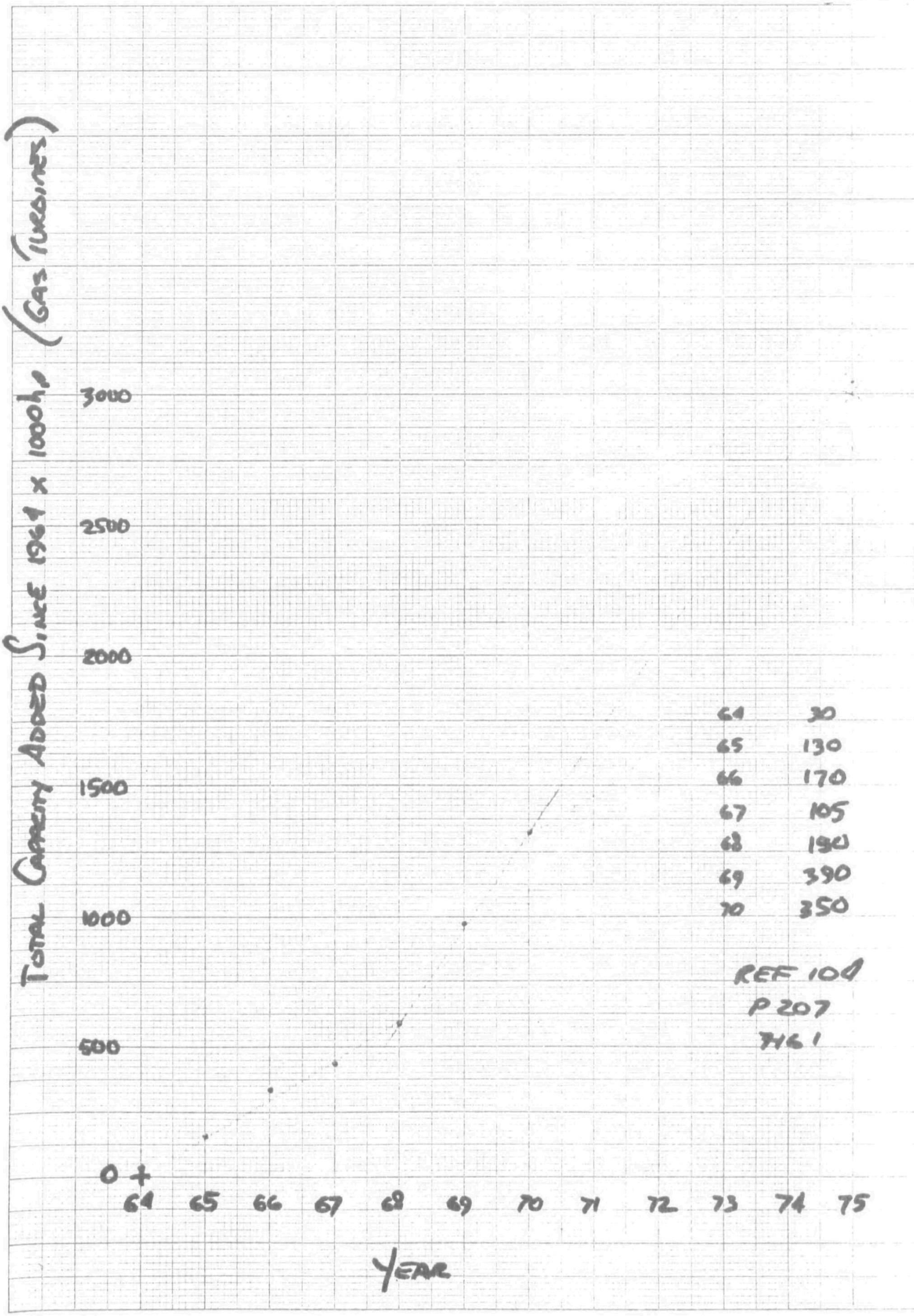
$(365)(24) - 4(120) = 8280 \frac{hrs}{yr}$ when unit could be used

(D) Assume gas turbine to run at peak or not at all since it is a steady state device. Short term demand changes handled by recips.

(E) Ref (75) p 3.3.1-1 Sec. 3.3.1.2 states "most gas turbines do not involve the frequent use of low power"

$\frac{7048}{8280} = K = 0.85$

$K = 0.85$


TOTAL CAPACITY ADDED SINCE 1964 x 1000hp (GAS TURBINES)
3000
2500
2000
1500
1000
500
0
64 65 66 67 68 69 70 71 72 73 74 75
YEAR
64 30
65 130
66 170
67 105
68 190
69 390
70 350
REF 104
P 207
FIG 1

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Computation Sheet For Industrial Factors

Calculations Done By HOMER Date 10/24/74

Source STATIONARY GAS TURBINES

DET'N of P_B

REF. 37 p. A1

IRS GUIDELINE = 50 yrs for
" HYDRAULIC PRODUCTION PLANT
INCLUDING dams, flumes, CANALS, WATERWAYS.
ALSO INCLUDES JET ENGINES AND OTHER INTERNAL COMBUSTION ENGINES USED TO OPERATE AUXILIARY FACILITIES FOR LOAD SHAVING PURPOSES OR IN CASE OF EMERGENCIES ..."

IRS GUIDELINE = 20 YRS for
" NUCLEAR PRODUCTION PLANT
INCLUDES JET ENGINES AND OTHER INTERNAL COMBUSTION ENGINES USED TO OPERATE AUXILIARY FACILITIES FOR LOAD SHAVING PURPOSES OR IN CASE OF EMERGENCIES ...."

IRS GUIDELINE = 28 YRS for
" STEAM PRODUCTION PLANTS
SAME QUOTE AS NUCLEAR POWER STATIONS

IT IS OUR JUDGEMENT THAT 25 YEARS REPRESENTS A REALISTIC AVERAGE
IF we double the allowable depreciation to be more CONSISTENT WITH REALITY, THEN

$$P_B = \frac{100\%}{50 \text{ yrs}} = 2\%$$

$$P_B = 0.02 \text{ SIMPLE}$$

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Computation Sheet For Emission Factors

Calculations Done By Hoppe? Date 8/14/74

Source Stationary Gas Turbines

I. Gas Pipeline Service

Ref 104 p... Fig 5 gives breakdown of # of units in service for

1. Gas pipelines
2. Liquid pipelines (assume oil)
3. Repressurizing systems (assume 50/50 gas/oil)

Assume that the avg HP rating for engines in each category is the same

in 1970

780 eng's - pipeline
160 eng's - liquid (extrap)
80 eng's - Repr. syst. (extrap)

1020 ← agrees with # turbines total Ref 104 p211 Tab 4

$\frac{780}{1020} = 76\%$ Assume to use Natural Gas

$\frac{160}{1020} = 17\%$ Assume to use #2 oil

$\frac{80}{1020} = 7\%$ Assume to use 50/50 gas/oil

Eu particulates:

For oil (#2) Eu = 8.4 #/10³ gals @ 140,500 BTU/gal Ref (75) P 3.3.1-1 Tab 3.3.1-1

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Computation Sheet For Emission Factors

Calculations Done By HOPPER Date 8/14/74

Source STATIONARY GAS TURBINES

Ref (220) P31 TAB 10

$$\frac{\left(\frac{8.4\ \#}{10^3 gal}\right)\left(11000 \frac{BTU}{HP \cdot HR}\right)\left(8760 \frac{HR}{YR}\right)}{(140,500) \frac{BTU}{gal}} = \frac{5.76\ \#}{HP \cdot YR}$$

" $Eu_{p_{oil}}$

REF (75) P 3.3.1-1

$Eu_{p_{gas}} = 0$ REF (75) P 3.3.1-2 TAB 3.3.1-2

$$Eu_p = (.76)(0) + .17(5.76) + (.07)(.5)(5.76) + (0)(.5)(.07)$$

$$.979 + .202 = 1.18$$

$$Eu_{p_{gas\ pipe}} = 1.18 \frac{\#}{HP \cdot YR}$$

THE ONLY PARTICULATE CONTROL MECHANISM USED ON gas turbine eng's ARE "SMOKE fix CANS." REF 104 P179 NEW ENGINES, WHICH ARE THE SUBJECT OF NSPS, SHOULD HAVE THIS TYPE OF COMBUSTOR &, THEREFORE, E_U WOULD BE LESS.

Assume that $E_N = 0$ for the purpose of determining MAX impact $(T_S - T_N)$. If the impact is insignificant, THE ASSUMPTION is VALID. If the impact is significant, A REEVALUATION of E_N WOULD BE in ORDER.

$$En_{p_{gas}} = 0$$

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Calculations Done By HOPPER Date 8/15/74

Source STATIONARY GAS TURBINES

NOx

$EU_{NO_x\,oil} = 120\ \#/10^3\,gal$ REF (75) P 3.3.1-1 TAB 3.3.1-1

$EU_{NO_x\,gas} = 0.57\ \#/10^6\,BTU$ REF (75) P 3.3.1-2 TAB 3.3.1-2

$$\frac{\left(120 \frac{\#}{10^3\,gal}\right)\left(11000 \frac{BTU}{HP \cdot HR}\right)\left(8760 \frac{HR}{YR}\right)}{\left(140{,}500 \frac{BTU}{GAL}\right)} = 82.3 \frac{\#\ NO_x}{HP\,YR}$$

for oil fired units

(140,500 BTU/GAL: REF 75 P 3.3.1-1)

$$\left(\frac{0.57\ \#}{10^6\,BTU}\right)\left(11000 \frac{BTU}{HP \cdot HR}\right)\left(8760 \frac{HR}{YR}\right) = 54.9 \frac{\#\ NO_x}{HP \cdot HR}$$

for gas fired units

Refer to p. 1 of these calc's for % breakdown

$$(.76)(54.9) + .17(82.3) + (.07)(.5)(82.3) + (.07)(.5)(54.9) =$$

$$41.7 + 14.0 + 2.9 + 1.9 = 60.5$$

$$EU_{NO_x\,GAS\,TUR} = 60.5 \frac{\#}{HP \cdot YR}$$

REF (32) SEC II % Reduction in NOx by "wet methods" reported up to 85%

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Computation Sheet For Emission Factors

Calculations Done By HOPPER Date 8/15/74

Source STATIONARY GAS TURBINES

$$.85 = \frac{60.5 - E_N}{60.5} \quad E_n = 9.08$$

$$E_{N_{NO_x}}\ (\text{GAS PIPE}) = 9.08 \ \frac{\#}{HP \cdot YR}$$

SO_x

FOR OIL FIRED UNITS

$E_{U_{SO_x}}$ (OIL) = 1.0 S

REF (75) p 3.3.1-1 TAB 3.3.1-1

FROM REF (97) p 19 TAB 4.9

AVG SULFUR CONTENT OF #2 OIL IN THE U.S. IS 0.265%
(BASED ON ARITHMETIC AVG OF TAB 4.9)

$E_{U_{OIL\ SO_2}}$ = 0.265 #/10⁶ BTU

$$(0.265)(HU^{-6})(11000)(8760) = 25.5 \ \frac{\# SO_2}{HP \cdot YR} \text{ for OIL UNITS}$$

FROM REF (75) P 3.3.1-2 TAB 3.3.1-2

$E_{U_{gas}}$ = 0.0006 #/10⁶ BTU

$$(.0006)(10^{-6})(11000)(8760) = 0.058 \ \frac{\# SO_2}{HP \cdot YR} \text{ for gas units}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 8/16/74

Source Stationary Gas Turbines

Refer to p, of these calc's for % breakdown

$(.76)(.058) + .17(25.5) + (.07)(.5)(.058) + (.07)(.5)(25.5) =$

$.0441 + 4.335 + .0020 + .8925 = 5.27$

$E_{U_{SO_x\,gas\,pipe}} = 5.27 \frac{\#}{hp \cdot yr}$

Control:

1. There is no demonstrated control technology for SO_2 on gas turbine engines
2. If there were, it would be quite \$. Ref (32) Sec II-10
3. Assume (for the time being) that all dual fuel units run 100% on NG

$.0441 + 4.335 + .0041 = 4.38$ 17% reduction

This would probably result in a (Ts - Tn) quite low on the priority list.

$E_{N_{SO_x\,gas\,pipe}} = 4.38$

Ref (32) Sec II-3

There is a trend to go to poorer, less refined fuels (higher S content). NSPS could be in the form of holding % S @ its present level & not allowing any deterioration in impact in the future.

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 8/16/74

Source: Stationary Gas Turbines

CO

Ref (32) Figs 9 & 10

Arithmetic avg of data points broken down into oil fired units & gas fired units with no regard for size or NO_x control

Gas (ppm)	Oil (ppm)
205	420
140	395
110	180
30	145
345	120
100	80
80	50
10	30
	160
	100
	95
	35
	30
	10
Avg = 115 ppm	Avg = 132 ppm

In order to convert ppmv to $\frac{\#CO}{HP \cdot YR}$ (for oil & gas) we must enter into a series of computations.

$$10^{-6}\left(\frac{FT^3\,CO}{FT^3\,gas}\right)\times\left(\frac{FT^3\,gas}{\#\,gas}\right)\times\left(\frac{mole\,CO}{FT^3\,CO}\right)\times\left(\frac{\#CO}{mole\,CO}\right)\times\left(\frac{\#\,gas}{\#\,FUEL}\right)\times\left(\frac{\#\,FUEL}{BTU}\right)\left(\frac{BTU}{HP\cdot HR}\right)\left(\frac{HRS}{YR}\right)$$

ppm $\frac{1}{\rho}$ 359 28 A/F RATIO $\frac{1}{HV}$ 11,000 8760

$$= \frac{\#CO}{HP \cdot YR}$$

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Computation Sheet For Emission Factors

Calculations Done By Homer Date 8/14/74

Source Stationary Gas Turbines

Assume $\rho = .075$ (Air) $HV = \frac{140,500}{7.309}$ BTU/# Ref (101) p 9-6 TAB 9-9

A/F Ratio

(a) oil = $\frac{1}{.015}$

(b) gas = $\frac{1}{.018}$

} Per Telcon 8/16/74 with H. Schwartz - Sr. Eng'r Pratt & Whitney Aircraft - Industrial Turbine Devel. Section of Combustion Group

For oil

$$\frac{\#CO}{HP\,YR} = 45.8$$

For gas

$$\frac{\#CO}{HP \cdot YR} = 25.1$$

Assume HV = 25,500 Ref (101) p 9-8 TAB 9 " & Ref (75) p 3.3.1-2 TAB 3.3.1-2

Refer to p1 of these calc's for breakdown

$$(.76)(25.1) + (.17)(45.8) + (.07)(.5)(25.1) + (.07)(.5)(45.8)$$

$$19.08 + 7.79 + .88 + 1.60 = 29.35$$

$$EU_{CO\ gas\ pipe} = 29.35 \frac{\#CO}{HP \cdot YR}$$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 8/16/74

Source Stationary Gas Turbines

Ref (32) Sec III-3 states
CO reduction by 67%

En_{CO}:

$$\frac{29.35 - En}{29.35} = .67$$

$$En_{CO\ gas\ pr} = 9.69 \ \frac{\#CO}{HP \cdot YR}$$

A CO std would be req'd to preclude excessive increases in NO_x which have been known to occur when NO_x control is added Ref (32)

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Computation Sheet For Emission Factors

Calculations Done By HOPPER Date 8/16/74

Source STATIONARY GAS TURBINES

II. Electric Power Generation

REF (105) p 186-208 list MW ratings for each electric company's gas turbines & the type of fuel burned. Of the total listed, there exist:

(a) 6714.87 MW using oil (#2)
(b) 1262.1 MW using gas
(c) 10,035.9 MW using oil/gas

The %age breakdown is

37% oil
7% gas
56% dual fuel (assume 50/50 gas/oil)

Particulates

From p2 of these calc's

$EU_{P_{OIL}} = 5.76$ #/HP·YR

$EU_{P_{GAS}} = 0$

$$EU_{P_{ELEC}} = (.37)(5.76) + (.07)(0) + .56(0)(.5) + (.56)(.5)(5.76)$$

$$2.13 + 1.61$$

$$EU_{P_{ELEC}} = 3.74 \ \frac{\#}{HP \cdot YR}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 8/16/74

Source Stationary Gas Turbines

Assume

$$E_{N_{P_{ELEC}}} = 0$$

for the same reasons stated @ the bottom of p2 of these calc's.

NOx

$$EU_{NOx_{OIL}} = 82.3$$

$$EU_{NOx_{GAS}} = 54.9$$

Using the same % breakdowns discussed on p9 of these calcs

$$(.37)(82.3) + (.07)(54.9) + (.56)(.5)(82.3) + (.56)(.5)(54.9) =$$

$$30.45 + 3.84 + 23.04 + 15.37$$

$$EU_{NOx_{ELEC}} = 72.7 \ \frac{\#}{HP \cdot YR}$$

Ref (32) Sec IV reports up to 85% reduction in NOx by wet methods

$$\frac{72.7 - E_N}{72.7} = .85$$

$$E_{N_{NOx_{ELEC}}} = 10.9 \ \frac{\#}{HP \cdot YR}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 8/16/74

Source Stationary Gas Turbines

SOx

$EU_{SOx\ oil} = 25.5$

$EU_{SOx\ gas} = .058$

Using, again, the same % breakdowns discussed on p 9 of these calc's

$(.37)(25.5)+(.07)(.058)+(.56)(.5)(25.5)+(.56)(.5)(.058) =$

$9.44 + .0041 + 7.14 + .016$

$EU_{SOx\ ELEC} = 16.6 \frac{\#}{HP \cdot YR}$

Assume all dual fuel units run 100% on gas

$(.37)(25.5)+(.07)(.058)+(.56)(.058) = 9.44 + .004 + .032$

9.48

% Reduction
" 43%

$EN_{SOx\ ELEC} = 9.48 \frac{\#}{HP \cdot YR}$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 8/15/74

Source Stationary Gas Turbines

CO

$EU_{CO_{oil}} = 45.8$

$EU_{CO_{gas}} = 25.1$

Assume same % breakdowns discussed on p 9 of these calc's.

$(.37)(45.8) + (.07)(25.1) + (.56)(.5)(45.8) + (.56)(.5)(25.1) =$

$16.95 + 1.76 + 12.82 + 7.03$

$EU_{CO_{ELEC}} = 38.56 \frac{\#}{HP \cdot YR}$

Ref (32) Sec III-3 states
CO reduction by 67%

$EN_{CO_{elec}} = 12.7 \frac{\#}{HP \cdot YR}$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/18/75

Source STAT. GAS TURBINES

E_S

FROM Ref (84) & (148), there are no specific STATE regulations for NOx (except Conn.). Some STATES appear to rule out stationary gas turbines from their fuel burning regs entirely. With others, it appears to be a case of interpretation — with respect to any pollutant. For the purpose of this study, we will assume that . . .

① States generally do not enforce fuel burning regs for gas turbine engines

② Connecticut's regulation will be disregarded since it will have an inconsequential effect on our results

So $E_S = E_U$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/18/75

Source Stat. Gas Turbines

Summary

	Gas Pipeline			Electric Utility		
	E_U	E_N	E_S	E_U	E_N	E_S
Particulate	1.18	0.0	1.18	3.74	0.0	3.74
NO_x	60.5	9.08	60.5	72.7	10.9	72.7
SO_x	5.27	4.38	5.27	16.6	9.48	16.6
CO	29.4	9.69	29.4	38.6	12.7	38.6

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/12/75

Source Internal Combustion & Diesel Engines

Several References were consulted regarding capacity & all Refs differed substantially

Ref (50) states
$(10-20) \times 10^6$ installed HP in 1972

Ref (100) p 5-6 Tab 5-3 states
(70×10^6) installed HP in 1969

Ref (220) p 2 states
(34.7×10^6) installed HP in 1971

Ref (50) is unpublished & a relatively "quick" analyses
Ref (100) indicates that their value is estimated

Ref (220) is
(a) More recent than Ref (100) or Ref (50)
(b) More detailed than " " "
(c) Based on published data & industry questionnaires

Although any Ref could be used, we chose Ref (220) information. Category breakdowns are also included in this Ref

$$A_{\substack{1971 \\ IC+D \\ Eng's}} = 34.7 \times 10^6 \text{ BHP}$$

Ref (220) p 2
54% — Spark Ignition Engines (Natural Gas)
34.2% — Diesel
11.8% — Dual fuel

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Calculations Done By Hopper Date 9/12/75

Source IC & D Engines

$$A_{\substack{1971 \\ SIE}} = (34.7\times10^6)(.54) = 18.74\times10^6 \text{ Bhp}$$

$$A_{\substack{1971 \\ D+DF}} = (.342+.118)(34.7\times10^6) = 15.96\times10^6 \text{ Bhp}$$

Ref (50) gives growth rates of

2.5×10^6 hp for SIE

&

0.50×10^6 hp for D & DF

This gives

$$A_{SIE} = [18.74 + (4)(2.5)]10^6 = 28.74$$

$$A_{SIE} = 28.74\times10^6 \text{ Bhp}$$

$$A_{D+DF} = [15.96 + (4)(.5)]10^6 = 17.96\times10^6$$

$$A_{D+DF} = 17.96\times10^6 \text{ Bhp}$$

$$P_{C_{SIE}} = \frac{2.5\times10^6}{28.74\times10^6} = 0.087$$

$$P_{C_{SIE}} = 0.087$$ simple

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Computation Sheet For Emission Factors

Calculations Done By HOPPER Date 9/12/75

Source IC & D Engines

$$P_{C_{D+DF}} = \frac{0.5 \times 10^6}{17.96 \times 10^6} = 0.028$$

$$P_{C_{D+DF}} = 0.028$$ simple

Depending upon future availability of natural gas, these values could change significantly!

Ref (220) p 3 gives

$$K = 0.58$$

We will use this for both SIE & D+DF

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/12/75

Source IC+D Engines

DET'N of P_B

REF 37 p.41

IRS GUIDELINE = 50 yrs for

" Hydraulic Production Plant
EXCLUDING dams, flumes, CANALS, WATERWAYS. ALSO INCLUDES JET ENGINES AND OTHER INTERNAL COMBUSTION ENGINES USED TO OPERATE AUXILIARY FACILITIES FOR LOAD SHAVING PURPOSES OR IN CASE OF EMERGENCIES ..."

IRS GUIDELINE = 20 YRS for

" NUCLEAR PRODUCTION PLANT
INCLUDES JET ENGINES AND OTHER INTERNAL COMBUSTION ENGINES USED TO OPERATE AUXILIARY FACILITIES FOR LOAD SHAVING PURPOSES OR IN CASE OF EMERGENCIES .... "

IRS GUIDELINE = 28 yrs for

" STEAM PRODUCTION PLANTS
SAME QUOTE AS NUCLEAR POWER STATIONS

IT IS OUR JUDGEMENT THAT 25 YEARS REPRESENTS A REALISTIC AVERAGE

IF we double the allowable depreciation to be more CONSISTENT WITH REALITY, THEN

$$P_B = \frac{100\%}{50 \text{ yrs}} = 2\%$$

$$P_B = 0.02 \text{ SIMPLE}$$

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Computation Sheet For Emission Factors

Calculations Done By Homer Date 9/12/75

Source IC & D Engines

NOx

Ref (220) p 24 Tab 6 gives Eu in grams/Bhp-Hr for a variety of cycle/charging config's Using the computed averages . . .

$$Eu_{SIE} = 11.9 \frac{\text{grams}}{\text{Bhp-Hr}}$$

$$Eu_{SIE_{NOx}} = \frac{(11.9)(8760)}{454} = 230$$

$$\boxed{Eu_{SIE_{NOx}} = 230 \frac{\#}{\text{Bhp-yr}}}$$

$$Eu_{D+DF_{NOx}} = 9.3 \frac{\text{grams}}{\text{Bhp-Hr}}$$

$$Eu_{D+DF_{NOx}} = \frac{(9.3)(8760)}{454} = 179$$

$$\boxed{Eu_{D+DF_{NOx}} = 179 \frac{\#}{\text{Bhp-yr}}}$$

Ref (50) Tab 2 Best %age reduction of NOx is 43% for SIE

$$Eu_{SIE_{NOx}} = 230(1-.43) = \boxed{131 \frac{\#}{\text{BHP-yr}} = EN_{SIE_{NOx}}}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 9/12/75

Source IC & D

Also, Ref (50)

Improvement for diesel = 28%
Improvement for dualfuel = 40%

From p1 of Ind. Factors,
34.2% of total cap. = diesel
11.8% of total cap. = dual fuel

$$\bar{\eta} = \left(\frac{34.2}{46}\right)(28\%) + \left(\frac{11.8}{46}\right)(40\%) = 31.1\%$$

$$179(1-.311) = 123$$

$$E_{N_{DTDF}\,NOx} = 123 \frac{\#}{Bhp\text{-}yr}$$

All these improvements can be realized through a series of combustion design/operating modifications

CO

Ref (220) p24 Tab Co (Using av'g values)

$$E_{U_{SIE}\,CO} = 2.22 \frac{gr}{Bhp \cdot hr}$$

$$E_{U_{SIE}\,CO} = \frac{(2.22)(8760)}{454} = 42.8$$

$$E_{U_{SIE}\,CO} = 42.8 \frac{lb}{Bhp\text{-}yr}$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 9/12/75

Source IC & D Engines

Ref (50) shows that for combustion modifications used to decrease NO_x, CO increases

Ref (220) p6 states that "over the long term, catalytic reduction...."

However, ... "A significant amount of development work must be carried out...."

We will assume, therefore, the hypothetical case of $E_N = 0.0$ for control ranking purposes

$$E_{N_{SIE}\,CO} = 0.0$$

Ref (220) p24 Tab 6 (using avg values)

$$Eu_{D+DF\,CO} = 2.84 \frac{\text{grams}}{\text{Bhp-hr}}$$

$$\left(\frac{34.2}{46}\right)(3.14) + \left(\frac{11.8}{46}\right)(2.0) = 2.33 + .513 = 2.84$$

$$Eu_{D+DF\,CO} = \frac{(2.84)(8760)}{454} =$$

$$Eu_{D+DF\,CO} = 54.8 \frac{\#}{\text{Bhp-yr}}$$

Since CO increases for those op'ns which decrease NO_x (Ref (50)) & catalytic reduction needs substantial development effort (Ref (220) p6), we will make the following assumptions:

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 9/12/75

Source IC & D Engines

① All dual-fuel units to use nat. gas 100% of time

② No change to diesel units

Using capacity breakdown figures on p1 of IND. FACTORS & emission factors for SIE in lieu of those for dual fuel engines (since gas is the fuel)

$$EN_{D+DF,CO} = \left(\frac{34.2}{46}\right)(3.14) + \left(\frac{11.8}{46}\right)(2.22) = 2.90$$

↑ Ref (220) p 29 TAB6 for DIESEL ONLY

$$EN_{D+DF,CO} = \frac{(2.90)(8760)}{454} = 56$$

$$EN_{D+DF,CO} = 56 \frac{\#}{Bhp\text{-}HR}$$

This approach is results in higher emissions. Assume ∴ $EN_{D+DF,CO} = 0.0$ as for SIE

NSPS for diesel units could be in the form of maintaining high quality of operation thru inspections, CO meters to indicate deterioration from "best operation." If % CO increases beyond a certain level, it will be necessary to return the unit to its "original condition."

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Computation Sheet For Emission Factors

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Source IC & D Engines

HYDROCARBONS

Ref (220) p24 TAB G (using avg values)

$$EU_{SIE, HC} = 2.9 \frac{gr}{Bhp\text{-}hr}$$

$$\frac{(2.9)(8760)}{454} = 56$$

$$EU_{SIE, HC} = 56 \frac{\#}{Bhp\text{-}yr}$$

Similar arguements for HC control hold as for CO control. ∴

$$EN_{SIE, HC} = 0.0$$

Ref (220) p24 TAB G (avg values) $\left(\frac{34.2}{46}\right)(1.11) + \left(\frac{11.8}{46}\right)(3.1)$

↑ DIESEL ↑ DF

$$EU_{D+DF, HC} = 1.62 \frac{gr}{Bhp\text{-}hr}$$

$.825 + .795 = 1.62$

$$EU_{D+DF, HC} = \frac{(1.62)(8760)}{454} = 25.7$$

$$EU_{D+DF, HC} = 31.3 \frac{\#}{Bhp\text{-}yr}$$

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Computation Sheet For Emission Factors

Calculations Done By Homer Date 9/12/75

Source IC+D Engines

For EN, assume that all dual-fuel units burn nat. gas 100% of the time & diesel units are unchanged

$$E_{N_{DIDF}\,HC} = \left(\frac{34.2}{46}\right)(1.11) + \left(\frac{11.8}{46}\right)(2.9) = .825 + .744 = 1.57$$

↑ Ref (220) p24 TAB 6 DIESEL only

$$\frac{(1.57)(8760)}{454} = 30.3$$

$$E_{N_{DIDF}\,HC} = 30.3 \frac{LB}{Bhp\text{-}YR}$$

This fuel switching approach was unacceptable for CO emissions but would have some for HC emissions. We will assume this practice to be used for HC reduction in spite of the slight increase in CO.

SOx

From Ref (97) $E_{U_{SIE}\,SOx} = 0.4 \frac{\#}{10^6 FT^3 gas}$

From Ref (220) p 31 TAB 10 $7000 \frac{BTU}{Bhp\text{-}hr}$

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Source IC+D Engines

$$\frac{\left[(0.4)\frac{LB}{10^6 FT^3}\right]\left[7000\frac{BTU}{Bhp\text{-}hr}\right]\left[8760\frac{hrs}{yr}\right]}{1000\frac{BTU}{FT^3}} = 0.025$$

$$EU_{SIE\ SO_x} = 0.025\ \frac{\#}{Bhp\text{-}yr}$$

Since this is negligible & N.G. is the "cleanest" fuel that can be used Assume EU=EN=0

∴ Eliminate from tables

From Ref (97) for diesel engines

$40\ \frac{LB\ SO_2}{10^3 gallons}$ (%S = 0.3)

From Ref (220) p31 Tab 10

$0.4\ \frac{LB\ FUEL}{Bhp\text{-}hr}$ Assuming HV = 140,500 $\frac{BTU}{gal}$

Ref (75) p 3.3.1-1 Tab 3.3.1-1

&

7.31 $\frac{LB}{gal}$ (#2 oil)

Ref (101) p 9-6 Tab 9-9 (Avg)

$$\frac{\left(40\frac{\#SO_2}{10^3 gal\ fuel}\right)\left(0.4\frac{\#fuel}{Bhp\text{-}hr}\right)\left(8760\frac{hrs}{yr}\right)}{\left(7.31\frac{\#fuel}{gal\ fuel}\right)}$$

$$\| $$

$$EU_{Dies\ SO_x} = 19.2\ \frac{LB}{Bhp\text{-}yr}$$

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Source IC & D Engines

Assume dual fuel engines 50/50 oil/gas

$$EU_{DF\ SO_x} = (.5)(19.2) + .5(0) = 9.6$$

$$EU_{DF\ SO_x} = 9.6 \frac{\#}{Bhp\text{-}yr}$$

$$EU_{D+DF\ SO_x} = \left(\frac{34.2}{46}\right)(19.2) + \left(\frac{11.8}{46}\right)(9.6) = 14.3 + 2.5 = 16.8$$

$$EU_{D+DF\ SO_x} = 16.8 \frac{\#}{Bhp\text{-}yr}$$

For control, assume that diesels still burn oil but dual fuel switches to all gas

$$EN_{D+DF\ SO_x} = \left(\frac{34.2}{46}\right)(19.2) + 0 = 14.3$$

$$EN_{D+DF\ SO_x} = 14.3 \frac{\#}{Bhp\text{-}yr}$$

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Calculations Done By HOPPER Date 9/12/75

Source IC & D Engines

PARTICULATES

$$EU_{SIE_P} = EN_{SIE_P} = 0$$

Ref (75) p 3.1.6-1 for gaseous fueled vehicles

For diesel
Ref (75) p 3-15-2 TAB 3.1.5-1

$$EU = 13 \ \#/10^3 \text{GAL}$$

$$\frac{\left(13 \ \#/10^3\text{GAL}\right)\left(0.4 \ \frac{\#\text{FUEL}}{\text{Bhp-hr}}\right)\left(8760\right)}{7.31 \ \frac{\#\text{FUEL}}{\text{GAL FUEL}}} = 6.2 = EU_{DIES_P}$$

Assume dual fuel engines use 50/50 oil/gas

$$EU_{DF_P} = (.5)(0) + (.5)(6.2) = 3.1 = EU_{DF_P}$$

$$EU_{D+DF_P} = \left(\frac{34.2}{46}\right)(6.2) + \left(\frac{11.8}{46}\right)(3.1) = 4.61 + .8 = 5.41$$

$$EU_{D+DF_P} = 5.41 \ \frac{\#}{\text{Bhp-hr}}$$

For control, assume diesels still burn oil but dual-fuel switches to all gas

$$EN_{D+DF_P} = \left(\frac{34.2}{46}\right)(6.2) + 0 = 4.61$$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 9/12/75

Source IC+D Engines

$$E_{N_{D+DF\ P}} = 4.61 \frac{\#}{Bhp \cdot YR}$$

Summary of Eu & En

	Spark Ign. Eng. Eu	Spark Ign. Eng. En	Diesel & Dual Fuel Eu	Diesel & Dual Fuel En
CO	42.8	0.0	54.8	0.0
HC	56.0	0.0	31.3	30.3
SOx	0	0	16.8	14.3
Part	0	0	5.41	4.61
NOx	230	131	179	123

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 9/12/75

Source IC+D Engines

No states have regs pertaining specifically to stationary internal combustion engines & diesel engines. Many states specifically do not include them within their fuel burning regs. Is is a matter of interpretation, however, with other states. We will assume

∴ $E_S = E_U$ for all pollutants & engine types

Ref 50 states, also, that there are no regs for this fuel burning equipment.

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-9-74

Source Autobody Incinerators

Ref D38 pg 137 states that "the great majority of autobody incinerators now operating or under construction are based on the Bureau of Mines Design.

Refractory-lined garage-type unit equipped with a natural gas afterburner. 6 car/hr or 12,500 car/yr

Two cars at a time charged

K:

Ref 038 pg 142-143

operating schedule $8 \frac{hr}{d} \times 5 \frac{day}{wk} \times 52 \frac{wk}{yr} = 2080 \frac{hr}{yr}$

Table 47 illustrates 5 plants

	Cap car/hr	Burn Rate car/hr	Schedule hr/yr
1.	10	10	1820
2.	6	3	N.A.
3.	6	6	2080
4.	7	7	N.A.
5.	10	N.A.	2,080

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Computation Sheet For Industrial Factors

Calculations Done By 2J. Marrone Date 8-9-74

Source Auto body Incinerators

K: cont'd

Calculating utilization factors from these data

1. $\frac{1820}{2080} \cong .875$

2. Not calcuable, however est at best as $\frac{3 \text{ car}}{6 \text{ car}} = .5$

3. $\frac{2080}{2080} \cong 1$

4. Not calculable, however est at ~~least~~ best as $\frac{7}{7} \cong 1$

5. Not calcuable, however est at best as $\frac{2080}{2080} \cong 1$

In light of the sketchy data above; (we see that the utilization seems to range between .5 and 1.0) We estimate a normal utilization factor as .90 to be representative of normal operating practice

$\therefore K = .90$

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-9-74

Source Autobody Incinerators

A:

From Ref 038 pg 143

Estimated installations in 1973 = 15

Using 6 car/hr capacity and and operating schedule of 2080 hr/yr we calculate the average disposal rate capacity for each installation.

$$6 \times 2080 = 12{,}480 \text{ or } 12{,}500 \frac{\text{car}}{\text{yr}}$$

for each installation

$$15 \text{ installation} \times 12{,}500 \frac{\text{car}}{\text{inst. yr}} = 187{,}500 \frac{\text{car}}{\text{yr}} \text{ in 1973}$$

Note! The above reference obtained 248,000 car/yr however this was based on error in calculating the average cars burned per installation. They obtained 16,500 car/installat. versus the true value of 12,500 car/yr. We will use 12,500 car/installat.-yr and 187,500 total car/yr as our data points.

The above source assumes that between 1973 and 1978 the autobody incinerators will capture 50% of the present open-burning rate. It was estimated by them from EPA data to be 530,000 car/yr for open burning.

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-9-74

Source Autobody Incinerator

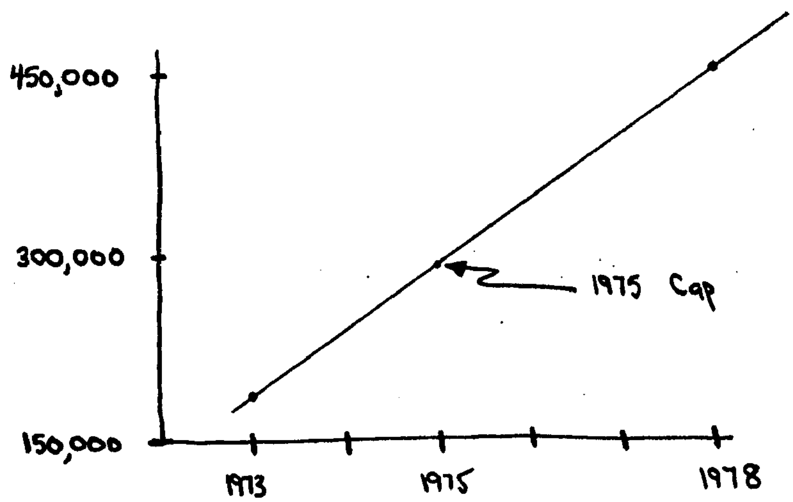
A: Cont'd

Added Capacity by 1978 = .5 × 530,000 = 265,000 car/yr

1978 Cap = 265,000 (Added 1973-1978) + 187,500 (1973)

1978 Cap = 452,500 car/yr

There is assumed no expected changes in incinerator size during this period.



We have assumed straight-line growth between 1973 and 1978

$$1978 = 1973\,(1 + P_c \cdot 5)$$ (5 years)

$$452{,}500 = 187{,}500\,(1 + P_c 5)$$

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-9-74

Source Autobody Incinerator

A: cont'd

$$P_{c_{73-78}} = \frac{\left(\frac{452,500}{187,500} - 1\right)}{5}$$

$$P_{c_{73-78}} = .28 \text{ simple}$$

We estimate 1975 Cap using this growth rate and the 1973 Capacity value of 187,500 car/yr

n = 2 years

$$1975 \text{ Cap} = 187,500 \left(1 + .28 \times 2\right)$$

$$1975 \text{ Cap} = 292,500 \text{ car/yr}$$

$$A = 292,500 \text{ car/yr}$$

P_c: We will assume that the above growth estimate is applicable for the remainder of the period 1978-1985

$$\therefore P_c = .28 \text{ simple}$$

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-9-74

Source Autobody Incinerator

P_B: Ref 037 does not specify any category which would be applicable to autobody incinerators. We make the assumption that the obsolecence rate will be approximated by the P_B for municipal incinerators

$$\therefore P_B = .039 \text{ simple}$$

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-9-74

Source Autobody Incinerators

E_u & E_N : Emission data was taken from Ref 038 Table 46 pg 141

All new incinerator installations have afterburners for control.

	E_u Uncontrolled lb/car	E_N Afterburner controlled lb/car
Particulate	2	.54
Carbon Monoxide	2.5	neg
Nitrogen oxides	.1	.02
Hydrocarbons (includes aldehydes and organic acids)	1.0	.46

Nat Gas is generally used as combustion fuel and afterburner fuel which would imply a very low sulfur oxide emission level For this reason we do not consider SO_x to be a major pollutant for this source.

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Computation Sheet For Emission Factors

Calculations Done By U.F. Russo Date 11/4/74

Source Autobody Incinerators

Particulate Emissions, E_s:

No distribution for Autobody Incinerators has been found. Ref. 038 Table 47 pg 142 list five (5) incinerators by location. We assume the remainder 10 incinerators' E_s is determined by the 50 State Average Process Weight Rate:

State	Rate (car/yr)	Rate (car/hr)*	Input Process Wt. (lbs/hr)**	Allow. Emiss.
Colorado	12,500	6.0	12000 lbs/hr	11.2 lbs/hr
N.C.	12,500	6.0	12000	13.5 lbs/hr
Utah	12,500	6.0	12000	10.2 lbs/hr
Texas	12,500	6.0	12000	17.0 lbs/hr
Iowa	12,500	6.0	12000	13.5 lbs/hr
10 Others	12,500	6.0	12000	13.0 lbs/hr

* Assuming 2080 hrs operation/YEAR

** Assuming 2000 lbs/car

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Computation Sheet For Emission Factors

Calculations Done By ______________________ Date ______________

Source ____

Since the State of NC, Texas, Iowa, and "10 others" have greater emissions than E_u, replace allowable emissions by E_u for these states

State	E_S^0 (lbs/car)	A_i
Col.	1.87	.067
Utah	1.70	.067
Others.	2.	.866

$$\therefore E_S = .239 + 1.732$$

$$E_S = 1.97 \text{ lbs/car}$$

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 11-4-74

Source Autobody Incinerators

E_s: Hydrocarbons

Ref 084 & 148 - there are no hydrocarbon regulations applicable to autobody incinerators
$\therefore E_s = E_u$

$\therefore E_s = 1$ lb/car

Carbon Monoxide

Ref 084 & 148

Only Illinois has regulations for CO applicable to autobody incinerators.

We make the assumption that this would not effect the overall value of E_s $\therefore E_s = E_u$

$E_s = 2.5$ lb/car

Nitrogen Oxide Ref 148 & 084

Only Illinois, Indiana, and Massachusetts have NO_x reg applicable to autobody incinerators however their contribution is assumed negligible to the total $\therefore E_s = E_u$

$E_s = .1$ lb/car

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-11-74

Source Conical Burners

Synononomous Names : Teepee and Wigwam Incinerators

Ref 038
pg74-98

These incinerators are mostly used for the disposal of wood wastes from the manufacture of forest products (pg74)

Majority located in; Western States
Texas
Louisiana
Arkansas
Kentucky
Georgia
North Carolina

Ref 051 pg1, pg14-15

These incinerators have been applied in limited cases to municipal waste, however, the refuse is limited to a great extent to wood, twig and brush wastes. Garbage, rubber, plastics, asphalt prod, leather, etc cause serious emission conditions and control requirements

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-11-74

Source Conical Burners

K: The average burning rate is 85% of design capacity Ref 038 pg 83

$\therefore$ K = .85

A:

Ref 038 Table 31 pg 90

Year	No of Teepees	Yearly Disposal Rate 10^6 units*/yr
1968	3,330	46.7
1973	835	11.7
1978	490	6.9

We plot this data (see attached graph) and estimate the 1975 disposal rate as; $P_{75} = 9.5 \times 10^6$ TON/yr

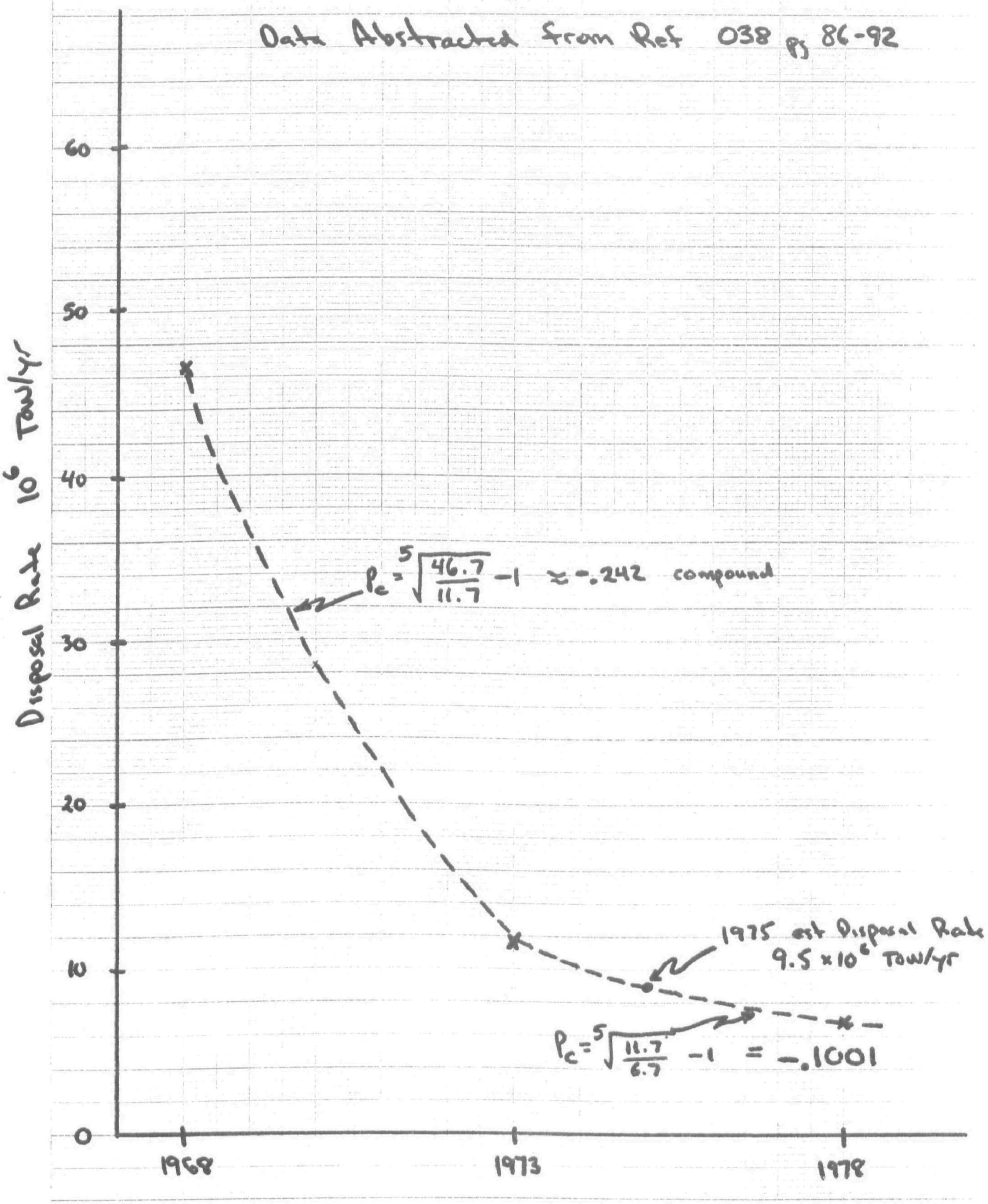
using K=.85 we estimate the production capacity for 1975

$$A = \frac{9.5 \times 10^6}{.85}$$

$\therefore$ $A = 11.2 \times 10^6 \frac{T}{yr}$ wastes

*UNIT is equivalent to about 1 ton of wood wastes

Conical Burners
Disposal Rate



46 1320

K+E 10 X 10 TO 1/2 INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-11-74

Source Conical Incinerators

P_c: The growth from 1968 - 1973 is estimated as -24.2%

$P_c = -.242$ compound

The growth est. for 1973 - 1978 is -10.01%

$P_c = -.1001$ compound

We assume that the growth rate from 1973-1978 will continue and therefore is applicable to the whole period 1975-1985

$\therefore P_c \cong -.10$ compound

P_B: Ref 038 pg 89 states that the trend of disposing of wood waste by burning in teepees has rapidly declined in the last 5 years and is expected to continue to decline in the near future.

We assume this to be true for disposal of municipal wastes even more so.

Modification of existing equipment is done only to meet air pollution regulations. Replacement of existing capacity is not expected $\therefore P_B \cong 0$

$\therefore P_B = 0$

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-11-74

Source Conical Incinerator

Since $P_C = -.10$ decline in industry growth rate

$P_B = 0$ no replacement of obsolete capacity

This sources is not a candidate for NSPS!

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-11-74

Source Conical Incinerators

Emission factors were obtained from Ref 038 Table 26 pg 81 with qualification on pg 89 and pg 92

400°F represent unmodified teepee
800°F " modified "

		Pt	HC	CO
Modified	lb/ton waste :	4	.5	20
Unmodified	lb/ton waste :	16	4.5	60

In 1968 disposal in unmodified only

In 1973 41% modified disposal
59% unmodified disposal

In 1978 all modified disposal

We assume the following percentages for 1975-1978

1975	64% modified	36% unmodified
1976	76% modified	24% unmodified
1977	88% modified	12% unmodified

Weighting the emission factor in each year by the above breakdown and combining this with the modified emission factor for the period 1978-1985 we may estimate (calculate) average emission factors 1975-1985

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-11-74

Source Conical Incinerators

Year	% modified	Emission Factor lb/TON waste Pt	HC	CO
1975	64%	8.3	1.9	34.4
1976	76%	6.9	1.5	29.6
1977	88%	5.4	1.0	24.8
1978	100%	4	.5	20
1979	"	4	.5	20
1980	"	4	.5	20
1981	"	4	.5	20
1982	"	4	.5	20
1983	"	4	.5	20
1984	"	4	.5	20
1985	"	4	.5	20
	Avg	4.8	.76	22.6

∴ E_u Part = 4.8 lb/TON waste
HC = .76 lb/TON waste
CO = 22.6 lb/TON waste

Controls were not applied since this source does not apparently come under NSPS! Best control is being met by redesign and use of "modified" configuration and burning conditions.

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Computation Sheet For Industrial Factors

Calculations Done By K. Tower Date 1/30/75

Source Industrial/Commercial Incinerators

Ref 075, p.2.1-2 states that industrial/commercial incinerators have capacities which cover a wide range, generally between 50 and 4000 pounds per hour.

Ref 163, p.33 defines intermediate-size incinerators as those incinerators with a design capacity of from 50-4000 lbs/hour. This includes commercial, industrial, medical (pathological), high-rise and school incinerators. We define industrial/commercial incinerators as all these incinerators listed as intermediate-size with the exception of pathological incinerators which will be covered as a separate industry. Ref 163, p.36 states that 4% of intermediate size incinerators are pathological. This means that industrial/commercial incinerators as we define them, are equal to 96% of intermediate size incinerators as Ref 163 defines them.

Ref 163, p.35 states that the average intermediate size incinerator operates 3 hrs/day. We assume the average owner of an industrial/commercial incinerator could possibly operate 8 hrs/day. Therefore, $K = 3/8 = .375$.

$$\boxed{K = 0.38}$$

Ref 163, p.34-38 gives a statistical analysis of "intermediate size" incinerator growth trends, based on a survey of the Incinerator Institute of America (IIA) covering the years 1962-1972. From the information in this analysis we develop the growth rate for the industrial/commercial industry, according to the following equation:

$$P_{c} = \sqrt[1972-1962]{\frac{\text{Industrial Capacity 1972}}{\text{Industrial Capacity 1962}}} - 1.0$$

compound

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Computation Sheet For Industrial Factors

Calculations Done By K. Tower Date 1/30/75

Source Industrial/Commercial Incinerators

Ref 163, p.35 states there were 101,755 operating intermediate incinerators in 1972 and that the average capacity is equal to 228 lb/hr. It can then be stated:

$$\text{Industrial Capacity}_{1972} = (101,755)(.96)\left(228\ \frac{\text{lbs}}{\text{hr}}\right) = 22.3\times10^{6}\ \frac{\text{lbs}}{\text{hr}}$$

From Ref 163, p.36, Fig 4 it can be determined that 4600 intermediate incinerators were sold from 1962-1972 (IIA data). Using the relationship described in ref 163, p.34 one can determine the Industrial Capacity$_{1962}$ as follows:

$$\text{Industrial Capacity}_{1962} = \left[10.697(8146-4600) + 10(1461.836)\right](.96)\left(150\ \frac{\text{lbs}}{\text{hr}}\right)$$

$$= 7.57\times10^{6}\ \text{lbs/hr}$$

No data could be found giving the average capacity of an industrial/commercial incinerator so we assumed 150 lbs/hr.

$$P_c = \sqrt[10]{\frac{22.3\times10^{6}}{7.57\times10^{6}}} - 1.0$$

$$= 1.11 - 1.0 = .11$$

$$P_{c\ \text{compound}} = 0.11$$

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Computation Sheet For Industrial Factors

Calculations Done By K. Tower Date 1/31/75

Source Industrial/Commercial Incinerators

From Ref 163, p. 35 we find "intermediate-size" incinerators processed 9.04×10^6 TON/YR in 1972. From this information we can calculate the amount of solid waste processed by industrial/commercial boilers in 1975 as follows:

$$P_{1975} = P_{1972}(1 + P_c)^{1975-1972}$$

$$= (9.04 \times 10^6)(1 + .11)^3$$

$$P_{1975} = 12.4 \times 10^6 \ \frac{\text{TONS}}{\text{YR}}$$

$$A = \frac{\text{Prod}_{1975}}{K} = \frac{12.4 \times 10^6 \ \frac{\text{TONS}}{\text{YR}}}{0.38} = 32.6 \times 10^6 \ \frac{\text{TONS}}{\text{YR}}$$

$$\boxed{A = 32.6 \times 10^6 \ \frac{\text{TONS}}{\text{YR}}}$$

We were not able to obtain specific information regarding the replacement rate of obsolete production capacity (P_B) however we will assume it to be the same as that for pathological incinerators → $.039_{\text{simple}}$ (Pathological Incinerators, Industrial Factors, p. 6)

$$\boxed{P_B = .039_{\text{simple}}}$$

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By K. Tower Date 1/31/75

Source Industrial/Commercial Incinerators

The following table found in Ref 075, p.2.13, Table 2.1-1 will be used to determine emissions factors for P_T, SO_x, CO, Hydrocarbons and NO_x.

Incinerator Type	* %	P_T emissions lbs/TON	SO_x lbs/TON	CO lbs/TON	HC lbs/TON	NO_x lbs/TON
Multiple Chamber	83	7	2.5	10	3	1.5
Single Chamber	2	15	2.5	20	15	1
Controlled Air	12	1.4	1.5	Neg	Neg	5
Other	3	$E_{u_{P_T}}$	$E_{u_{SO_x}}$	$E_{u_{CO}}$	$E_{u_{HC}}$	$E_{u_{NO_x}}$

* These data are taken from Ref 163, p.35, Table 5

E_u:

$$E_{u_{P_T}} = (.02)(15) + (.83)(7) + (.12)(1.4) + (.03)(E_{u_{P_T}})$$

$$\boxed{E_{u_{P_T}} = 6.47 \text{ lbs/TON}}$$

$$E_{u_{SO_x}} = (.83)(2.5) + (.02)(2.5) + (.12)(1.5) + (.03)(E_{u_{SO_x}})$$

$$\boxed{E_{u_{SO_x}} = 2.38 \text{ lbs/TON}}$$

$$E_{u_{CO}} = (.83)(10) + (.02)(20) + (.03)(E_{u_{CO}})$$

$$\boxed{E_{u_{CO}} = 8.97 \text{ lbs/TON}}$$

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Computation Sheet For Emission Factors

Calculations Done By K. Tower Date 1/31/75

Source Industrial/Commercial Incinerators

E_u con'd:

$$E_{u_{HC}} = (.83)(3) + (.02)(15) + (.03)(E_{u_{HC}})$$

$$E_{u_{HC}} = 2.88 \text{ lbs/TON}$$

$$E_{u_{NO_x}} = (.83)(1.5) + (.02)(1.0) + (.12)(5.0) + (.03)(E_{u_{NO_x}})$$

$$E_{u_{NO_x}} = 1.87 \text{ lbs/TON}$$

E_N

Ref 075, p.2.1-4, Table 2.1-2 indicates that collection efficiencies of up to 99% on particulate emissions can be expected by using a fabric filter.

$$E_{N_{PT}} = (.01)(6.47) = .065 \text{ lbs/TON}$$

$$E_{N_{PT}} = .065 \text{ lbs/TON}$$

Only wet scrubbing devices are shown to control to some extent nitrogen oxides. Table VI-1 Ref 085: Maximum efficiency was for medium energy wet scrubbers → 65%

$$E_{N_{NO_x}} = 0.35 \times E_{u_{NO_x}} = 0.35 \times 1.87 \text{ lbs/Ton} = 0.65 \text{ lbs/Ton}$$

$$E_{N_{NO_x}} = 0.65 \text{ lbs/Ton}$$

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Computation Sheet For Industrial Factors

Calculations Done By K. Tower Date 2/7/75

Source Industrial/Commercial Incinerators

There is no technology available that is known for the control of SO_x, CO & HC emissions from industrial/commercial incinerators. In order to maximize the potential impact for these sources we assume $E_N = 0$.

$$E_{N_{SO_x}} = 0.00 \text{ lbs/Ton}$$

$$E_{N_{CO}} = 0.00 \text{ lbs/Ton}$$

$$E_{N_{HC}} = 0.00 \text{ lbs/Ton}$$

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Computation Sheet For Emission Factors

Calculations Done By K. Tower Date 2/3/75

Source Industrial/Commercial Incinerators

E_s

Ref 163, p.33 Table 1 gives a distribution by state of IIA incinerator units. We assume this to be the same distribution as that for industrial/commercial incinerators. The following is a list of the top contributors and the individual states' allowable emissions (ref 084, Ref 148) based on an average process weight rate for industrial/commercial incinerators as 228 lbs/hr. → ref 163, p.35.

State	%	Allowable Emissions (lbs/hr)
Illinois	8.58	0.82
Indiana	8.0	0.94
Massachusetts	5.12	0.95
Michigan	5.61	0.94
Minnesota	6.21	0.94
New York	5.57	0.89
Ohio	10.62	0.94
Wisconsin	11.94	0.95
	61.65	

$$\text{Allowable Emissions} = (.086)(0.82) + (.08)(0.94) + (.051)(0.95) + (.056)(0.94) + (.062)(0.94) + (.056)(0.89) + (.106)(0.94) + (.119)(0.95) + (1.00 - .6165)(\text{Allowable Emissions})$$

$$\text{Allowable Emissions} = \frac{.071 + .075 + .048 + .053 + .058 + .050 + .100 + .113}{.616}$$

$$\text{Allowable Emissions} = .922 \text{ lbs/hr.}$$

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Computation Sheet For Emission Factors

Calculations Done By K. Tower Date 2/3/75

Source Industrial/Commercial Incinerators

E_s (cont'd)

$$E_{s_{PT}} = \frac{(.922 \text{ lbs/hr})(2000 \text{ lbs/TON})}{(228 \text{ lbs/hr})} = 8.09 \text{ lbs/TON}$$

Since this value is greater than $E_{u_{PT}}$ we will assume $E_{s_{PT}} = E_{u_{PT}}$.

$$E_{s_{PT}} = 6.47 \text{ lbs/TON}$$

Specific regulations applicable to incinerator emissions other than particulate do not exist and no general regulations were seen to apply $\therefore$ $E_s = E_u$ Ref (84) & (148)

$$E_{s_{SO_x}} = 2.38 \text{ lbs/TON}$$

$$E_{s_{NO_x}} = 1.87 \text{ lbs/TON}$$

$$E_{s_{CO}} = 8.97 \text{ lbs/TON}$$

$$E_{s_{HC}} = 2.88 \text{ lbs/TON}$$

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Computation Sheet For Emission Factors

Calculations Done By K. Tower Date 2/3/75

Source Industrial/Commercial Incinerators

Summary of Emission Factor

Pollutant	E_u (lbs/TON)	E_N (lbs/TON)	E_S (lbs/TON)
Particulate	6.47	0.065	6.47
SO_x	2.38	0.00	2.38
NO_x	1.87	0.65	1.87
CO	8.97	0.00	8.97
Hydrocarbons	2.88	0.00	2.88

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-12-74

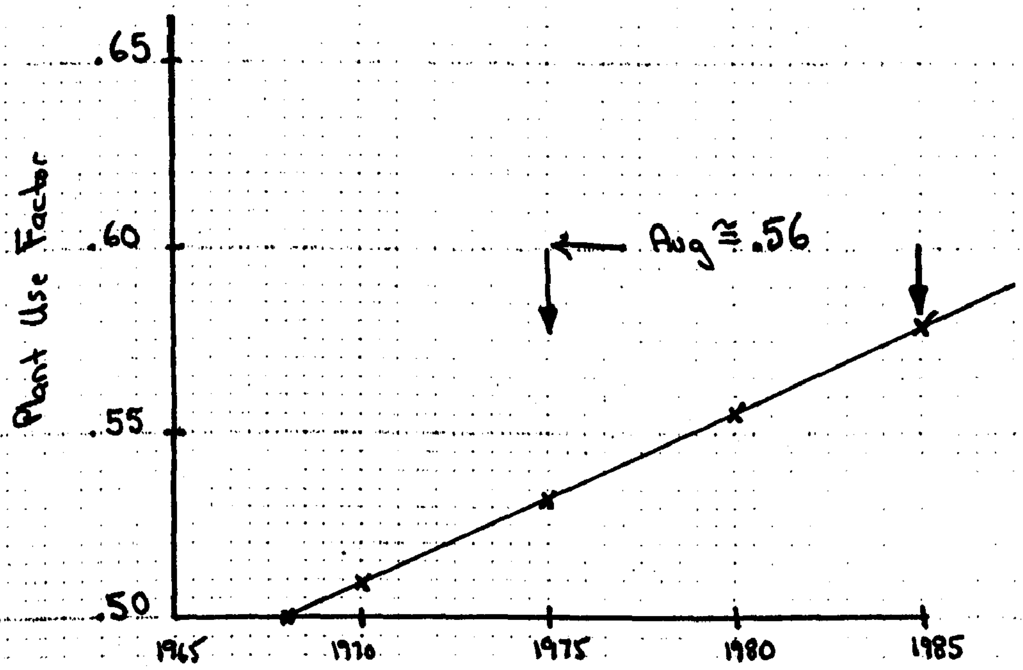
Source Municipal Incinerators

K:

Ref 085 Fig III-8 pg III-24

Plant use factor 1968 = 50%
Plant use factor 2000 = 65%

Assuming a linear relationship of factor growth during this period we may establish the following graph



We will use this average plant use factor for the period 1975 - 1980 as an estimate of plant utilization of capacity (K)

∴ K = .56

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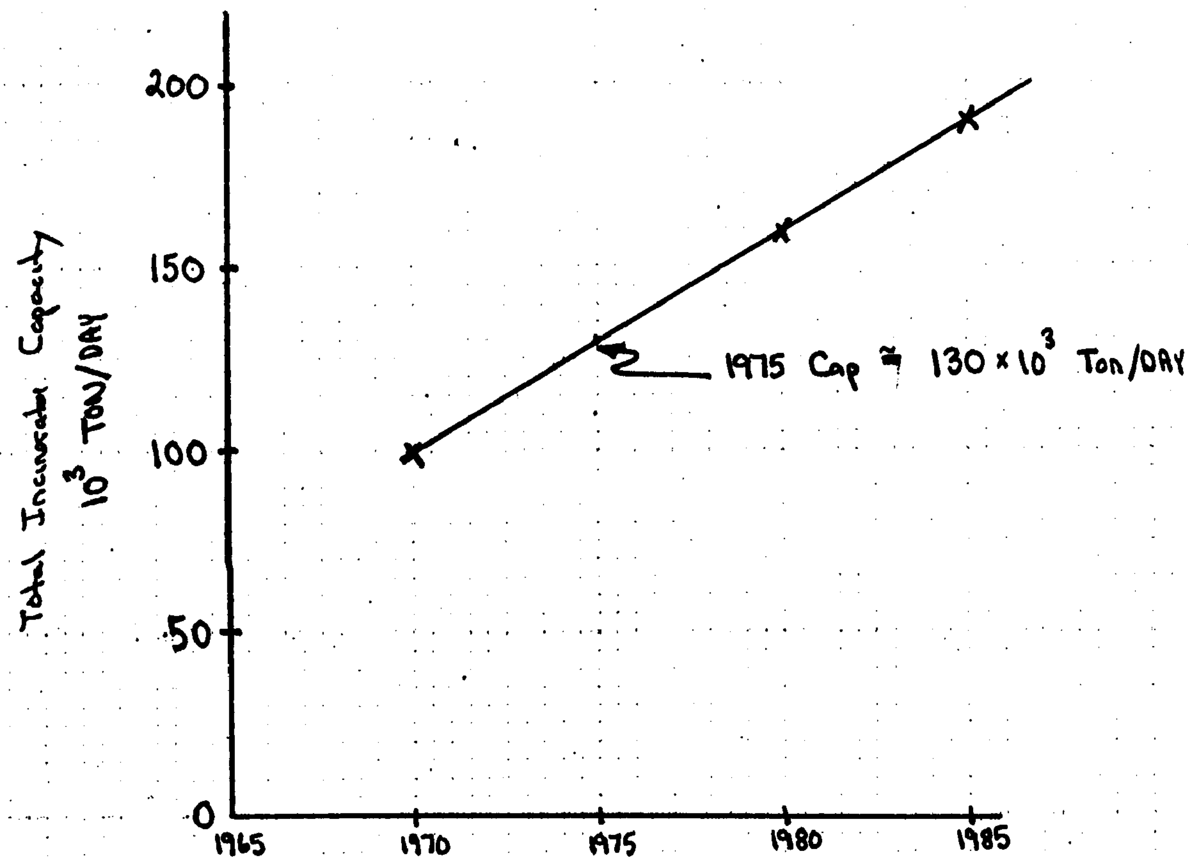
Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-12-74

Source Municipal Incinerator

A: Ref 085 Fig III-7 pg III-23

Projected total active incinerator capacity is presented which we have graphed below



We assume a plant schedule of 250 D/yr. 24 hr/day and may estimate the 1975 annual cap as $A = 250 \frac{D}{yr} \times (130 \times 10^3) \frac{T}{Day}$

$A = 3.25 \times 10^7$ T/yr

∴ $A = 32.5 \times 10^6$ T/yr refuse burned

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-12-74

Source Municipal Incinerators

P_c:

An estimate of growth during the period 1975 to 1985 is obtained by referring to our graph of Incinerator Cap.

The growth is assumed linear

$$\frac{(190 \times 10^3) - (100 \times 10^3)}{15 \text{ year}} = 6 \times 10^3 \text{ TPD/yr}$$

$$P_c = \frac{6 \times 10^3 \text{ TPD/yr}}{130 \times 10^3 \text{ TPD}} = .046$$

based on 1975 base-line year (simple growth)

$\therefore$ $P_c = .046$ simple

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-12-74

Source Municipal Incinerators

P_B:

Ref 062 pg I-40 (Appendix)

Average life of incinerator based on the replies of 87 operating plants gave a value of 25.73 yrs. Using this expected life to estimate P_B

$$\frac{100\% \text{ depreciation}}{25.73 \text{ year}} = 3.88\ \%/\text{yr simple}$$

$$P_B \cong .039 \text{ simple}$$

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-12-74

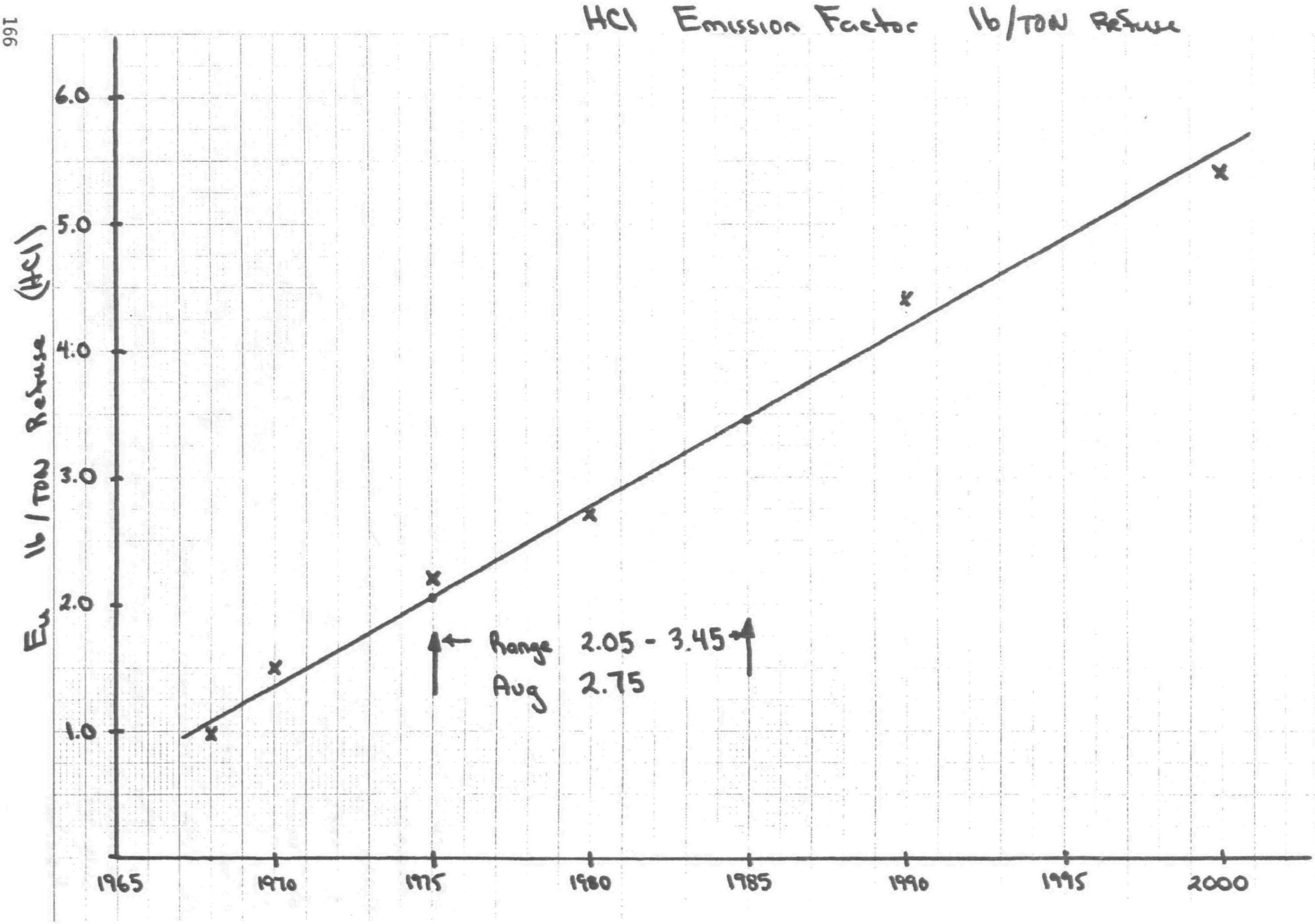
Source Municipal Incinerators

E_u: The following uncontrolled emission factors were obtained from Table III-6 of Ref 085

	E_u lb/TON refuse
Pt (total)	19.7 lb/TON
HC	2.7
CO	34.8
NO_x	3.0
SO_x	3.9

In addition HCl has been cited as a growing emission due to increase plastic (PVC) disposal Table III-5 pg III-20 of Ref 085 gives a tabulation of HCl uncontrolled emission factors as a function of year from 1968-2000. This factor increases due to a growth in the percentage of plastics in refuse burned. Attached graph plots the estimates of HCl emission factors

The average emission factor between 1975-1985 developed from the straight-line through the data will be used to approx. an uncontrolled HCl emission factor


HCl Emission Factor lb/TON Refuse
E_u lb / TON Refuse (HCl)
6.0
5.0
4.0
3.0
2.0
1.0
1965
1970
1975
1980
1985
1990
1995
2000
Range 2.05 - 3.45
Avg 2.75

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Computation Sheet For Emission Factors

Calculations Done By 2J. Marrone Date 9-12-74

Source Municipal Incinerator

E_u: cont'd

$$\therefore E_{u_{HCl}} = 2.75 \text{ lb/TON refuse}$$

Trace metals were discussed on pg III-18 of Ref-085
Zinc, Lead, Cadium, Selenium are identified however, data were not available.

We were not able to determine specific or total trace metal emission factors.

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-12-74

Source Municipal Incinerators

E_N :

Table VI-2 of Ref 085 suggests that the greatest share of the control market on municipal incinerators will be held by
① Dry Mechanical Cyclones
② Medium Energy Wet Scrubbers
③ Electrostatic Precipitators

Bag Fabric Filters do not appear attractive (although believed to be effective) to incinerator designers and/or operators.

The "proposed standards" (Ref 147 Tech Report No 2) state that a 90-95% eff would be required to meet the standard level. Electrostatic Prec, Bag Filters, and high energy scrubbers are being used and all may achieve this level.

Particulate

We assume that the attainable collection efficiency for total particulate (between the 99% of mineral and 90% for combustible in Ref 085 Table VI-1) will be achieved by best available technology and be about 95%

$$E_N = .05 \times E_u = .05 \times 19.7 = .985$$

$\therefore E_N = .99$ lb/TON refuse Particulates

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Computation Sheet For Emission Factors

Calculations Done By R.W. Marrone Date 9-12-74

Source Municipal Incinerator

E_N: cont'd

HCl

Due to the high solubility of HCl in water, we expect a good collection efficiency in a wet scrubber.

Ref 085 Table VI-1 Medium Energy Scrubber 95% eff for HCl

$$E_N = .05 \times E_u = .05 \times 2.75 = .138$$

$$E_N \doteq .14$$

$$\therefore E_N = .14 \text{ lb/TON refuse}$$

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-12-74

Source Municipal Incinerators

E_N: NO_x CO HC

Modifications in combustion design and/or operation are the prime options available to reduce NO_x emissions. Carbon Monoxide and hydrocarbons are suspected of being associated Ref 085 pg V-39

CO : HC = 13 : 1

Reduction of CO (likewise HC) is best handled by improved incinerator operation or design pg III-16 Ref 085. APC devices are inadequate or ineffective at controlling these emissions.

Only wet scrubbing devices are shown to control to some extent nitrogen oxides Table VI-1 Ref 085: Max eff was for Med-Energy Wet Scrubber 65%.

We will use 65% eff for NO_x and assume that CO, HC are only limitly controlled.

More data on incinerator design features may suggest the optimum operating parameters which would result in the lowest NO_x, HC, CO relationship concurrent with acceptable incineration performance. We will refine this when such data appears.

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-12-74

Source Municipal Incinerators

E_N cont'd

NO_x, CO, HC

$$E_N (NO_x) = .35 \times E_u = .35 \times 3.0$$

$$E_N (NO_x) \cong 1.1 \text{ lb/TON refuse}$$

Since control for municipal incinerators do not apply to CO and HC then, $E_N = 0$ for maximum impact determination

$$E_N = 0 \quad (HC)$$
$$E_N = 0 \quad (CO)$$

SO_x

Ref 097 pg 93 states that sulfur oxide emission from municipal incinerators are not normally ~~req~~ controlled.

E_N is assumed = 0 for maximum impact
demonstrated control tech not available

$$E_N (SO_x) = 0$$

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Computation Sheet For Emission Factors

Calculations Done By W. Morrone Date 10-24-74

Source Municipal Incinerators

E_S : Particulate

Ref 062 pg I-27 Average Plant Size 400 TPD

$$\frac{400 \text{ TPD}}{24 \text{ hr/D}} \times \frac{2000 \text{ lb}}{T} \cong 33{,}300 \text{ lb/hr}$$

It is assumed that this average plant size is typical of existing and new plants

The attached tables of emission limitations was used to estimate a synthsized value for E_S for existing and new municipal incinerators.

The following conditions or assumptions were employed;

(a) Alaska and Nevada and new have opacity reg for existing incinerators We assume $E_{si} = E_u$

(b) California has no state-wide reg - use $E_{si} = E_{s_{Avg}}$ (Existing and New)

(c) Delaware (Existing & New) has no reg above 3000 lb/hr cap therefore we assume $E_{si} = E_u$

(d) Illinois has no reg for existing incin above 2000 lb/hr therefore we assume $E_{si} = E_u$

(e) New Mexico does not permit incineration after 1976 Therefore it is not included in calculation.

(f) Oklahoma emission equation gives ≈ .10 lb/100 lb for 33,300 lb/hr (Existing & New)

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 10-24-74

Source Municipal Incinerators

E_s: particulate cont'd

(g) North Dakota emission equation gives ≈ .08 lb/100 lb for 33,300 lb/hr cap
(Existing & New)

(h) S. Carolina has reg based on heat input. We assume $E_{si} = E_{s\,Avg}$ (Existing & New)

(i) Texas has no gen regulation (assume $E_{si} = E_{s\,Avg}$)
[Existing & New]

(j) Utah require 85% control (Existing & New) ∴ $E_{si} = .15 \times E_u$

*(k) In the end, since NSPS has been proposed for Municipal Incinerator > 50 TPD then E_s (new) must be at least as good as NSPS

Ref 147 pg 19 $E_{Allow} = 1.9$ lb/TON waste

or .095 lb/100 lb

Any state standard < .095 lb/100 lb will be kept
Any state standard > .095 lb/100 lb will be changed to .095 lb/100 lb

Note Promulgated standard is .08 gr/scf as opposed to .1 gr/scf for proposed standard.

Ref 273
pg 24880

$$\therefore \text{NSPS} = \frac{.08}{.10} \times .095 \text{ lb/100 lb} = .076 \text{ lb/100 lb}$$

This value of .076 lb/100 lb will be used to replace the limit of .095 lb/100 lb

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 10-24-74

Source Municipal Incinerator

E_s: particulate cont'd

"Existing Plants" 51 states - 1 (N. Dak) = 50 States to consider with each acting equally which is equivalent to taking the average

1. $E_{si} = E_u$ $4 \times E_u = 4 \times (19.7 \frac{lb}{TON} \times \frac{TON}{2000\ lb}) \times 100 = 4 \times .985 \frac{lb}{100\ lb}$

$= 3.94\ lb/100\ lb$

2. ΣE_{si} 42 states $\Sigma E_{si} = 6.81$

3. $E_{si} = E_{sAvg}$ 3 state $3\ E_{sAvg}$

4. Utah $E_{si} = .15 \times E_u = .15 \times 19.7 \frac{lb}{TON} \times \frac{TON}{2000\ lb} \times 100 = .15\ lb/100\ lb$

3.94
6.81
.15
$3 \times E_{sAvg}$

or $\frac{10.9 + 3E_{sAvg}}{50} = E_{sAvg} = \frac{10.9}{47}$

$E_{SA} \cong .23\ lb/100\ lb$ (Existing Incin)

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 5-8-75

Source Municipal Incinerator

E_s: cont'd
Particulate
"New Plants"

① 42 states have limits $> .076$ lb/100 lb
② 1 states has limit $< .076$ lb/100 lb E_{s_i}(new) = .02 lb/100 lb
③ 1 state does not permit incineration E_{s_i}(new) = 0
④ 7 states have values for allowable emission which are unknown we assume they represent E_s Avg

Therefore

$$\frac{42}{44}(.076) + \frac{1}{44}(.02) + \frac{1}{44}(0) = E_s'(\text{new})$$

$$.073 + .00045 + 0 = .073 \text{ lb}/100\text{lb} \cdot \frac{20\ (100}{\text{ton})}$$

$$E_s(\text{new}) = 1.46 \text{ lb/TON waste}$$

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 5-8-75

Source Municipal Incinerator

E_S: Particulate

Existing Incinerator

$$E_{SA} = .23 \frac{lb}{100 lb} \times 20 \frac{(100 lb)}{TON} = 4.6 \; lb/TON$$

E_S (existing) = 4.6 lb/TON waste

E_S (new) = 1.46 lb/TON waste

Incineration Sources
lb Part / 100 lb Refuse Charge.

Existing Sources
Capacity lb/hr

	<200	≥200	<2000	≥2000	<4000	≥4000	≥10,000	other	All	COMMENT
Alabama	.20	.20	.20	.20	.20	.20	.20		.20	
Alaska			assume	$E_{sc} = E_{Avg}$						opacity only
Arizona	.22	.22	.22	.22	.22	.22	.22		.22	
Arkansas	.29	.19	.19	.19	.19	.19	.19			
Colorado	.15	.09	.09	.09	.09	.09	.09			
California			use	avg						only county reg
Conn.	.23	.23	.23	.23	.23	.23	.23		.23	
Delaware	.20	.20	.20	.18	.16	Eu	Eu			no reg above 5000 lb/hr
D.C.	.08	.08	.08	.08	.08	.08	.08		.08	
Florida	Eu			Eu	—	.09	.09			no reg below 4000 lb/hr
Georgia	.19	.19	.19	.19	.19	.19	.19		.19	
Hawaii	.20	.20	.20	.20	.20	.20	.20		.20	
Idaho	.20	.20	.20	.20	.20	.20	.20		.20	
Illinois	.19	.19	.19	— Eu —		Eu	—			no reg above 2000
Indiana	.39	.39	.39	.23	.23	.23	.23			
Iowa	.33	.33	.33	.19	.19	.19	.19			
Kansas	.29	.19	.19	.19	.19	.19	.19	>20,000 .09		
Kentucky	.19	.19	.19	.19	.19	.19	.19		.19	
Louisiana	.19	.19	.19	.19	.19	.19	.19		.19	
Maine	.19	.19	.19	.19	.19	.08	.08			
Maryland	.29	.19	.19	.19	.19	.19	.19			
Mass.	.09	.09	.09	.09	.09	.09	.09		.09	
Michigan	.30	.30	.30	.30	.30	.30	.30		.30	
Minn.	.30	.20	.20	.10	.10	.10	.10			
Miss.	.19	.19	.19	.19	.19	.19	.19		.19	
Missouri	.29	.19	.19	.19	.19	.19	.19			
Montana	.29	.19	.19	.19	.19	.19	.19			
Nebraska	.19	.19	.19	.09	.09	.09	.09			
Nevada			E_s =	E_{Avg}						opacity only
N. Hampshire	.29	.19	.19	.19	.19	.19	.19			
N. Jersey	.19	.19	.19	.09	.09	.09	.09			
N. Mexico	0	0	0	0	0	0	0		0	incin not permitted
New York	.35	.35	.35	.35	.35	.35	.35	use 50% NYC 50% NY	.50	.2 for NYC
N. Carolina	.20	.20	.20	.02	.02	.02	.02			
N. Dakota										emission equation
Ohio	.10	.10	.10	.10	.10	.10	.10			

Existing Cont'd

	<200	≥200	<2000	≥2000	<4000	≥4000	≥10,000	other	All	COMMENT
Oklahoma			use	avg						emission equation
Oregon	.29	.19	.19	.19	.19	.19	.19			
Penn.	.09	.09	.09	.09	.09	.09	.09		.09	
R.I.	.15	.15	.15	.08	.08	.08	.08			
S. Carolina			use	avg						reg based on heat input
S. Dakota	.20	.20	.20	.20	.20	.20	.20		.20	
Tennessee	.60	.40	.40	.40	.40	.40	.40			
Texas			use	avg						no gen regulation
Utah	←		.15 × Eu				→			85% Control
Vermont	.10	.10	.10	.10	.10	.10	.10		.10	
Virginia	.13	.13	.13	.13	.13	.13	.13		.13	
Washington	.09	.09	.09	.09	.09	.09	.09		.09	
W. Virginia	.41	.27	.27	.27	.27	.27	.13			
Wisconsin	.34	.27	.27	.27	.27	.27	.27			
Wyoming	.20	.20	.20	.20	.20	.20	.20		.20	

Incineration Sources

lb Part / 100 lb Refuse Charged

New Sources

	Capacity lb/hr							other	All	COMMENT
	<200	≥200	<2000	≥2000	<4000	≥4000	≥10,000			
labama	.20	.20	.20	.20	.20	.20	.20		.20	
laska	.29	.19	.19	.09	.09	.09	.09			
rizona	.22	.22	.22	.22	.22	.22	.22		.22	
Arkansas	.29	.19	.19	.19	.19	.19	.19			
Colorado	.15	.09	.09	.09	.09	.09	.09			
California			use	avg						only county reg
Conn.	.08	.08	.08	.08	.08	.08	.08		.08	
Delaware	.20	.20	.20	.18	.16	Eu	Eu			no reg above 3000 lb/hr
D.C.	.03	.03	.03	.03	.03	.03	.03		.03	
Florida	—	—	—	—	—	.08	.08			no reg below 4000 lb/hr
Georgia	.10	.10	.10	.10	.10	.08	.08			
awaii	.20	.20	.20	.20	.20	.20	.20		.20	
Idaho	.20	.20	.20	.20	.20	.20	.20		.20	
Illinois	.09	.09	.09	.08	.08	.08	.08	≥60,000 .05		
ndiana	.39	.39	.39	.23	.23	.23	.23			
Iowa	.33	.33	.33	.19	.19	.19	.19			
Kansas	.29	.19	.19	.19	.19	.19	.19	>20,000 .09		
Kentucky	.19	.19	.19	.19	.19	.08	.08			
Louisiana	.19	.19	.19	.19	.19	.19	.19		.19	
Maine	.19	.19	.19	.19	.19	.08	.08			
Maryland	.09	.09	.09	.03	.03	.03	.03			
Mass.	.05	.05	.05	.05	.05	.05	.05		.05	
Michigan	.30	.30	.30	.30	.30	.30	.30		.30	
Minn.	.30	.20	.20	.10	.10	.10	.10			
Miss.	.09	.09	.09	.09	.09	.09	.09		.09	
Missouri	.29	.19	.19	.19	.19	.19	.19			
Montana	.29	.19	.19	.19	.19	.19	.19			
Nebraska	.19	.19	.19	.09	.09	.09	.09			
evada	—		use Eu							opacity only
N. Hampshire	.29	.19	.19	.19	.19	.19	.19			
N. Jersey	.19	.19	.19	.09	.09	.09	.09			
N. Mexico	0	0	0	0	0	0	0		0	Incin not permitted
ew York	.25	.25	.25	.25	.25	.25	.22	50% NYC 50% NY		.2 for NYC
N. Carolina	.20	.20	.20	.02	.02	.02	.02			
N. Dakota		use	Avg							- emission equation
hio	.10	.10	.10	.10	.10	.10	.10			

New cont'd

	<200	≥200	<2000	≥2000	<4000	≥4000	≥10,000	other	All	COMMENT
Oklahoma			use avg							Emission equation
Oregon	.09	.09	.09	.09	.09	.09	.09		.09	
Penn.	.09	.09	.09	.09	.09	.09	.09		.09	
R.I.	.15	.15	.15	.08	.08	.08	.08			
S. Carolina			use avg							reg based on heat input
S. Dakota	.20	.20	.20	.20	.20	.20	.20		.20	
Tennessee	.20	.20	.20	.10	.10	.10	.10			
Texas			use avg							no gen. regulation
Utah	←		.15 × Eu				→			85% Control
Vermont	.10	.10	.10	.10	.10	.10	.10		.10	
Virginia	.13	.13	.13	.13	.13	.13	.13		.13	
Washington	.09	.09	.09	.09	.09	.09	.09		.09	
W. Virginia	.41	.27	.27	.27	.27	.27	.13			
Wisconsin	.17	.11	.11	.11	.11	.08	.08			
Wyoming	.20	.20	.20	.20	.20	.20	.20		.20	

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 10-24-74

Source Municipal Incinerators

E_s: cont'd

Specific regulations applicable to incinerator emissions other than particulate do not exist and no general regulations were seen to apply $\therefore$ $E_s = E_u$

$E_s(HC) = 2.7$ lb/TON refuse

$E_s(CO) = 34.8$ lb/TON refuse

$E_s(NO_x) = 3.0$ lb/TON refuse

$E_s(SO_x) = 3.9$ lb/TON refuse

$E_s(HCl) = 2.75$ lb/TON refuse

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 10-31-74

Source Municipal Incinerator

E_{111d} : HCl

Adaption of a wet scrubbing system to control HCl emissions was proposed as suitable for municipal incineration achieving about 75% efficiency. It does not appear impractical to expect this collection efficiency on a retro-fitted scrubber

$$\therefore E_{111d} = E_N$$

$$E_{111d} = .14 \text{ lb/TON refuse}$$

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-10-74

Source Pathological Incinerators (Animal Shelters & Crematories)

K:

Ref 038 Table 51 pg 153

For the five pathological incinerator installations listed we may estimate burning/capacity ratios for three of them.

① $\frac{B}{C} = \frac{130}{300} = .433$

④ $\frac{B}{C} = \frac{29}{85} = .341$

⑤ $\frac{B}{C} = \frac{93}{400} = .233$

Operating schedules vary widely from 830 hr/yr to 4730 hr/yr. Assuming 5 d/wk and 52 wk/yr (260 d/yr), the daily hr usage for the 5 installations are;

① $\frac{3280}{260} = 12.6$ hr/day

② $\frac{4730}{260} \cong 18.2$ hr/day

③ $\frac{1040}{260} = 4$ hr/day

④ $\frac{830}{260} \cong 3.2$ hr/day

⑤ $\frac{2340}{260} = 9$ hr/day

Avg 9.4 hr/day or $9.4 \times 260 = 2444$ hr/yr

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-10-74

Source Pathological Incinerators (Animal shelters & Crematories)

K: cont'd

Our best estimate of a utilization factor for this source will be based on an average value for the ratio of B/C calculated above (3 installations)

We see that these estimates are based on three plants having time schedule spanning the full range of calculated values;

3.2 hrs/day for ④ low

9 hr/day for ⑤ medium

12.6 hr/day for ① high

$$\text{Average } B/C = \frac{.433 + .341 + .233}{3} = .336$$

approx $K \cong \frac{B}{C} \cong .34$

$$\therefore K = .34$$

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-10-74

Source Pathological Incinerators (Animal Shelter & Crematories)

A: Waste consumed in pathological incinerators was developed from data presented in Ref 038 pg 152-155

Animals Incinerated:	1968	26,000	T/yr
	1973	30,000	T/yr
	1978	34,500	T/yr

Cremations:	1968	83,977	bodies
	1973	94,500	bodies
	1978	105,000	bodies

We calculate the mass rate for cremations using the factor of 255 lb/casket for converting to ton/yr of human cremation [redacted]. This figures was obtained from pg 155 of the above source.

$$\frac{\text{bodies}}{\text{yr}} \times \frac{255\ \text{lb}}{\text{body}} \times \frac{\text{Ton}}{2000\ \text{lb}} = \text{Ton/yr}$$

Cremation Mass Rate	1968	10,707	T/yr
	1973	12,049	T/yr
	1978	13,388	T/yr

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Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-10-74

Source Pathological Incinerators (Animal Shelters & Crematories)

A: cont'd

The process weights consumed for animal and crematory sources is plotted along with the totals for the period 1968 to 1978 (see attached graph.

From this graph and the curve of total wastes consumed we may estimate the figure for 1975. This is done by calculating a compound growth between 1973 and 1978

$$P_c = \sqrt[5]{\frac{47,888}{42,049}} - 1$$

$$P_c = \sqrt[5]{1.1388} - 1$$

$$P_c = .026 \text{ compound}$$

then

$$1975 = 1973\,(1 + .026)^2$$

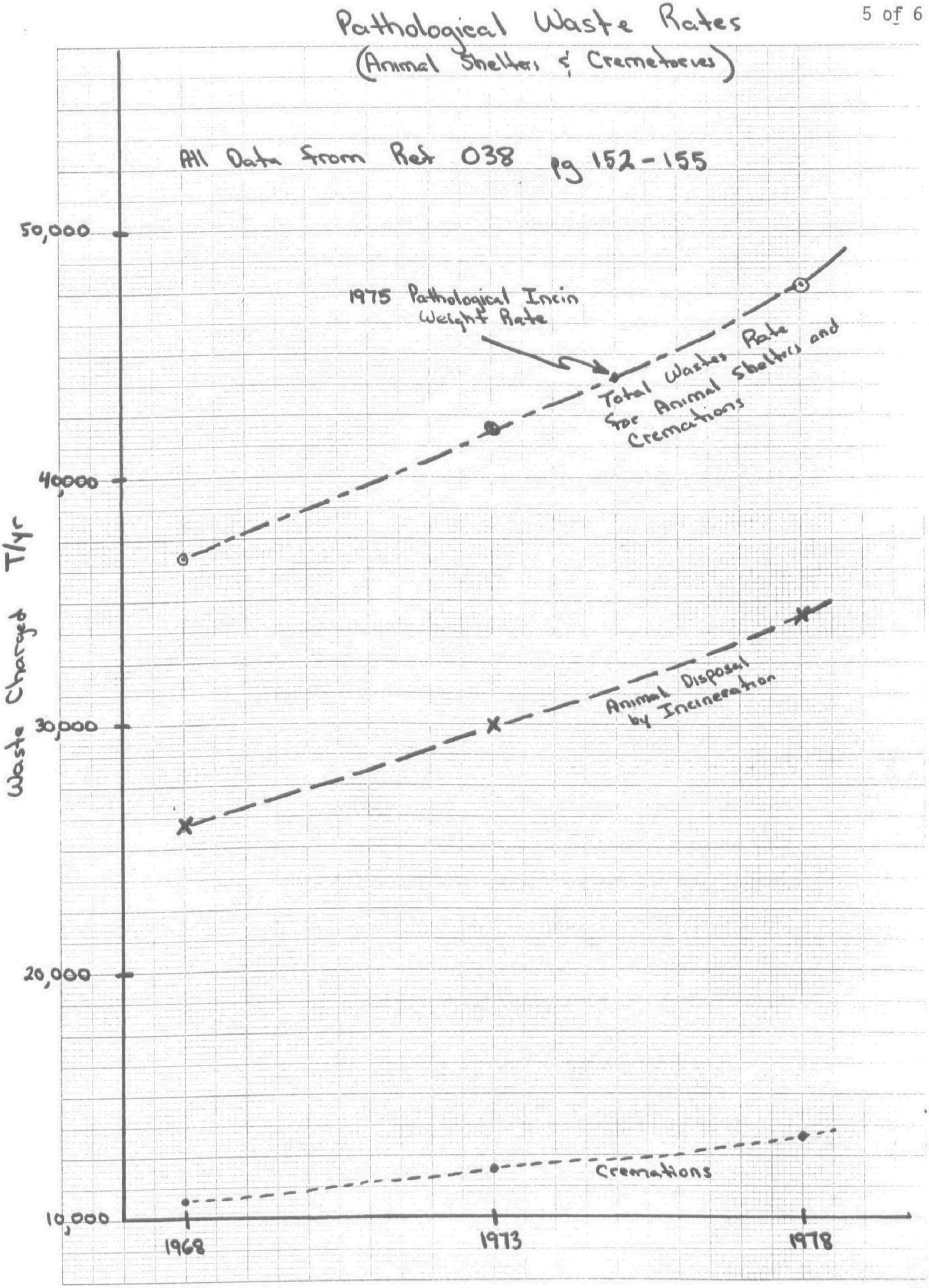
$$1975 = 42,049\,(1.026)^2$$

$$1975 \cong 44,265 \text{ T/yr}$$

Using K = .34 we determine the 1975 Prod Cap as:

$$A = \frac{44,265}{.34} = 130,191 \text{ T/yr}$$

$$\therefore A = 130,191 \text{ T/yr}$$


Pathological Waste Rates
(Animal Shelters & Cremetories)
All Data from Ref 038 pg 152-155
1975 Pathological Incin Weight Rate
Total Wastes Rate for Animal Shelters and Cremations
Animal Disposal by Incineration
Cremations
Waste Charged T/yr
50,000
40,000
30,000
20,000
10,000
1968
1973
1978

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Industrial Factors

Calculations Done By W. Marrone Date 9-10-74

Source Pathological Incinerators (Animal Shelters & Crematories)

P_c: We will use the compound growth determined above for the period 1973-1978 and assume it applicable to 1975-1985

$\therefore P_c = .026$ compound

P_B: Ref 037 did not specify a category which would be applicable to pathological incinerators. We will assume that the obsolescence rate will be approximated by the P_B for municipal incinerators

$\therefore P_B \cong .039$ simple

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-10-74

Source Pathological Incinerators (Animal Shelter & Crematory)

E_u:

From Ref 038 Table 50 pg 151

	E_u
Particulate	12.8 lb/ton waste
NO_x	25 lb/ton waste
HC	3.8 lb/TON waste
CO	4.1 lb/TON waste

From Ref 075 Table 2.1-1 pg 2.1-3

	E_u
Particulate	8 lb/ton
NO_x	3 lb/TON
HC	Neg
SO_x	Neg
CO	Neg

Ref 046 pg 485 Table 129

Avg NO_x 8 Tests 11.5 lb/TON

Avg HC (Ald & Acids from 84 Tests) .93 lb/TON

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-10-74

Source Pathological Incinerators

E_u: cont'd

There is a wide variation in reported emission quantities in the literature. We are lead to use the values appearing in Ref 038 since this is derived from more recent data.

Therefore;

	E_u lb/TON waste
Particulate	12.8
Hydrocarbons	3.8
Carbon Monoxide	4.1
Nitrogen Oxides	25.0

Good equipment design and operating practices are cited by ref 038 pg 149 and Ref 046 pg 485-486 as the best means of maintaining emission control. Minimum levels due to these practices were not found in the literature.

Wet scrubbers are indicated in Ref 098 pg 149 as useful in controlling smoke, odor, and particulate.

Ref 046 pg 486 states that an afterburner is applicable to pathological incinerator control.

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 9-10-74

Source Pathological Incinerators

E_N: cont'd

Achievable control efficiency were not found in the literature for pathological incinerators

We assume: ① 85% control of Pt (wet scrubber or improved design & operation)

② 99% control of CO and HC in well designed incinerator - afterburner package

③ 50% reduction in NO_x emission due to improved incinerator design and operation

E_N part = $.15 \times E_u$ = $.15 \times 12.8$ = 1.9 lb/TON

E_N HC = $.01 \times E_u$ = $.01 \times 3.8$ ≅ .04 lb/TON

E_N CO = $.01 \times E_u$ = $.01 \times 4.1$ ≅ .04 lb/TON

E_N NO_x = $.5 \times E_u$ = $.5 \times 25$ ≅ 12.5 lb/TON

*May Assum $E_N(NO_x) = 0$ for max impact

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By D. Marrone Date 9-10-74

Source Pathological Incinerators (Animal Shelter & Crematory)

From our survey of the literature in particular, Ref 075, 038, and 046 it appears that most if not all of the incinerators mentioned used natural gas as the fuel. Due to the low sulfur content of gas we would not expect significant sulfur oxide emission.

SO_x is a negligible emission from pathological incinerators

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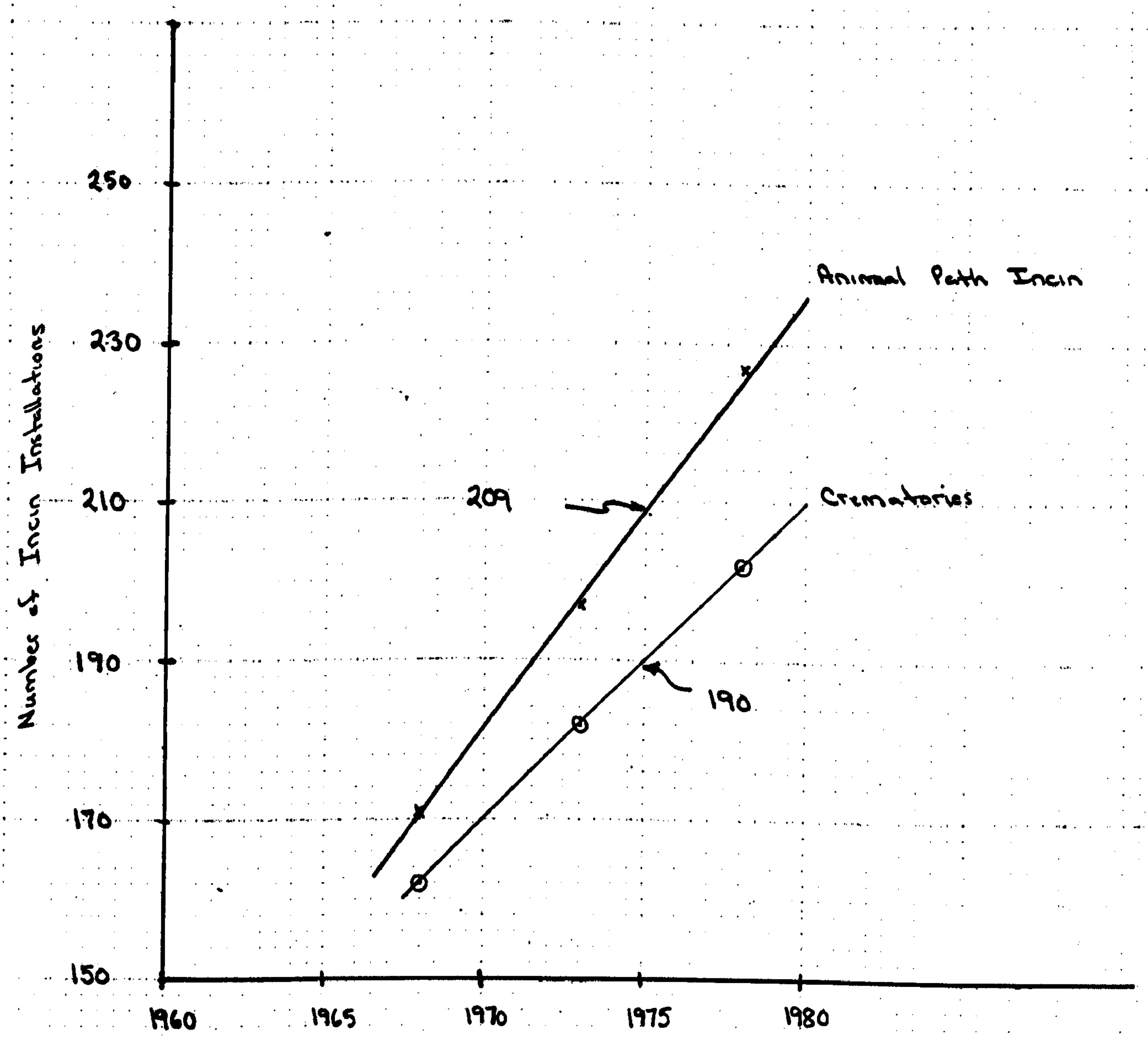
Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 10-24-74

Source Pathological Incinerator

E_S:



Total installations = 399

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Computation Sheet For Emission Factors

Calculations Done By 2) Marrone Date 10-24-74

Source Pathological Incinerators

E_s: cont'd

Taking the 1975 capacity of 130,191 T/yr and the 399 installation we estimate an average incinerator capacity

$$\frac{130{,}191\ T/yr}{399} = 326\ T/yr \text{ capacity per incinerator}$$

Assuming; $8\ hr/day \times 5\ \frac{d}{wk} \times 52\ \frac{wk}{yr} = 2080\ \frac{hr}{yr}$

$$\text{Avg Process Weight} = 326\ \frac{Ton}{yr} \times 2000\ \frac{lb}{TON} \times \frac{yr}{2080\ hr}$$

$$= 313\ lb/hr$$

Emission regulations for incinerators is applied to pathological incinerators in this investigation. All state will be considered to have equivalent capacity so that an average limitation estimate would suffice. E_s is calculated for Existing and New Facilities. Ref to the Attached Tables under "Municipal Incinerators E_s" for pertinent State allowable levels.

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 10-24-74

Source Pathological Incinerator

E_s: cont'd

The following assumptions or conditions were employed:

(1) Alaska (Existing) has only opacity reg assume $E_{si} = E_u$

(2) California (Existing & New) has no ~~state-wide~~ Reg.
Use $E_{si} = E_{s\,Avg}$

(3) Florida (Existing & New) has no reg applicable < 4000 lb/hr
Use $E_{si} = E_u$

(4) Nevada (Existing & New) has only opacity regu. Assum $E_{si} = E_u$

(5) New Mexico does not permit incineration after 1976
Therefore it is not included in calculation

(6) North Dakota emission equation (Existing & New) yields .29 lb/100 lb

(7) Oklahoma emission equation (Existing & New) yields .30 lb/100 lb

(8) S. Carolina (Existing & New) based on heat input - use $E_{si} = E_{s\,Avg}$

(9) Texas has no gen regulation - use $E_{si} = E_{s\,Avg}$ (New & Existing)

(10) Utah (New & Existing) require 85% control $E_{si} = .15 \times E_u$

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Project Number - 32391 New Source Performance Standards

Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 10-24-74

Source Pathological Incinerators

E_s: cont'd Particulates

"Existing Incin" based on 50 states

① $E_{si} = E_u$; 3 states × E_u = $3 \times (12.8 \frac{lb}{Ton} \times \frac{Ton}{2000 lb} \times 100) = 3 \times .64$

$= 1.92$ lb/100lb

② $E_{si} = E_{s Avg}$ 3 states × $E_{s Avg}$

③ Utah $E_{si} = .15 \times E_u = .15 \times (12.8 \times \frac{1}{2000} \times 100) = .096$ lb/100 lb

④ ΣE_{si} 43 states $\Sigma E_{si} = 8.72$ lb/100 lb

1.92
.096
8.72

10.74 + 3 $E_{s Avg}$

$$\frac{10.74 + 3E_{sA}}{50} = E_{s Avg}$$

$$E_{s Avg} = \frac{10.74}{47}$$

$E_{s Avg} = .23$ lb/100 lb

(Existing)

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 10-24-74

Source Pathological Incinerator

E_s: cont'd

Particulates

"New Incin" based on 50 states

① $E_{si} = E_u$; 2 states × E_u $2 \times (12.8 \times \frac{I}{2000} \times 100) = 2 \times .64 = 1.28$ lb/100 lb

② $E_{si} = E_{s\,Avg}$ 3 states × $E_{s\,Avg}$

③ Utah $E_{si} = .15 \times E_u = .15\,(12.8 \times \frac{I}{2000} \times 100) = .096$ lb/100 lb

④ ΣE_{si} 44 states $\Sigma E_{si} = 7.72$ lb/100 lb

$$\begin{array}{r} 7.72 \\ 1.28 \\ .096 \\ \hline 9.096 \end{array}$$

$$\frac{9.096 + 3E_{s\,Avg}}{50} = E_{s\,Avg}$$

$$E_{s\,Avg} = \frac{9.096}{47} = .19$$

$$E_{s\,Avg} = .19$$

(New)

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Computation Sheet For Emission Factors

Calculations Done By W. Morrone Date 10-24-74

Source Pathological Incinerators

E_s: cont'd

Particulates

$$E_s \text{ (Existing)} = \frac{.23 \text{ lb}}{100 \text{ lb}} \times \frac{1}{100} \times 2000 \frac{\text{lb}}{\text{TON}} = 4.6 \text{ lb/TON}$$

$$E_s \text{ (New)} = \frac{.19 \text{ lb}}{100 \text{ lb}} \times \frac{1}{100} \times 2000 \frac{\text{lb}}{\text{T}} = 3.8 \text{ lb/TON}$$

$$E_s \text{ (Existing)} = 4.6 \text{ lb/TON}$$

$$E_s \text{ (New)} = 3.8 \text{ lb/TON}$$

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Calculations Done By W. Marrone Date 10-24-74

Source Pathological Incinerators

E_s : cont'd

Regulations specifically or generally applicable to to pathological incinerators for HC, CO, NO_x pollutants. were not found in state reg (Ref 084 & 148)

Therefore $E_s = E_u$

E_s (HC) = 3.8 lb/TON waste

E_s (CO) = 4.1 lb/TON waste

E_s (NO_x) = 25.0 lb/TON waste

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Calculations Done By W. Marrone Date 1-29-75

Source Pathological Incinerators

Trace Metals:

E_u: Emission factors for trace metals was not obtained from the literature.

Ref 270 pg 69 Table 3.1 gives a breakdown of animal tissue by element

We will use the figures for the major metals identified. Although this composition is given for man, we make the assumption that animal tissue will not be significantly different

	wt %
Magnesium	.05
Iron	.004
Manganese	.0003
Copper	.0002
	.0545 % by wt

Other elements (metals) are identified but are not quantified. We believe that the above covers the majority of the trace metals

$$\frac{.0545 \text{ lb}}{100 \text{ lb}} \times 2000 \frac{\text{lb}}{\text{TON}} = 1.09 \text{ lb/TON waste}$$ TOTAL Trace metals available

Judgment at this time leads us to assume that 50% of the trace metals are emitted from the incinerator along with particulates

$$E_u \cong .5 \times 1.09 = .545 \text{ lb/TON waste}$$

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Source Pathological Incinerator

Trace Metals cont'd

$$E_u \cong .545 \text{ lb/TON waste}$$

E_N:

We see that the trace metal to particulate emissions ratio for pathological incinerators is $\frac{.545 \text{ lb Tr Met}}{12.8 \text{ lb Pt}} \cong .0426 \frac{\text{lb Tr Met}}{\text{lb Pt}}$

It is assumed that particulate control will be as effective on trace metals so that

$$E_N(TM) = .15 \times .545 \text{ lb/TON} \cong .082 \text{ lb/TON waste}$$

$$E_N = .082 \text{ lb/TON waste}$$

We assume $E_{IIId} = E_N$ controls can be applied to existing plants as effectively as new plants

$$E_{IIId} = .082 \text{ lb/TON waste}$$

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Calculations Done By W. Marrone Date 1-29-75

Source Pathological Incinerators

Trace Metals, cont'd

E_S:

Although there are no regulations applicable to trace metals we assume that particulate emission regulation will by "defacto" inforce limits on trace metals.

$$E_S(TM) = E_S(PT) \times .0426 \frac{\text{lb Tr met}}{\text{lb Pt}}$$

$$E_{S(Exist)}(\text{Trace Met}) = 4.6 \times .0426 = .196 \text{ lb/TON waste}$$

$$E_{S(New)}(\text{Trace Met}) = 3.8 \times .0426 = .162 \text{ lb/TON waste}$$

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Calculations Done By W. Marrone Date 1-27-75

Source Sludge Incineration - Municipal

K:

Ref 266 pg 14

Most incincerators that have been built are reported to be operated at throughputs much less than designed for present municipality

Referring to pg 15 Table 1 of the above ref we see that the units tested by EPA had operating rates ranging from 35% to 100% of capacity.

We suspect that most operating at >90% of design were doing so for the actual test and not as a representation of normal operating practice.

In light of little information regarding normal capacity operating rate we will make a judgement that 50% is a suitable value of K for sludge incineration

K = .50

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Calculations Done By W. Marrone Date 1-27-75

Source Sludge Incineration - Municipal

A:

Ref 267 pg 75

Estimated 280 municipal sludge incineration sites, Report Oct 1974 - which we assume is close to 1975 so that it may be used to estimate A.

Ref 044 describes a "typical" incinerator with a rated dry solids charging rate of .5 ton/hr and a gas flow of 3000 dscfm

Assuming an operating schedule of $24 \frac{hr}{d} \times 7 \frac{d}{wk} \times 50 \frac{wk}{yr} = 8400 \frac{hr}{yr}$

$$A = .5 \frac{T}{hr} \times 8400 \frac{hr}{yr} \times 280 \text{ plants}$$

$$A = 1.176 \times 10^6 \text{ TON/yr}$$ dry solids feed to incinerator

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Source Sludge Incineration - Municipal

P_c:

Specific growth rates for sludge incineration was not given in the literature. Ref 044 pg 60 estimates that about 70 new sludge incinerators will be constructed annually. This is interpreted to be a simple growth. If we assume that generally the new plants do not change the average appreciably then we may estimate the growth by

280 plant 1975

70 plants/yr added

$$P_c = \frac{70}{280} \cong .25 \text{ simple}$$

P_B:

Replacement rate is estimated by assuming that the amortization of 30 years specified in Ref 268 pg 51 will equate well with the life of a unit.

$$\frac{100\%}{30\text{yrs}} = 3.3\%/\text{yr simple}$$

$$\therefore P_B = .033 \text{ simple}$$

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 1-27-75

Source Sludge Incinerators - Municipal

Particulate

E_u: Ref 044 pg 57

Average uncontrolled emissions

Multiple Hearth	23 lb/hr
Fluid-Bed	205 lb/hr

Ref 268 pg viii 143 sludge incinerator plants
pg 45 120 multiple hearth units

$\frac{120}{143} \times 100 \approx 84\%$ multiple hearth

We assume that 80% multiple hearth and 20% fluid-bed will be representative in 1985. Fluid-bed may find faster growth. although this is not certain.

$$E_u' = .8(23) + .2(205) \text{ lb/hr}$$

$$E_u' \approx 59.4 \text{ lb/hr}$$

Using a typical plant size as stated on pg 2 of "Ind Factors" of .5 TON/hr dry solids feed we may estimate E_u in lb/TON dry solids feed.

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 4-28-75

Source Sludge Incinerators - Municipal

Particulate cont'd

$$E_u = \frac{59.4 \text{ lb/hr}}{.5 \text{ TON/hr dry solid feed}} = 119 \text{ lb/TON dry solid feed}$$

E_N:

Ref 271 pg 9312

NSPS actually promulgated for Sewage Treatment Plant Sludge Incinerators specifies a standard of 1.3 lb/TON dry sludge input for particulate matter.

Ref 044 pg 57 describes the proposed standard for sludge incinerator of .031 gr/dscf which was mentioned in Ref 271 to be equivalent to the 1.3 lb/TON limit just stated in more meaningful units.

The standard was proposed after many performance tests on well-controlled plants. We will assume this value to be indicative of best control technology.

$$E_N = 1.3 \text{ lb/TON dry solid feed}$$

this represents an efficiency level of 98.9% based on the weighted uncontrolled value of 119 lb/TON

Controls generally used are wet scrubbers (impingement or venturi)

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Computation Sheet For Emission Factors

Calculations Done By W. Marrone Date 4-28-75

Source Sludge Incineration - Municipal

Particulate: cont'd

E_s: A complete breakdown of sludge incineration by state was not obtained however, it was assumed that it would be dispersed uniformly enough to use the generalized process weight rate curve. Although this is a combustion source, the particulate is attributable to the solid content of the sludge.

For existing plant with avg PWR of .5 TON/hr or 1000 lb/hr the allowable emission would be 2.5 lb/hr

$$E_s \text{ (existing)} = \frac{2.5 \text{ lb/hr}}{.5 \text{ TON/hr}} = 5.0 \text{ lb/TON dry solid feed}$$

We equate $E_s\text{(new)} = E_{\text{promulgated}} = 1.3 \text{ lb/TON}$

$$E_s \text{ (new)} = 1.3 \text{ lb/TON dry solid feed}$$

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Computation Sheet For Emission Factors

Calculations Done By W. Massone Date 1-28-75

Source Sludge Incineration - Municipal

Trace Metals

Ref 266 pg 28-36 discusses the tests run on several sludge incinerators plants to determine the metal content. Most of the determinations were for sludge and ash metal content. It is mentioned that there is great variability to metal content in sludge and that little conclusive data has been assembled to derive adequate metal emission factors.

E_u:

Our best estimate will be derived from Table 9 Ref 266 pg 33 by using the data for the Lake Tahoe, Calif Incinerator which was identified on pg 28 as largely a domestic sewage plant. We will total the metal content of sludge based on mg metal / g of fixed solids.

Ag	.6
Al	27.0
Ba	6.0
Ca	62.0
Cd	.37
Cr	2.0
Cu	2.6
Fe	18.0
Hg	neg
K	1.4
Mg	~~12.7~~
Mn	1.1
Na	1.8
P	81
Pb	5.8
Sb	neg
Se	neg
Sr	1.0
Zn	1.6

$\Sigma \cong 212$ mg/g or .212 g/g or .212 lb/lb

This implies that about 20% of solids is trace metal.

We make the assumption that the trace metal content of the emitted particulate will be the same so that

$$E_{u_{TT}} \cong .2 \times E_u(PT)$$

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Computation Sheet For Emission Factors

Calculations Done By W. Morrone Date 4-28-75

Source Sludge Incineration - Municipal

Trace Metals

E_u (Trace Metal) = .2 × 119 = 24 lb/TON dry solid feed

E_N: Trace metals will be assumed to be controlled as effectively as total particulate:

E_N (TM) = .011 × 24 = .26 lb/TON dry solid feed
(.011 ↑ 98.9% eff.)

E_{IIId}:

E_{IIId} is assumed equivalent to E_N for trace metals.

E_{IIId} (TM) = .26 lb/TON dry solid feed

E_S: Trace metals will be controlled defacto along with particulate by PWR curve.

E_S (TM) = .2 E_S (Part)

E_S (exist) TM = .2 × 5 = 1.0 lb/TON dry solid feed

E_S (new) TM = .2 × 1.3 = .26 lb/TON dry solid feed

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 12/23/74

Source Open Burning

Open burning will be defined as the uncontrolled, outdoor combustion of the following classes of solid waste:

(a) Residential & commercial
(b) Construction & demolition waste
(c) Institutional solid waste
(d) Industrial " "
(e) Agricultural " "

This category will not include open burning as the result of accident.

Ref (77) p26 estimates 5.3 #/person-day of solid waste are collected of which approx 64.5% (p29) resulted in some form of open burning (1968). However, since that time, the practice of open burning has been on the decline due to the enforcement of State & Local regulations.

Therefore Pc < 0

In fact, by the year 1985, it is conceivable that there will be no open burning permissable anywhere.

Also,

(1) P_B is not applicable to this situation
(2) $E_N = 0.0$ (If such a situation is to be defined)
(3) A_{1975} is a highly questionable number & changing daily.

However, the practice of burning agricultural wastes still exists & could continue to exist for sometime. No information

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Calculations Done By Hopper Date 12/23/74

Source Open Burning

exists regarding the rate at which such a practice may increase.

One could assume a rate equal to the increase in pop. population & consequently an increase in agricultural product. Offsetting this would be the effect of some local regulations & the use of alternate means of agricultural waste elimination.

Previous work on this project (see "Industrial Factors – Dry Cleaning") indicated a population trend of 1.8% (compound). For the reasons stated above, we will ASSUME a P_c equal to ½ the value -0.09

$$P_c = 0.009$$ compound

The term P_B is not applicable in this case

$$P_B = 0.0$$ This is necessary to use the model.

K is, likewise, not applicable. In order to evaluate the impact of a national standard, we must set

$$K = 1.0$$

From Ref (49) p 93 TAB 8-2 The tons of stubble burned in 1968 was 280×10^6 tons. Since $P_c = 0$ & $K = 1.0$

$$A = 280 \times 10^6 \text{ tons burned}$$

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Computation Sheet For Industrial Factors

Calculations Done By Hopper, Date 12/23/74

Source Open Burning

It must be noted that open burning is not an industry but a process associated with many industries. The use of NSPS under Section 111 of the Clean Air Act should be studied to determine if this is the most effective path for control.

Our analysis is based on the fact that it is, & the input factors have been determined so as to fit the model & yield meaningful results. Since P_C & P_B are zero, there is no new or modified capacity to which NSPS can be applied. Therefore, the value $(T_S - T_N)$ really represents the impact of 100% control as would be applied by the States.

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 12/23/74

Source Open Burning

From Ref (75) p 2.4-1 TAB 2.4-1, the following emission factors are presented for Agricultural field burning

$$E_{U_P} = 17 \ \#/\text{ton burned}$$

$$E_{U_{SO_2}} = 0.0$$

$$E_{U_{CO}} = 100 \ \#/\text{ton burned}$$

$$E_{U_{HC}} = 20 \ \#/\text{ton burned}$$

$$E_{U_{NO_x}} = 2 \ \#/\text{ton burned}$$

Since the "best available control technology" would be to eliminate the practice of open burning, we will assume, for all pollutants

$$E_{N_{\text{all pollutants}}} = 0.0$$

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Computation Sheet For Emission Factors

Calculations Done By HOPPER Date 12/23/74

Source Open Burning

Since the level & effect of local regulations cannot be ascertained, we will let Es equal Eu for all pollutants

$$E_{S\,\text{each pollutant}} = E_{U\,\text{each pollutant}}$$

(See p1)

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Computation Sheet For Industrial Factors

Calculations Done By K. Tower Date 1/23/75.

Source Orchard Heaters

Orchard heaters are commonly used in various areas of the United States, primarily Florida and the Southwest, to prevent frost damage to fruit and fruit trees The five common types of orchard heaters are pipeline, lazy flame, return stack, cone and solid fuel. From references 262 and 263 the current trend is with the use of the return stack type. We assume in our calculations that all orchard heaters are return stack type.

Since the emissions from orchard heaters come from their operation rather than from their production we define production (A) in units of Heater hrs/yr. It follows therefore that we define all emission factors in units of lbs/Heater hr.

In this case we are not concerned with fractional utilization of production capacity. K is equal to 1.0 for this industry because we assume orchard heaters operate at 100% capacity once fired.

$$K = 1.0$$

From ref 262 we find that the average life of an orchard heater is 30 years.

$$P_B = \frac{1}{30} = .033$$

$$P_B = .033 \text{ simple}$$

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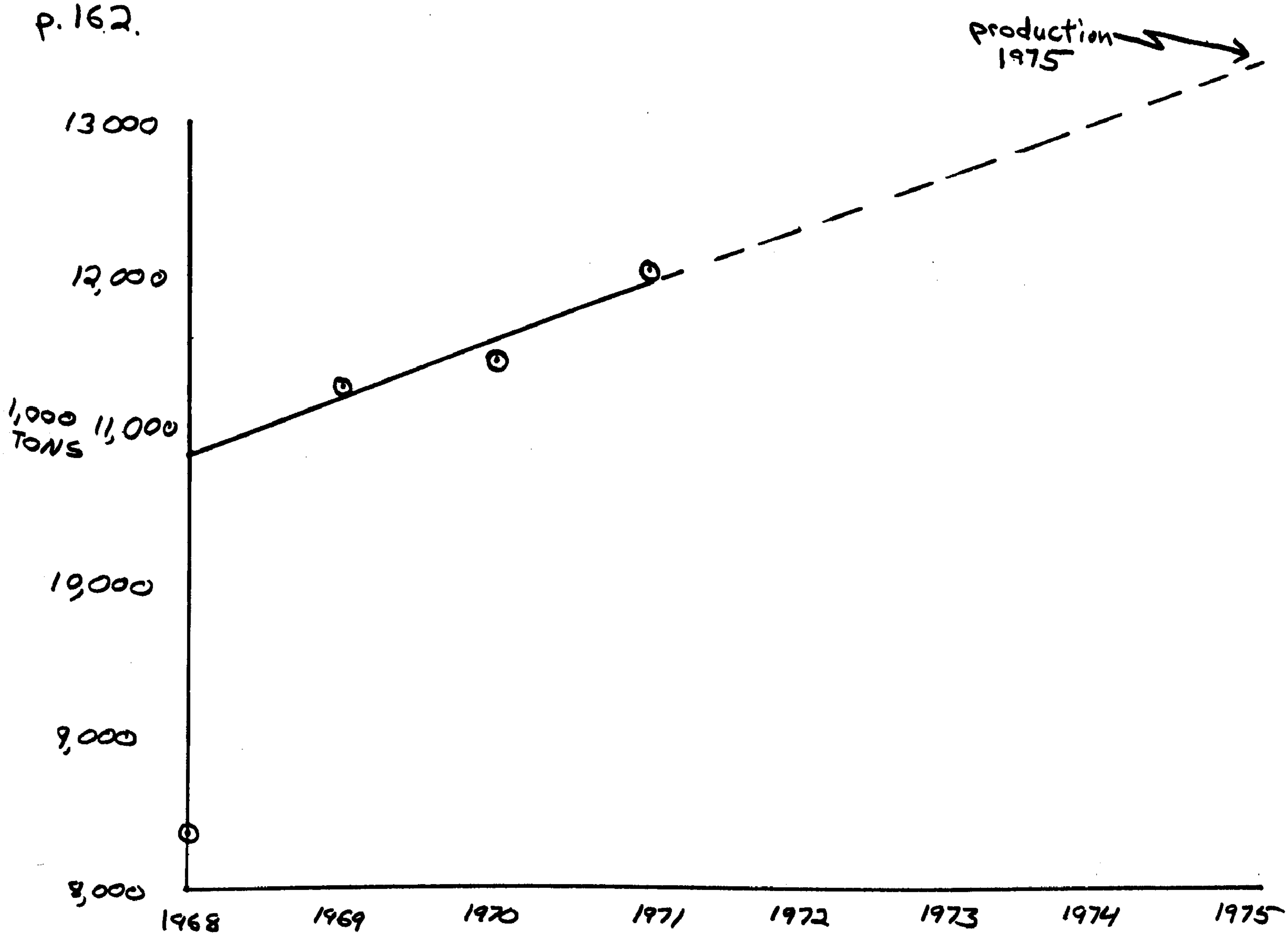
Calculations Done By K. Tower Date 1/24/75

Source Orchard Heaters

The following graph shows the growth in production of citrus fruits which employ the use of orchard heaters. This includes production of nectarines, avocados, oranges, tangerines, grapefruit, lemons, limes, tangelos, and temples in the years 1968-1971 ref 247, p. 162.



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Calculations Done By K. Tower Date 1/24/75

Source Orchard Heaters

Assuming a simple growth rate we can calculate the growth rate by the following formula:

$$P_c = \frac{\text{Production in 1971} - \text{Production in 1969}}{(1971-1969)(\text{Production in 1975})}$$

$$= \frac{11{,}920{,}000 \text{ TONS} - 11{,}180{,}000 \text{ TONS}}{(2)(13{,}400{,}000 \text{ TONS})}$$

$$= \frac{740{,}000}{26{,}800{,}000} = .0276$$

$$\boxed{P_c = .028 \text{ simple}}$$

Ref 262 indicates there are approximately 10,000,000 orchard heaters in the US. Ref. 263 indicates that the average orchard heater operates 6 hrs./yr. "A" as defined earlier in units of heater hrs/yr can be detirmined as follows:

$$A = (10{,}000{,}000 \text{ heaters})(6 \text{ hrs/yr}) = 60 \times 10^6 \text{ heater hrs/yr}$$

$$\boxed{A = 60 \times 10^6 \text{ heater hrs/yr}}$$

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Calculations Done By K. Tower Date 1/24/75

Source Orchard Heaters

Ref 247, p.170, figure 9 presents a graph of the particulate emission rate for orchard heaters as a function of fuel usage rate (lb/heater-hr). Once again we assume the emission rate for the return stack type orchard heater to be representative of the entire industry.

Ref. 264 indicates that the average orchard heater will generate approximately 125,000 BTU's/hr. Ref 101, p. 9-6 gives the density of #2 distallate oil as 7.13 lbs/gal. Ref 075, p. 1.3-1 gives the heating value of distillate oil as 140,000 BTU/gal. Therefore the fuel usage rate of an average orchard heater can be calculated as follows:

$$\text{Fuel Usage Rate} = \frac{\left(125{,}000 \frac{BTU}{\text{Heater-hr}}\right)\left(7.13 \frac{lbs}{gal}\right)}{140{,}000 \frac{BTU}{gal}} = 6.37 \text{ lb/heater-hr.}$$

Refering once again to Ref 247, p. 170, figure 9, a 6.37 lb/heater-hr gives $7 \frac{\text{lb Emissions}}{1000 \text{ heater-hrs}}$

$$E_{U_{PT}} = .007 \text{ lbs/heater-hr}$$

There is no practical technique for the reduction of orchard heater particulate emissions so to detirmine the maximum potential impact of the reduction of these emissions we assume $E_{N_{PT}} = 0.00$ lbs/heater-hr.

$$E_{N_{PT}} = 0.00 \text{ lbs/heater-hr}$$

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Calculations Done By K. Tower Date 1/24/75

Source Orchard Heaters

California & Florida have .132 lb/hr & .066 lbs/hr (1 gm/min & .5 gm/min) pt. limitations on orchard heaters. However these values are so much greater than $E_{u_{PT}}$ for an average size orchard heater we assume $E_{s_{PT}} = E_{u_{PT}}$, in order to demonostrate the true effect of potential new source performance standards.

$$E_{s_{P_T}} = .007 \frac{lbs}{heater\text{-}hr}$$

Ref 097, p. 19, Table 4-9 gives the % S found in #2 distillate oil as .265%. This value represents an arithmetic average of the data in the table. Ref 247, p 169, Table 70 shows that SO_x emissions from a return stack orchard heater is equal to 0.14 S lbs/heater-hr.

$$E_{u_{SO_x}} = (0.14)(.265) = .0371 \text{ lbs/heater-hr.}$$

$$E_{u_{SO_x}} = .037 \text{ lbs/heater-hr}$$

There is no practical technique for the reduction of orchard heater SO_x emissions so to detirmine the maximum potential impact of the reduction of these emissions we assume $E_{N_{SO_x}} = 0.00$ lbs/heater-hr.

$$E_{N_{SO_x}} = 0.00 \text{ lbs/heater-hr.}$$

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Source Orchard Heaters

California has a .5%S regulation for fuel burning sources and Florida has no S regulation for fuel burning sources with fuel usage rates as low as those for orchard heaters. We have previously referenced the average sulfur content for #2 distillate oil as .265%S. Therefore in order to accurately demonstrate the true effect of potential new source performance standards we assume $E_{S_{SO_x}} = E_{U_{SO_x}}$

$$E_{S_{SO_x}} = .037 \text{ lbs/heater-hr.}$$

Ref 075, p. 1.3-2, Table 1.3-1 gives a general CO emission factor of .004 lbs/gal of distillate oil for fuel combustion units. Ref 264 gives the average heating value of oil used with orchard heaters as 125 BTU/heater-hr. Ref. 075, p. 1.3-1 states there are 140,000 BTU/gal of distillate oil. $E_{U_{CO}}$ for orchard heaters can therefore be calculated as follows:

$$E_{U_{CO}} = \frac{(125{,}000 \text{ BTU/Heater-hr.})(.004 \frac{\text{lbs}}{\text{gal.}})}{(140{,}000 \text{ BTU's/gal.})} = .0036 \text{ lbs/Heater-hr.}$$

$$E_{U_{CO}} = .004 \text{ lbs/heater-hr}$$

There is no practical technique for the reduction of orchard heater CO emissions so to determine the maximum potential impact of the reduction of these emissions we assume $E_{N_{CO}} = 0.00$ lbs/heater-hr.

$$E_{N_{CO}} = 0.00 \text{ lbs/heater-hr.}$$

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Source Orchard Heaters

There are no applicable CO regulations for orchard heaters in Florida or California. Therefore $E_{S_{CO}} = E_{U_{CO}}$

$$E_{S_{CO}} = .004 \text{ lbs/heater-hr.}$$

Ref 247, p. 169, Table 70 gives the hydrocarbon emission factor for return stack type orchard heaters as 16 lbs/heater-hr.

$$E_{U_{HC}} = 16 \text{ lbs/heater-hr.}$$

Since there is no practical technique for the reduction of orchard heater hydrocarbon emissions we assume $E_{N_{HC}} = 0.00$ lbs/heater-hr. In order to determine maximum potential impact of the reduction of these emissions.

$$E_{N_{HC}} = 0.00 \text{ lbs/heater-hr.}$$

There are no applicable regulations concerning orchard heaters so we will assume $E_{S_{HC}} = E_{U_{HC}}$

$$E_{S_{HC}} = 16 \text{ lbs/heater-hr.}$$

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Calculations Done By K. Tower Date 1/27/75

Source Orchard Heaters

Ref 247, p. 169, Table 70 states that NO_x emissions from orchard heaters are negli ible.

$$E_{u_{NO_x}} = 0.00 \text{ lbs/heater-hr.}$$

It follows therefore that $E_{N_{NO_x}}$ also $= 0.00$ lbs/heater-hr.

$$E_{N_{NO_x}} = 0.00 \text{ lbs/heater-hr}$$

In order to demonstrate the true effect of potential new source performance standards we assume $E_{S_{NO_x}} = E_{u_{NO_x}}$

$$E_{S_{NO_x}} = 0.00 \text{ lbs/heater-hr.}$$

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Computation Sheet For Emission Factors

Calculations Done By K. Tower Date 1/27/75

Source Orchard Heaters

Summary of Emission Factors

Pollutant	E_u (lbs/heater-hr)	E_N (lbs/heater-hr.)	E_u (lbs/heater-hr)
Particulate	.007	0.00	.007 ✓
SO_x	.037	0.00	.037 ✓
CO	.004	0.00	.004 ✓
HC	16	0.00	9.2
NO_x	0.00	0.00	0.00

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Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 6/3/75

Source Combustion of Waste Crankcase Oil

Ref (277) App. (A) p 2 The national am't of waste oil is estimated to be 730×10^6 gallons in 1975.

From (277) App. B. "It is estimated that 50% of the oil is burned

$$\text{Usage} = \frac{730 \times 10^6}{2} = 365 \times 10^6 \text{ gallons}$$

If we assume that the typical size range of boilers used is greater than 250×10^6 BTU/HR, the K is 0.58 (See, "Industrial Factors - Boilers")

$$\therefore A = \frac{365 \times 10^6}{.58} = 629 \times 10^6 \text{ gal}$$

$$A = 629 \times 10^6 \text{ gallons}$$

$$K = 0.58$$

From Ref (277) App (A) p 2 the 1967 am't of waste oil was 680×10^6 gals & the estimated 1975 am't is 730×10^6. Assuming cmpd growth

$$P_c = \sqrt[8]{\frac{730}{680}} - 1 = 0.009$$

$$P_c = 0.009 \text{ cmpd}$$

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Wethersfield, Connecticut 06109

Project Number - 32391 New Source Performance Standards

Computation Sheet For Industrial Factors

Calculations Done By Hopper Date 6/3/75

Source Comb. Of Waste Crankcase Oil

Obsolescence rate, P_B, is not applicable in this situation.

$\therefore$ $P_B = 0.0$

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Computation Sheet For Emission Factors

Calculations Done By Hopper Date 6/3/75

Source Comb. of Waste Crankcase Oil

From Ref (277) App B

Sp. Wt of oil is 7.5 LB/GAL & 1% is lead.
If all the lead is vented thru the exhaust, then

$$E_{U_{Pb}} = 0.075 \text{ LB/GALLON}$$

We will assume that the oil is burned in processes with efficient control systems & that the 12/6/73 Regs for Pb are not in effect.

Ref (277) App (A) p 4 indicates 99% η with a baghouse

$$E_{N_{Pb}} = .075(1-.99) = 0.00075$$

$$E_{N_{Pb}} = 0.00075 \text{ LB/gallon}$$

For existing plants, we will assume an $\eta = 90\%$ using baghouses.

$$E_{111d} = .075(1-.9) = 0.0075$$

$$E_{111d} = 0.0075 \text{ LB/gallon}$$

There are no Regs for lead; however,

$E_{SP_{>250 \text{ EXIST}}} = 0.277 \text{ LB}/10^6 \text{ BTU}$ (See "Emission Factors – Boilers)

@ 5.817×10^6 BTU/BBL & 42 gal/BBL (Ref (22) p 4-2 TAB 4-1)

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Source Comb. Of Waste Crankcase Oil

$$\frac{(.277\times10^{-6})(5.817\times10^{6})}{42} = 0.038$$

This would be the top limit for particulate ∴ lead

$$E_{S_{Pb}} = 0.038 \text{ lb/gallon}$$

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT

The purpose of this document is to present the results of a study to determine the impact of new source performance standards on nationwide emissions. The work presented covers 14 potential pollutants from approximately 200 source categories for the year 1985. The results are being used by EPA as input to the development of an overall standard setting strategy. The report contains information regarding controlled and uncontrolled emission factors, State emission limitations, industrial capacity, utilization, growth and retirement rates. The results of this study have been published as three volumes which encompass ten separate documents. This document contains Appendix 4A of Volume II - Calculation Sheets for Combustion Sources.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS		c. COSATI Field/Group
Air Pollution Air Pollution Control Industrial Processes Combustion Regulations Economic Factors	Priorities Chemical Industry Paper Industry Petroleum Industry	Metal Industry Agricultural Mineral Flyash Exhaust Gases	

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