United States Environmental Protection Agency

Control Technology Center
Research Triangle Park NC 27711

EPA-600/8-90-075
October 1990

EPA

ASSESSMENT OF THE CONTROLLABILITY OF CONDENSIBLE EMISSIONS

control technology center

CONTROL TECHNOLOGY CENTER
SPONSORED BY:

Emission Standards Division
Office of Air Quality Planning and Standards
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

Air and Energy Engineering Research Laboratory
Office of Research and Development
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

Center for Environmental Research Information
Office of Research and Development
U. S. Environmental Protection Agency
Cincinnati, OH 45268

EPA-600/8-90-075
October 1990

ASSESSMENT OF THE CONTROLLABILITY OF CONDENSIBLE EMISSIONS

by:

G. S. Shareef and J. T. Waddell
Radian Corporation
P.O. Box 13000
Research Triangle Park, North Carolina 27709

EPA Contract No. 68-02-4286
Work Assignment Nos. 67 and 105

EPA Project Officer

Carlos M. Nunez

Air and Energy Engineering Research Laboratory
Research Triangle Park, North Carolina 27711

Prepared for:

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the SPECIAL REPORTS series. This series is reserved for reports which are intended to meet the technical information needs of specifically targeted user groups. Reports in this series include Problem Oriented Reports, Research Application Reports, and Executive Summary Documents. Typical of these reports include state-of-the-art analyses, technology assessments, reports on the results of major research and development efforts, design manuals, and user manuals.

EPA REVIEW NOTICE

This report has been reviewed by the U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policy of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

EXECUTIVE SUMMARY

As part of current U.S. Environmental Protection Agency (EPA) efforts to better understand and quantify condensible emissions, this study was initiated to develop an understanding of condensible emissions from an air toxics perspective. The major objectives of the study were to: (a) develop a data base on condensible emissions, (b) determine chemical makeup of condensible emissions, and (c) evaluate effectiveness of various control devices in reducing condensible emissions and identify modifications to improve performance.

Two data bases were developed from a review of emissions source test reports from EPA's Emission Measurement Branch (Office of Air Quality Planning and Standards/Technical Support Division) files and from the State of California. The Condensibles Data Base contains information on condensible emissions covering 43 emission source categories. The Speciated Condensibles Data Base focuses on the chemical composition of condensible emissions. for the purposes of this study, the back-half catch of the EPA Reference Method 5 or its equivalent was considered to represent the condensible fraction.

Based on the data contained in the Condensibles Data Base, source categories with a relatively high percentage of condensibles in the total particulate catch (i.e., greater than 50 percent) included the following: plywood manufacturing, asphaltic concrete, electric utilities, fertilizer manufacturing, and secondary lead smelting. From the limited data on chemical composition of condensed particulate matter, the toxic fraction (composed of arsenic, beryllium, cadmium, chromium, lead, mercury, and vanadium) of condensed particulate matter was less than one percent in most cases.

For many sources in the Condensibles Data Base, wet scrubbers including venturi scrubbers, fabric filters, electrostatic precipitators (ESP's), and wet ESP's were the commonly employed particulate matter control devices. There was a wide variation in performance of these devices in controlling condensible emissions. This was attributed to differences in emission source characteristics such as temperature, composition, and concentration. Although limited performance data were available for specific control devices, venturi scrubbers and other wet scrubbers appeared to be more effective in reducing condensible emissions than other control devices. No general conclusions were drawn regarding controllability of specific components because of limited data.

Modification in control device operation/design that would affect potential reductions in condensible emissions include the following: (a) operating at lower temperatures and higher humidity levels to enhance condensed particulate formation prior to the control device, (b) adding an ionizing section before wet/venturi scrubbers to improve collection efficiency of the fine particulate, and (c) using gas conditioning agents to induce condensed particle agglomeration.

CONTENTS

		Page
Executive Summary		iii
TABLES		vi
1	INTRODUCTION	1-1
	1.1 Background	1-1
	1.2 Approach	1-2
	1.3 Recommendations	1-2
	1.4 Report Organization	1-3
2	CONDENSIBLE EMISSIONS DATA	2-1
	2.1 Definitions of Condensible Emissions	2-1
	2.2 Condensibles Data Base	2-1
	2.2.1 Data Sources	2-16
	2.2.2 Sampling Methods	2-16
	2.2.3 Condensibles Data Analysis	2-17
	2.3 Speciated Condensibles Data Base	2-18
	2.3.1 Data Sources	2-21
	2.3.2 Speciated Condensibles Data Analysis	2-21
3	CONTROLLABILITY OF CONDENSIBLE EMISSIONS	3-1
	3.1 Condensible Emissions Control Data	3-1
	3.1.1 Condensible Emissions Control Efficiency	3-1
	3.1.2 Control Device-Specific Performance	3-6
	3.1.3 Controlled Condensible Emissions	3-9
	3.2 Speciated Condensible Emissions Control Data	3-9
	3.3 Condensible Emissions Control Improvement	3-14
4	REFERENCES	4-1

TABLES

No.		Page
2-1	Condensibles Data Base	2-2
2-2	Percentage of Condensibles in Particulate Emissions	2-19
2-3	Category Ranking According to Percentage of Condensibles in Particulate Emissions	2-20
2-4	Contribution of Major Stationary Point Sources to Particulate Emissions	2-22
2-5	Speciated Condensibles Data Base	2-23
3-1	Condensible Emissions Control Efficiency	3-2
3-2	Control Device-Specific Performance	3-7
3-3	Variation in Control Device Effectiveness for Selected Categories	3-10
3-4	Comparison of Control Device Effectiveness for Selected Categories	3-10
3-5	Variation in Controlled Condensible Emissions for Selected Categories	3-11
3-6	Comparison of Condensible Emissions for Selected Categories	3-13
3-7	Control Effectiveness for Speciated Condensible Emissions	3-15

SECTION 1

INTRODUCTION

1.1 BACKGROUND

The PM_{10} SIP Development Guideline document broadly defines condensible particulate matter as "material that is not particulate matter at stack conditions but which condenses and/or reacts (upon cooling and dilution in the ambient air) to form particulate matter immediately after discharge from the stack."[1] Almost all condensed particulate matter falls within the PM_{10} size fraction (aerodynamic particle diameter less than or equal to 10 microns).[2]

Condensible particulate emission factors, as such, are not explicitly included in AP-42 for most source categories. Because of the manner by which particulate matter is measured in stack gases, the mass of the condensed particulate matter is generally not included in calculations of particulate matter emission factors. A 1983 study has shown that the estimated particulate emissions may have to be increased by a third or more to account for condensed particulate.[2] Therefore, there are current efforts underway within the U.S. Environmental Protection Agency (EPA) to better understand and quantify condensible emissions.

As part of these efforts, the EPA has initiated the current study to gain insights into the condensible emissions area from an air toxics perspective, with emphasis on controllability and chemical composition of these emissions. The primary objectives of the study were to:

(a) compile existing data on condensible emissions;

(b) determine chemical composition of condensible emissions, where possible;

(c) identify source categories that are major emitters of condensibles;

(d) evaluate effectiveness of various control devices in reducing condensible emissions; and

(e) evaluate how performance of currently available control technologies can be improved to better control condensible emissions.

1.2 APPROACH

The data compiled for this study were obtained from a review of literature on condensible emissions. For the purposes of this study, the back-half catch from the EPA Reference Method 5 or its equivalent was considered to represent condensible emissions. The EPA Method 5 or its equivalent, where the back-half catch is determined gravimetrically, includes no corrections for acid or sulfate formation in the impingers from the SO_2/SO_3 in the stack gas. Therefore, the Method 5 results overestimate what is caught in the back-half of the sampling train as condensibles.

The major sources of information reviewed included emission test reports from the U.S. EPA's Emission Measurement Branch (EMB) and from the States of California and New York. The data obtained from the test reports were screened to ensure their suitability and completeness for inclusion in this study. Test reports containing questionable results were excluded from further analysis.

Two data bases were developed in this study. The first data base contains information on condensible emission rates for specific emission source-control device combinations. The second data base focuses on composition or speciation of condensible emission rates. These data bases were used to: (a) identify major sources of condensible emissions; and (b) analyze and evaluate the performance of existing control devices in controlling condensible emissions. An attempt was made to assess potential control and process improvements to further reduce condensible emissions.

1.3 RECOMMENDATIONS

This study provided the first step in developing estimates of condensible emission factors, identifying major sources of condensible emissions, and evaluating the effectiveness of particulate matter control devices for reducing condensible emissions. The analysis was limited to total condensible emissions due to the limited nature of speciated condensibles data.

A logical extension of this study would involve the following:

(a) Develop a prioritized list of source categories for use in potential future studies:

- using the preliminary analysis results from this study, complete characterization of all source categories with respect to condensible emission factors;

- develop a condensible emissions inventory on a national basis by applying the condensible emission factors to facilities within each source category. (This inventory could also be broken down by condensible species where possible.)

- rank source categories according to condensible emissions and identify major emitters (including sources of specific air toxics).

(b) Conduct an engineering evaluation of high-priority source categories to identify the components of condensible emissions and determine their physical/chemical characteristics. This would provide the framework for developing source category-specific control strategies.

(c) Collect and compile stack data generated using EPA's draft method on condensibles: Based on conversations with STAPPA/ALAPCO, a number of States have begun implementing the draft Method 202 Determination of Condensible Emissions from Stationary Sources. Compilation of these data and results from tests conducted by

EPA using the draft method would provide a valuable source of information to interested parties.

1.4 REPORT ORGANIZATION

This report is divided into four sections. Section 1 contains the introduction. Section 2 describes and discusses the Condensibles Data Base and the Speciated Condensibles Data Base. Section 3 presents a discussion on the effectiveness of control devices in reducing condensible emissions. It includes an evaluation of potential improvements in control device performance to further reduce condensible emissions. Section 4 contains the references used in this document.

SECTION 2

CONDENSIBLE EMISSIONS DATA

This section describes the condensible emissions data compiled in this study. The definition of condensible emissions used in this report is followed by a discussion of the two data bases developed. The Condensibles Data Base described in Section 2.2 presents the condensible emission factors estimated for specific emission source-control technology combinations. Section 2.3 describes the Speciated Condensibles Data Base, which presents the available chemical species data corresponding to the condensible emissions.

2.1 DEFINITION OF CONDENSIBLE EMISSIONS

As stated in the PM_{10} SIP Development Guideline document, condensible particulate matter is defined broadly as "material that is not particulate matter at stack conditions but condenses and/or reacts (upon cooling and dilution in the ambient air) to form particulate matter immediately after discharge from the stack."[1] Currently available test data on condensible emissions have been collected using the EPA Reference Method 5 or its equivalent. For the purposes of this study, condensible emissions are considered as the particulate matter collected downstream of the heated filter in the EPA Reference Method 5 sample train or its equivalent. Emissions that pass through the heated filter and condense in the impingers in the "back-half" of the train are assumed to comprise the condensible emissions.

2.2 CONDENSIBLES DATA BASE

Table 2-1 presents condensible emissions data for approximately 40 emission source categories. The following information is provided, where available, for each emission source:

- Source category,
- Process type,
- Emission control type,
- Uncontrolled emissions - total particulate (front-half and back-half catch), condensibles, and percent condensibles,

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Aluminum Manufacturing	Reverberatory furnace	None	0.74 lb/hr 0.0132 gr/dscf	0.09 lb/hr 0.0016 gr/dscf	12	NA	NA	NA	NA	NA	SCAQMD 5.2	N	118
Aluminum Processing	Remelt furnace	None	0.048 lb/hr 0.0022 gr/dscf	0.048 lb/hr 0.0022 gr/dscf	100	NA	NA	NA	NA	NA	SCAQMD 5.2	N	101
Anhydrous Calcium Sulfate Manufacturing	Calciner	Baghouse	NA	NA	NA	0.167 lb/hr 0.02 gr/dscf	0.066 lb/hr 0.0079 gr/dscf	40	NA	NA	SCAQMD 5.2	N	115
Asphalt Concrete	Conventional	Knockout box and venturi scrubber	3.41 lb/ton 7.53 gr/dscf	0.139 lb/ton 0.312 gr/dscf	4	0.073 lb/ton 0.164 gr/dscf	0.048 lb/ton 0.107 gr/dscf	66	98	66	EPA 5E	Y	4
	Recycle asphalt pavement	Knockout box and venturi scrubber	2.2 lb/ton 4.33 gr/dscf	0.261 lb/ton 0.536 gr/dscf	12	0.065 lb/ton 0.13 gr/dscf	0.052 lb/ton 0.105 gr/dscf	80	97	80	EPA 5E	Y	4
	Recycle asphalt pavement	Knockout box and venturi scrubber	6.41 lb/ton 5.71 gr/dscf	0.041 lb/ton 0.052 gr/dscf	1	0.115 lb/ton 0.153 gr/dscf	0.018 lb/ton 0.023 gr/dscf	16	97	56	EPA 5E	Y	3
Asphalt Plant	Dryer	Baghouse	NA	NA	NA	4.3 lb/hr 0.0166 gr/dscf	2.4 lb/hr 0.009 gr/dscf	56	NA	NA	SCAQMD 5.2	N	120
Brass & Bronze Smelters	Brass furnace	Fabric filter	NA	NA	NA	2.3 lb/hr 0.008 gr/dscf	0.6 lb/hr 0.002 gr/dscf	26	NA	NA	EPA 5	N	5
	Smelter	Fabric filter	NA	NA	NA	3.3 lb/hr 0.011 gr/dscf	0.95 lb/hr 0.003 gr/dscf	29	NA	NA	EPA 5	N	6
Building Brick Manufacturing	Tunnel kiln	None	12.6 lb/hr 0.066 gr/dscf	0.9 lb/hr 0.005 gr/dscf	7	NA	NA	NA	NA	NA	EPA 5	N	7
	Dryer	None	1.34 lb/hr 0.003 gr/dscf	0.85 lb/hr 0.002 gr/dscf	63	NA	NA	NA	NA	NA	EPA 5	N	7

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Cable Covering	Lead presses, lead pots, dross kettle	None	0.31 lb/ton	0.1 lb/ton	32	NA	NA	NA	NA	NA	EPA 5	Y	8
Carbon Black	Process line vent (via off-gas boiler)	Fabric filter	0.0056 lb/lb	0.0024 lb/lb	43	0.0016 lb/lb	0.0007 lb/lb	44	71	71	EPA 5	N	9
Catalyst Manufacturing	Rotary dryer	Baghouse	NA	NA	NA	0.933 lb/hr 0.0085 gr/dscf	0.674 lb/hr 0.006 gr/dscf	72	NA	NA	SCAQMD 5.2	N	108
Coal Preparation Plants	Air tables	Fabric filter	NA	NA	NA	2.5 lb/hr 0.011 gr/scf	1.4 lb/hr 0.006 gr/scf	56	NA	NA	EPA 5	N	58
	Fluid bed dryer	Venturi scrubber	NA	NA	NA	20.3 lb/hr 0.021 gr/scf	1.8 lb/hr 0.002 gr/scf	9	NA	NA	EPA 5	N	59
	Thermal dryer	Venturi scrubber	NA	NA	NA	43.3 lb/hr 0.03 gr/scf	13.1 lb/hr 0.009 gr/scf	30	NA	NA	EPA 5	N	60
Coke Ovens	Oven battery stack	Maintenance (mobile gunning)	NA	NA	NA	54.4 lb/hr 0.121 gr/dscf	1.4 lb/hr 0.003 gr/dscf	3	NA	NA	EPA 5	N	10
	Oven battery stack	Wet ESP	0.47 lb/ton 0.0135 gr/dscf	0.18 lb/ton 0.005 gr/dscf	38	0.08 lb/ton 0.002 gr/dscf	0.03 lb/ton 0.0008 gr/dscf	38	83	83	EPA 5	Y	11
	Oven battery stack	Maintenance	NA	NA	NA	9 lb/ton 0.051 gr/dscf	2.1 lb/ton 0.012 gr/dscf	23	NA	NA	EPA 5	Y	84
	Oven battery stack	Fabric filter	25.88 lb/hr 0.085 gr/dscf	2.21 lb/hr 0.007 gr/dscf	9	8.6 lb/hr 0.027 gr/dscf	1.71 lb/hr 0.005 gr/dscf	20	67	23	EPA 5	N	80

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions			Controlled Emissions			Efficiency (%)			Species	
			Total Particulate	Condensible	% Condensible	Total Particulate	Condensible	% Condensible	Total Particulate	Condensible	Test Method	Data (Y/N)	Reference Number
Electric Utilities	Coal-fired boiler	ESP	NA	NA	NA	0.122 lb/MMBtu 0.0578 gr/dscf	0.038 lb/MMBtu 0.0181 gr/dscf	31	NA	NA	EPA 5	N	56
	Coal-fired boiler	ESP	NA	NA	NA	1096 lb/hr 0.081 gr/dscf	882 lb/hr 0.0651 gr/dscf	80	NA	NA	EPA 5	N	57
Ferroalloy	Ferro-chrome electric arc furnace	ESP	1312 lb/hr 1.87 gr/dscf	19 lb/hr 0.0271 gr/dscf	1	24.1 lb/hr 0.0183 gr/dscf	3.6 lb/hr 0.0027 gr/dscf	15	98	81	EPA 5	N	85
	Silicon metal electric arc furnace	Fabric filter	2360 lb/hr 0.706 gr/dscf	151 lb/hr 0.045 gr/dscf	6	27.65 lb/hr 0.0053 gr/dscf	12.13 lb/hr 0.0023 gr/dscf	44	99	92	EPA 5	N	13
	Silico-manganese electric arc furnace	Venturi scrubber and demister	230 lb/hr 1.65 gr/dscf	3.6 lb/hr 0.0259 gr/dscf	2	14.21 lb/hr 0.0856 gr/dscf	1.42 lb/hr 0.0085 gr/dscf	10	94	60	EPA 5	N	81
Fertilizer (NPK)	Ammoniator, Granulator, Dryer, and Cooler	Cyclones, spray chamber, and venturi scrubber (in series)	NA	NA	NA	0.75 lb/ton 0.0785 gr/dscf	0.29 lb/ton 0.0257 gr/dscf	39	NA	NA	EPA 5	N	14
Fertilizer (Phosphate)	Dryer kiln and cooler	Fabric filter	133.2 lb/ton 14.78 gr/dscf	0.6 lb/ton 0.06 gr/dscf	<1	0.346 lb/ton 0.05 gr/dscf	0.302 lb/ton 0.043 gr/dscf	87	>99	50	EPA 5	N	15
	Ammoniator	Venturi scrubber and demister	4.67 lb/ton 3.14 gr/dscf	0.1 lb/ton 0.07 gr/dscf	2	0.24 lb/ton 0.123 gr/dscf	0.12 lb/ton 0.062 gr/dscf	50	95	(a)	EPA 5	N	15
	Dryer and cooler	Wet scrubber	NA	NA	NA	15.1 lb/hr 0.042 gr/dscf	6.8 lb/hr 0.019 gr/dscf	45	NA	NA	EPA 5	N	16

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Glass Manufacturing	Glass melting furnace	Fabric filter	NA	NA	NA	25.25 lb/hr 0.1115 gr/dscf	20.87 lb/hr 0.0926 gr/dscf	83	NA	NA	EPA 5 and EPA 17	N	54
	Regenerative furnace	Packed tower, venturi scrubber, and demister	NA	NA	NA	5.52 lb/hr 0.0422 gr/dscf	2.25 lb/hr 0.0173 gr/dscf	41	NA	NA	EPA 5	N	55
	Melting furnace	Scrubber	NA	NA	NA	0.33 lb/hr 0.0125 gr/dscf	0.04 lb/hr 0.0016 gr/dscf	12	NA	NA	SCAQMD 5.2	N	105
	Melting furnace	None	8.42 lb/hr 0.101 gr/dscf	4.87 lb/hr 0.058 gr/dscf	58	NA	NA	NA	NA	NA	SCAQMD 5.2	N	117
	Melting furnace	ESP	NA	NA	NA	1.057 lb/hr 0.0109 gr/dscf	0.417 lb/hr 0.0043 gr/dscf	39	NA	NA	SCAQMD 5.2	N	111,112
	Melting furnace	Scrubber	NA	NA	NA	2.91 lb/hr 0.00169 gr/dscf	0.291 lb/hr 0.00019 gr/dscf	10	NA	NA	SCAQMD 5.2	N	103
	Melting furnace	Baghouse	NA	NA	NA	4.834 lb/hr 0.0143 gr/dscf	2.641 lb/hr 0.0078 gr/dscf	55	NA	NA	SCAQMD 5.2	N	107
	Melting furnace	Scrubber and ESP	NA	NA	NA	0.65 lb/hr 0.0069 gr/dscf	0.49 lb/hr 0.0052 gr/dscf	75	NA	NA	SCAQMD 5.2	N	98
Grain Processing	Grain dryer	Polyester screen filter	NA	NA	NA	5.44 lb/hr 0.0148 gr/dscf	3.67 lb/hr 0.01 gr/dscf	67	NA	NA	EPA 5	N	61
	Grain elevator (grain loading)	Fabric filter	NA	NA	NA	0.54 lb/hr 0.0126 gr/dscf	0.2 lb/hr 0.0047 gr/dscf	37	NA	NA	EPA 5	N	62
	Grain elevator (grain cleaning)	Fabric filter	NA	NA	NA	0.13 lb/hr 0.004 gr/dscf	0.04 lb/hr 0.0012 gr/dscf	31	NA	NA	EPA 5	N	62
	Hammer mill	Cyclone	NA	NA	NA	0.09 lb/hr 0.004 gr/dscf	0.027 lb/hr 0.0012 gr/dscf	30	NA	NA	EPA 5	N	63

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Grey Iron Foundry	Electric Arc Furnace (EAF)	Fabric filter	195 lb/hr 0.33 gr/dscf	9.9 lb/hr 0.0173 gr/dscf	5	3.86 lb/hr 0.0058 gr/dscf	1.27 lb/hr 0.0019 gr/dscf	33	98	87	EPA 5	N	77
Incinerator	Municipal Solid Waste (MSW) fired	ESP	393 lb/hr 1.09 gr/dscf	21 lb/hr 0.06 gr/dscf	5	19 lb/hr 0.05 gr/dscf	4.7 lb/hr 0.01 gr/dscf	25	95	78	EPA 5	N	91
	MSW and industrial SW-fired	ESP	460 lb/hr 1.673 gr/dscf	3.75 lb/hr 0.012 gr/dscf	1	22.4 lb/hr 0.073 gr/dscf	1.53 lb/hr 0.005 gr/dscf	7	95	59	EPA 5	N	90
	MSW and ISW fired	ESP	557 lb/hr 1.764 gr/dscf	352 lb/hr 0.011 gr/dscf	63	18.5 lb/hr 0.056 gr/dscf	2.31 lb/hr 0.007 gr/dscf	12	97	34	EPA 5	N	90
	Wood waste-fired fluidized bed incinerator	Multi-cyclone	NA	NA	NA	0.602 lb/MMBtu 0.239 gr/dscf	0.011 lb/MMBtu 0.004 gr/dscf	2	NA	NA	EPA 5	N	92
Industrial Boiler	Hog fuel-fired	Multi-cyclone and wet scrubber	NA	NA	NA	4.46 lb/hr 0.034 gr/dscf	0.38 lb/hr 0.003 gr/dscf	9	NA	NA	EPA 5	N	93
	Coal/coke fired	ESP, caustic scrubber	NA	NA	NA	19.1 lb/hr 0.0097 gr/dscf	9.49 lb/hr 0.0048 gr/dscf	50	NA	NA	EPA 5	N	100
Iron Ore Beneficiation	Pelletizing - hood exhaust	None	205 lb/hr 0.127 gr/dscf	16.7 lb/hr 0.0104 gr/dscf	8	NA	NA	NA	NA	NA	EPA 5	N	17
	Pelletizing - hood exhaust	Cyclone	NA	NA	NA	204 lb/hr 0.11 gr/dscf	21.3 lb/hr 0.0113 gr/dscf	10	NA	NA	EPA 5	N	17
	Secondary and tertiary crushing	Wet scrubber	NA	NA	NA	2.8 lb/hr 0.0121 gr/dscf	0.2 lb/hr 0.0008 gr/dscf	7	NA	NA	EPA 5	N	17

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Iron and Steel Plants	Basic Oxygen Furnace (BOF)	Drop-out chamber and ESP	NA	NA	NA	0.269 lb/ton 0.0347 gr/dscf	0.0593 lb/ton 0.0077 gr/dscf	22	NA	NA	EPA 5	N	20
	BOF	Venturi scrubber	NA	NA	NA	0.1143 lb/ton 0.0369 gr/dscf	0.0212 lb/ton 0.0071 gr/dscf	19	NA	NA	EPA 5	N	86
	BOF	Venturi scrubber	NA	NA	NA	0.008 lb/ton 0.0081 gr/dscf	0.0035 lb/ton 0.0035 gr/dscf	44	NA	NA	EPA 5	Y	19
	BOF	Venturi scrubber	NA	NA	NA	0.0047 lb/ton 0.0049 gr/dscf	0.0019 lb/ton 0.002 gr/dscf	40	NA	NA	EPA 5	N	87
	BOF	ESP	NA	NA	NA	0.0827 lb/ton 0.0106 gr/dscf	0.0303 lb/ton 0.0039 gr/dscf	37	NA	NA	EPA 5	Y	18
	EAF	Fabric filter	0.0537 gr/dscf	0.0019 gr/dscf	4	0.0027 gr/dscf	0.0013 gr/dscf	48	95	32	EPA 5	N	12
	Sintering	Cyclones and ESP	NA	NA	NA	1.17 lb/ton 0.192 gr/dscf	0.208 lb/ton 0.033 gr/dscf	18	NA	NA	EPA 5	Y	45
	Sintering	Cyclones and fabric filter	NA	NA	NA	66.16 lb/hr 0.0578 gr/dscf	17.93 lb/hr 0.0157 gr/dscf	27	NA	NA	EPA 5	N	46
	Sintering	Cyclones, venturi scrubber, and demister	619 lb/hr 0.403 gr/dscf	99 lb/hr 0.065 gr/dscf	16	72.3 lb/hr 0.042 gr/dscf	40.2 lb/hr 0.023 gr/dscf	56	88	59	EPA 5	Y	47

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Kraft Pulp Mills	Smelt-dissolving tank	Wet scrubber	NA	NA	NA	5.85 lb/hr 0.0359 gr/dscf	1.95 lb/hr 0.012 gr/dscf	33	NA	NA	EPA 5	N	21
	Recovery furnace	ESP	NA	NA	NA	32.47 lb/hr 0.0442 gr/dscf	13.86 lb/hr 0.0191 gr/dscf	43	NA	NA	EPA 5	N	22
	Smelt-dissolving tank	Wet scrubber	NA	NA	NA	5.15 lb/hr 0.0643 gr/dscf	1.5 lb/hr 0.0189 gr/dscf	29	NA	NA	EPA 5	N	22
	Lime kiln	Venturi scrubber and demister	NA	NA	NA	13.32 lb/hr 0.317 gr/dscf	0.94 lb/hr 0.262 gr/dscf	7	NA	NA	EPA 5	N	22
	Smelt-dissolving tank	Wet packed scrubber	1.79 lb/ton 0.492 gr/dscf	0.09 lb/ton 0.025 gr/dscf	5	0.285 lb/ton 0.0708 gr/dscf	0.018 lb/ton 0.0047 gr/dscf	6	84	80	EPA 5	N	23
	Smelt-dissolving tank	Wet packed scrubber	NA	NA	NA	0.223 lb/ton 0.135 gr/dscf	0.021 lb/ton 0.007 gr/dscf	9	NA	NA	EPA 5	Y	24
Lead	Blast furnace	Packed scrubber	NA	NA	NA	1.19 lb/hr 0.0093 gr/dscf	0.36 lb/hr 0.0028 gr/dscf	30	NA	NA	EPA 5	N	
Lead Acid Battery	Casting furnace	None	0.197 lb/ton 0.0091 gr/dscf	0.053 lb/ton 0.0025 gr/dscf	27	NA	NA	NA	NA	NA	EPA 5	Y	25
	Stacking, element burning, and casing	Fabric filter	1.469 lb/hr 0.0149 gr/dscf	0.713 lb/hr 0.0072 gr/dscf	49	1.029 lb/hr 0.0096 gr/dscf	0.543 lb/hr 0.0051 gr/dscf	53	30	24	EPA 5	Y	25
	Paste mixer	Wet scrubber	0.545 lb/ton 0.0614 gr/dscf	0.021 lb/ton 0.0027 gr/dscf	4	0.124 lb/ton 0.0142 gr/dscf	0.037 lb/ton 0.0043 gr/dscf	30	77	(a)	EPA 5	Y	25

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Lead Oxide Plant	Barton pot	Fabric filter	NA	NA	NA	0.57 lb/ton 0.0411 gr/dscf	0.01 lb/ton 0.0009 gr/dscf	2	NA	NA	EPA 5	N	26
	Materials handling	Fabric filter	NA	NA	NA	0.088 lb/hr 0.0029 gr/dscf	0.08 lb/hr 0.0002 gr/dscf	91	NA	NA	EPA 5	N	26
	Calcining furnace	Cyclones and fabric filter	86.7 lb/hr 11.64 gr/dscf	0.1 lb/hr 0.014 gr/dscf	<1	0.084 lb/hr 0.0121 gr/dscf	0.017 lb/hr 0.0021 gr/dscf	20	>99	83	EPA 5	N	26
	Materials Handling and Grinding	Fabric filter	49.32 lb/hr 1.0893 gr/dscf	0.03 lb/hr 0.0007 gr/dscf	<1	0.054 lb/hr 0.001 gr/dscf	0.022 lb/hr 0.0005 gr/dscf	41	>99	27	EPA 5	N	26
	Loading	None	0.038 lb/hr 0.0457 gr/dscf	0.0001 lb/hr 0.0009 gr/dscf	<1	NA	NA	NA	NA	NA	EPA 5	N	26
Lead Processing	Lead melting furnace	Baghouse and scrubber	NA	NA	NA	0.29 lb/hr 0.0043 gr/dscf	0.11 lb/hr 0.0016 gr/dscf	38	NA	NA	SCAQMD 5.2	N	109
Lightweight Aggregate	Rotary kiln	Wet scrubber	NA	NA	NA	10.13 lb/hr 0.0563 gr/dscf	2.53 lb/hr 0.0142 gr/dscf	25	NA	NA	EPA 5	Y	27
	Clinker cooler	Cyclone and fabric filter	12.09 lb/hr 0.0825 gr/dscf	0.09 lb/hr 0.0007 gr/dscf	1	2.36 lb/hr 0.0047 gr/dscf	1.91 lb/hr 0.0018 gr/dscf	81	81	(a)	EPA 5	Y	27
	Rotary kiln	Wet scrubber	9190 lb/hr 26.28 gr/dscf	61.3 lb/hr 0.18 gr/dscf	1	21.13 lb/hr 0.0586 gr/dscf	5.73 lb/hr 0.0156 gr/dscf	27	>99	91	EPA 5	Y	28
	Clinker cooler	Settling chamber	NA	NA	NA	4.436 lb/hr 0.0743 gr/dscf	0.636 lb/hr 0.0103 gr/dscf	14	NA	NA	EPA 5	Y	28
	Rotary kiln	Wet scrubber	3699 lb/hr 17.421 gr/dscf	4.5 lb/hr 0.0214 gr/dscf	<1	123.3 lb/hr 0.29 gr/dscf	3.9 lb/hr 0.0093 gr/dscf	3	97	13	EPA 5	Y	29
	Clinker cooler	Settling chamber	NA	NA	NA	14.64 lb/hr 0.0587 gr/dscf	0.54 lb/hr 0.0027 gr/dscf	4	NA	NA	EPA 5	Y	29

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Lime Manufacturing	Rotary kiln	ESP	NA	NA	NA	0.533 lb/ton 0.0134 gr/dscf	0.263 lb/ton 0.0067 gr/dscf	49	NA	NA	EPA 5	N	64
	Rotary kiln	Fabric filter	NA	NA	NA	0.315 lb/ton 0.0346 gr/dscf	0.039 lb/ton 0.004 gr/dscf	12	NA	NA	EPA 5	N	65
	Seasoning chamber	Wet scrubber	NA	NA	NA	0.1 lb/ton 0.0341 gr/dscf	0.016 lb/ton 0.0056 gr/dscf	16	NA	NA	EPA 5	N	66
	Hydrator	Wet scrubber	NA	NA	NA	0.112 lb/ton 0.1487 gr/dscf	0.0036 lb/ton 0.0048 gr/dscf	3	NA	NA	EPA 5	N	67
Petroleum Refining	FCCU	ESP	NA	NA	NA	0.11 gr/dscf	0.067 gr/dscf	61	NA	NA	EPA 5	N	50
	FCCU	Cyclones and ESP	NA	NA	NA	189 lb/hr 0.214 gr/dscf	116 lb/hr 0.07 gr/dscf	61	NA	NA	EPA 5	N	51
	FCCU	ESP	NA	NA	NA	323 lb/hr 0.204 gr/dscf	85 lb/hr 0.151 gr/dscf	26	NA	NA	EPA 5	N	52
	FCCU	Venturi scrubber	0.0213 gr/dscf	0.0083 gr/dscf	39	0.0129 gr/dscf	0.0013 gr/dscf	10	61	84	EPA 5 and EPA 8	Y	53
	FCCU	ESP	NA	NA	NA	22.65 lb/hr 0.0171 gr/dscf	3.21 lb/hr 0.0024 gr/dscf	14	NA	NA	SCAQMD 5.2	N	119
	FCCU	ESP	NA	NA	NA	28.68 lb/hr 0.0218 gr/dscf	13.66 lb/hr 0.0104 gr/dscf	48	NA	NA	SCAQMD 5.2	N	78

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions			Controlled Emissions			Efficiency (%)				
			Total Particulate	Condensible	% Condensible	Total Particulate	Condensible	% Condensible	Total Particulate	Condensible	Test Method	Species Data (Y/N)	Reference Number
Petroleum Refining (continued)	FCCU	ESP	NA	NA	NA	19 lb/hr 0.0658 gr/dscf	16.06 lb/hr 0.055 gr/dscf	85	NA	NA	CARB 5.2	N	114
	FCCU	ESP	NA	NA	NA	20.15 lb/hr 0.0447 gr/dscf	14.61 lb/hr 0.0324 gr/dscf	73	NA	NA	CARB 5.2	N	114
	FCCU	ESP	NA	NA	NA	24.85 lb/hr 0.1053 gr/dscf	1.531 lb/hr 0.0065 gr/dscf	6	NA	NA	SCAQMD 5.2	N	123
	FCCU	ESP	NA	NA	NA	18 lb/hr 0.0216 gr/dscf	11.54 lb/hr 0.014 gr/dscf	64	NA	NA	SCAQMD 5.2	N	122
	FCCU	ESP	NA	NA	NA	8.83 lb/hr 0.026 gr/dscf	0.521 lb/hr 0.0015 gr/dscf	6	NA	NA	SCAQMD 5.2	N	113
	FCCU	ESP	NA	NA	NA	8.44 lb/hr 0.021 gr/dscf	1.24 lb/hr 0.003 gr/dscf	15	NA	NA	SCAQMD 5.2	N	113
	FCCU	ESP	NA	NA	NA	18.51 lb/hr 0.012 gr/dscf	2.64 lb/hr 0.0017 gr/dscf	14	NA	NA	SCAQMD 5.2	Y	104
	FCCU	ESP	NA	NA	NA	26.2 lb/hr 0.014 gr/dscf	20.15 lb/hr 0.0108 gr/dscf	77	NA	NA	SCAQMD 5.2	N	79
	FCCU	ESP	NA	NA	NA	7.98 lb/hr 0.038 gr/dscf	2.25 lb/hr 0.011 gr/dscf	28	NA	NA	SCAQMD 5.2	N	121
	FCCU	ESP	NA	NA	NA	8.92 lb/hr 0.04 gr/dscf	2.46 lb/hr 0.011 gr/dscf	28	NA	NA	SCAQMD 5.2	N	125

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Phosphate Rock Processing	Rotary dryer and fluid bed dryer	Cyclones, wet scrubber, and wet ESP	NA	NA	NA	0.033 lb/ton 0.013 gr/dscf	0.008 lb/ton 0.003 gr/dscf	24	NA	NA	EPA 5	N	69
	Fluid bed dryer	Cyclone and wet cyclonic scrubber	2.81 lb/ton 1.677 gr/dscf	0.069 lb/ton 0.038 gr/dscf	2	0.102 lb/ton 0.058 gr/dscf	0.026 lb/ton 0.015 gr/dscf	25	96	62	EPA 5	N	70
	Roller mill and bowl mill	Cyclones and fabric filter	201 lb/hr 3.21 gr/dscf	0.15 lb/hr 0.0024 gr/dscf	<1	0.146 lb/hr 0.003 gr/dscf	0.042 lb/hr 0.001 gr/dscf	29	>99	72	EPA 5	N	71
Plywood Manufacturing	Veneer dryer and wood-fired boiler	None	33.4 lb/hr 1.19 lb/1000ft2 0.161 gr/dscf	31 lb/hr 1.1 lb/1000ft2 0.15 gr/dscf	93	NA	NA	NA	NA	NA	EPA 5X	Y	36
	Veneer dryers		18.3 lb/hr 0.53 lb/1000ft2 0.164 gr/dscf	16.6 lb/hr 0.47 lb/1000ft2 0.148 gr/dscf	91	14.9 lb/hr 0.43 lb/1000f 0.103 gr/dscf	11.7 lb/hr 0.34 lb/1000ft2 0.081 gr/dscf	79	18	28	EPA 5X	Y	37
Portland Cement	Clinker cooler	Fabric filter	NA	NA	NA	0.483 lb/ton 0.0617 gr/dscf	0.018 lb/ton 0.0023 gr/dscf	4	NA	NA	EPA 5	N	89
	Rotary kiln	ESP	NA	NA	NA	0.972 lb/ton 0.1099 gr/dscf	0.088 lb/ton 0.01 gr/dscf	9	NA	NA	EPA 5	N	89
	Finish mill	Fabric filter	NA	NA	NA	0.0213 lb/ton 0.0132 gr/dscf	0.0079 lb/ton 0.0049 gr/dscf	37	NA	NA	EPA 5	N	88
	Air separator	Fabric filter	NA	NA	NA	0.0668 lb/ton 0.0088 gr/dscf	0.0278 lb/ton 0.0036 gr/dscf	42	NA	NA	EPA 5	N	88
	Rotary kiln	Fabric filter	NA	NA	NA	0.184 lb/ton 0.0188 gr/dscf	0.114 lb/ton 0.0116 gr/dscf	62	NA	NA	EPA 5	N	30

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Portland Cement (continued)	Rotary kiln	Fabric filter	NA	NA	NA	1.026 lb/ton 0.127 gr/dscf	0.427 lb/ton 0.053 gr/dscf	42	NA	NA	EPA 5	N	31
	Rotary kiln	Fabric filter	NA	NA	NA	0.396 lb/ton 0.0496 gr/dscf	0.124 lb/ton 0.0158 gr/dscf	31	NA	NA	EPA 5	N	99
Primary Aluminum	Anode prebake cell	Fabric filter	NA	NA	NA	0.744 lb/ton 0.0061 gr/dscf	0.251 lb/ton 0.0035 gr/dscf	34	NA	NA	EPA 5	N	32
	Anode prebake	Fabric filter	99.3 lb/ton 0.1401 gr/dscf	1.3 lb/ton 0.0019 gr/dscf	1	1.8 lb/ton 0.0022 gr/dscf	0.57 lb/ton 0.0007 gr/dscf	32	98	56	EPA 5	N	33
	Horizontal Soderburg	ESP	81.8 lb/ton 0.0875 gr/dscf	15.2 lb/ton 0.0163 gr/dscf	19	5.95 lb/ton 0.0064 gr/dscf	2.99 lb/ton 0.0032 gr/dscf	50	93	80	EPA 5	N	34
Primary Copper	Reverberatory furnace	Settling chamber and ESP	398.5 lb/hr 0.597 gr/dscf	103.5 lb/hr 0.155 gr/dscf	26	138.8 lb/hr 0.157 gr/dscf	61.7 lb/hr 0.07 gr/dscf	44	65	69	EPA 17	N	35
	Converter, electric furnace, and fluidized bed roaster	Spray chamber and fabric filter	8678 lb/hr 6.264 gr/dscf	122.2 lb/hr 0.088 gr/dscf	1	111.3 lb/hr 0.078 gr/dscf	82.5 lb/hr 0.058 gr/dscf	74	99	33	EPA 5	Y	82
	Reverberatory furnace and multi-hearth roaster	Spray chamber and ESP	2415 lb/hr 2.207 gr/dscf	51.4 lb/hr 0.047 gr/dscf	2	75 lb/hr 0.055 gr/dscf	16.4 lb/hr 0.012 gr/dscf	22	97	68	EPA 5	Y	83
Primary Lead	Blast furnace	Spray chamber and fabric filter	NA	NA	NA	22.35 lb/hr 0.02 gr/dscf	13.5 lb/hr 0.012 gr/dscf	60	NA	NA	EPA 5	Y	38
	Sintering	Spray chamber and fabric filter	58.2 lb/ton 3.47 gr/dscf	3.2 lb/ton 0.53 gr/dscf	5	0.095 lb/ton 0.002 gr/dscf	NA	NA	>99	NA	EPA 5	N	39
	Blast furnace	Spray chamber and fabric filter	174 lb/ton 3.16 gr/dscf	2 lb/ton 0.05 gr/dscf	1	2.5 lb/ton 0.0275 gr/dscf	1.2 lb/ton 0.0133 gr/dscf	48	99	40	EPA 5	Y	39

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Residential Woodheaters	Catalytic	Catalyst	NA	45.3-52.9 lb/ 1000 lb wood	NA	NA	3.1 lb/ 1000 lb wood	NA	NA	93 - 94	EPA 5H	N	94,95, 96
	Non-catalytic	Design modification	NA	45.3-52.9 lb/ 1000 lb wood	NA	NA	5.7 lb/ 1000 lb wood	NA	NA	87 - 89	EPA 5H	N	95,96, 97
	Pellet-fired	Controlled air & fuel delivery	NA	45.3-52.9 lb/ 1000 lb wood	NA	NA	5.7 lb/ 1000 lb wood	NA	NA	87 - 89	EPA 5H	N	95,96
Secondary Lead	Blast furnace	Afterburner, cyclones, and fabric filter	NA	NA	NA	3.16 lb/ton 0.0433 gr/dscf	2.98 lb/ton 0.0408 gr/dscf	94	NA	NA	EPA 5	Y	41
	Blast furnace	Venturi scrubber and demister	NA	NA	NA	1.785 lb/ton 0.0222 gr/dscf	0.039 lb/ton 0.0079 gr/dscf	2	NA	NA	EPA 5	Y	42
	Blast furnace and refining kettles	Afterburner, fabric filter, venturi scrubber, demister	NA	NA	NA	2.944 lb/ton 0.0412 gr/dscf	2.342 lb/ton 0.0333 gr/dscf	80	NA	NA	EPA 5	Y	43
	Blast furnace	Afterburner, settling chamber, fabric filter	1506 lb/hr 3610 lb/ton	15.72 lb/hr 400 lb/ton	1	13.67 lb/hr 3.3 lb/ton	12.54 lb/hr 3 lb/ton	92	99	20	EPA 5	Y	44
	Refining kettles and slag tap	Venturi scrubber and wet cyclone	34.7 lb/hr	1.67 lb/hr	5	5.53 lb/hr	0.95 lb/hr	17	84	43	EPA 5	Y	44
Sewage Sludge Incinerator	Fluid bed incinerator	Venturi scrubber and demister	NA	NA	NA	0.44 lb/ton 0.0081 gr/dscf	0.259 lb/ton 0.0048 gr/dscf	59	NA	NA	EPA 5	Y	48

(continued)

TABLE 2-1. CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Uncontrolled Emissions: Total Particulate	Uncontrolled Emissions: Condensible	Uncontrolled Emissions: % Condensible	Controlled Emissions: Total Particulate	Controlled Emissions: Condensible	Controlled Emissions: % Condensible	Efficiency (%): Total Particulate	Efficiency (%): Condensible	Test Method	Species Data (Y/N)	Reference Number
Soap & Detergent Manufacturing	Spray tower	Cyclones and fabric filter	273 lb/hr 1.09 gr/dscf	6 lb/hr 0.02 gr/dscf	2	1.88 lb/hr 0.0087 gr/dscf	1.59 lb/hr 0.0074 gr/dscf	85	99	74	EPA 5	N	72
	Spray tower	Cyclones, wet packed scrubber, wet ESP	NA	NA	NA	0.622 lb/ton 0.0198 gr/dscf	0.512 lb/ton 0.0163 gr/dscf	82	NA	NA	EPA 5	N	73
	Spray tower	Wet scrubber	NA	NA	NA	1.785 lb/ton 0.0225 gr/dscf	0.254 lb/ton 0.0032 gr/dscf	14	NA	NA	EPA 5	N	74
	NA	Cyclone and scrubber	NA	NA	NA	1.96 lb/hr 0.0069 gr/dscf	0.118 lb/hr 0.0004 gr/dscf	6	NA	NA	SCAQMD 5.2	N	110
Steel Manufacturing	Sintering	Baghouse	NA	NA	NA	13.2 lb/hr 0.013 gr/dscf	4.95 lb/hr 0.0049 gr/dscf	38	NA	NA	SCAQMD 5.2	N	102
Stone Crushing	Secondary and tertiary crushers, primary/secondary classifiers	Fabric filter	NA	NA	NA	0.0107 lb/ton 0.009 gr/dscf	0.0006 lb/ton 0.0005 gr/dscf	6	NA	NA	EPA 5	N	75
	Final sizing and auxiliaries	Fabric filter	NA	NA	NA	0.0037 lb/ton 0.0039 gr/dscf	0.0009 lb/ton 0.001 gr/dscf	24	NA	NA	EPA 5	N	75
	Pneumatic drilling	Fabric filter	NA	NA	NA	0.04 lb/hr 0.041 gr/dscf	0.002 lb/hr 0.002 gr/dscf	5	NA	NA	EPA 5	N	76
Taconite Ore Processing	Fine crusher	Wet cyclone	NA	NA	NA	0.0016 lb/ton 0.0049 gr/dscf	0.0001 lb/ton 0.0003 gr/dscf	6	NA	NA	EPA 5	N	68

NA = not available
SCAQMD = South Coast Air Quality Management District
CARB = California Air Resources Board
FCCU = Fluid Catalytic Cracking Unit
(a) Due to reasons unclear from the test reports, the back-half catch at the outlet was greater than that at the inlet.

- Controlled emissions - total particulate (front-half and back-half catch), condensibles, and percent condensibles,
- Emission control efficiency - total particulate and condensibles,
- Availability of chemical species data,
- Emission test method, and
- Reference.

2.2.1 Data Sources

A large proportion of the data compiled in this study was obtained from emission test reports. The source test reports were gathered from EPA's Emission Measurement Branch files, the South Coast Air Quality Management District (SCAQMD) source testing files, New York State Energy Research and Development Authority (NYSERDA), and other sources.

A large number of reports reviewed did not include the back-half catch and were excluded from further analysis. In addition, test data collected using an adsorbent (e.g., XAD resin traps used in dioxin/furan testing) in the back-half of the sampling train were not included, because samples collected in this manner would not represent condensible matter as defined in this study.

Test data gathered in this study were screened to ensure data quality. Only the tests performed using EPA or State agency approved sampling methods or their equivalent were included in the data base. Additionally, any questionable testing results were excluded from the data base.

The condensible emissions reported in Table 2-1 were either taken directly from the test reports or calculated from the test results presented. If back-half data were presented, these were taken as the condensible fraction. Where the back-half results were not reported explicitly, condensible emissions were calculated by either subtracting the front-half catch from the total catch or multiplying the total catch by the percent impinger catch.

2.2.2 Sampling Methods

About 70 percent of the tests summarized in Table 2-1 were conducted using the EPA Reference Method 5. Data collected using the SCAQMD Method 5.2 account for about 20 percent of the tests. In addition, 2-3 tests each were performed using EPA Methods 5E, 5H, 5X, and 17.

The sampling train used in all the tests was essentially the same. In tests conducted using EPA methods, the filter temperature was maintained at 250°F except in three tests. These tests involved petroleum refining and plywood manufacturing source categories where the filter temperature was kept at 350°F. In more than half of the SCAQMD tests, the filter temperature was maintained at 200-250°F. The remaining SCQAMD tests were conducted at filter temperatures less than 200°F or at unspecified filter temperatures.

For a given source, maintaining the front-half filter temperature at <250°F would result in smaller quantities of condensible material collected in the impingers than that collected at filter temperatures of 250°F. If the filter temperature is kept at temperatures higher than 250°F, a greater proportion of the particulate matter would be collected in the impingers. For a given source, the condensibles emission rate estimated using the EPA Method 5 test data would be higher than that estimated using the SCQAMD Method 5.2 (filter temperature <250°F) test data.

Typically, deionized water was used in the impingers. However, in some tests, impinger solutions containing nitric acid or sodium hydroxide were used (e.g., cadmium sulfide pigments and asphalt concrete source categories). Since these solutions have greater affinity for certain species, the condensibles emission rate estimated using such systems would be greater than that of a typical sampling train.

The EPA Method 5 or its equivalent, where the back-half catch is determined gravimetrically, includes no corrections for acid or sulfate formation in the impingers from the SO_2/SO_3 in the stack gas. Therefore, the Method 5 results overestimate what is caught in the back-half of the sampling train as condensibles. The SCQAMD Method 5.2 procedures incorporate corrections for formation of acid/sulfate species in the impingers. When reporting total particulate matter (front-half and back-half) emission rates, an adjustment is made for formation of such species. In addition, if ammonia is injected to increase the efficiency of a control device, a second adjustment to the impinger catch is made (only for fluid catalytic cracking units). Therefore, for a given source, the condensibles emission rate measured using the SCAQMD Method 5.2 would be lower than that measured using the EPA Method 5 back-half catch.

The EPA is currently developing a test method to measure condensible emissions from stationary sources. This method is similar to the SCAQMD Method 5.2 in that it contains procedures to correct for acid/sulfate species formation in the back-half of the sampling train.

2.2.3 Condensibles Data Analysis

The Condensibles Data Base in Table 2-1 characterizes 43 source categories. For 13 of the categories, only one set of data is available, making it difficult to draw any conclusions about these categories.

Table 2-2 presents a summary of percent condensibles [100 x back-half catch/(back-half catch + front-half catch)] data for each source category with more than one set of test data. As shown in this table, the average percent condensible value ranges from 8 (iron ore benefication) to 86 (plywood manufacturing).

The relative standard deviation (100 x standard deviation/average) values shown in Table 2-2 provide a measure of the variation in the percentage of condensibles within a given source category. This parameter ranges from 7 percent (brass and bronze smelting) to over 100 percent (building brick manufacturing, lead oxide, lightweight aggregate, and primary lead). In a majority of the cases, the relative standard deviation is in excess of 50 percent. The high degree of variation for these categories is probably due to differences in individual emission source characteristics, since the data in most cases were collected using the same measurement method.

To identify source categories where future efforts on condensible emissions should be focused, a preliminary analysis was conducted. As part of this analysis, Table 2-3 ranks the source categories according to the percentage of condensibles in the particulate catch. Based on the information collected in this study, the categories where the percentage of condensibles is greater than 50 include the following: plywood manufacturing, asphalt concrete, electric utilities, fertilizer manufacturing, and secondary lead smelting. Particulate emissions from stationary point source categories are ranked according to their contributions to national emissions in Table 2-4. These data were extracted from the 1985 NAPAP Emission Inventory.[124] The percentages of condensibles estimated from the current study are also listed in Table 2-4. Source categories characterized with high percentage of condensibles and significant contribution to national particulate emission levels would be ideal candidates for further study. From the two tables, it appears that the combustion source category (utility/industrial boilers fueled with coal/oil/wood/bark) would be a suitable candidate for future studies.

2.3 SPECIATED CONDENSIBLES DATA BASE

Table 2-5 presents the speciated condensible emissions data identified in this study for 13 source categories. Most of these source categories are also included in Table 2-1. The information presented for each emission source includes the following:

- Source category,
- Process Type,
- Emission control type,
- Condensible species,
- Uncontrolled emissions - condensible species,

TABLE 2-2. PERCENTAGE OF CONDENSIBLES IN PARTICULATE EMISSIONS

Source Category	% Condensibles[a]	Relative Standard Deviation (%)
Asphalt Concrete	54	63
Brass & Bronze Smelters	28	7
Building Brick Manufacturing	35	114
Coal Preparation Plants	32	75
Coke Ovens	21	67
Electric Utilities	56	32
Ferroalloy Manufacturing	23	78
Fertilizer Manufacturing	55	40
Glass Manufacturing	47	57
Grain Processing	41	41
Incinerators	12	83
Industrial Boilers	30	97
Iron Ore Beneficiation	8	25
Iron and Steel Plants	35	40
Kraft Pulp Mills	21	76
Lead Acid Battery Manufacturing	37	38
Lead Oxide	31	119
Lightweight Aggregate	26	111
Lime Manufacturing	20	100
Petroleum Refining	39	72
Phosphate Rock Processing	26	12
Plywood Manufacturing	86	12
Portland Cement Manufacturing	32	63
Primary Aluminum	39	26
Primary Copper Smelting	47	55
Primary Lead Smelting	33	118
Secondary Lead Smelting	57	77
Soap and Detergent Manufacturing	47	91
Stone Crushing	12	92

[a]As defined by the back-half (Method 5 or equivalent) catch.

TABLE 2-3. CATEGORY RANKING ACCORDING TO PERCENTAGE OF CONDENSIBLES IN PARTICULATE EMISSIONS

% Condensibles (Average)	Source Category
80 - 90	Plywood manufacturing
50 - 60	Asphalt concrete
	Electric utilities
	Fertilizer manufacturing
	Secondary lead smelting
40 - 50	Glass manufacturing
	Grain processing
	Primary copper smelting
	Soap and detergent manufacturing
25 - 40	Brass and bronze smelters
	Building brick manufacturing
	Coal preparation plants
	Industrial boilers
	Iron and steel plants
	Lead acid battery manufacturing
	Lead oxide manufacturing
	Lightweight aggregate
	Petroleum refining
	Phosphate rock processing
	Portland cement manufacturing
	Primary aluminum
	Primary lead smelting

- Controlled emissions - condensible species,
- Emission control efficiency - condensible species, and
- Reference.

2.3.1 Data Sources

The data in Table 2-5 were extracted from source test reports in EPA's Emission Measurement Branch files. Results representing only the back-half catch of the sampling train were incorporated in the data base. In several cases, conversion factors based on process data (e.g., stack gas flow rate, production rate) were applied to the analytical results to estimate the condensible emission rates. Determination of organic and inorganic fractions of the back-half catch was typically based on gravimetric methods. However, analyses for other species such as trace metals were based on instrumental techniques.

2.3.2 Speciated Condensibles Data Analysis

The data collected on quantification of specific components within the condensible fraction were very limited, making it difficult to draw any conclusions. As shown in Table 2-5, the most common breakdown of the condensible fraction involved expressing the back-half catch as organic/inorganic. Results from tests conducted to characterize emissions of specific species such as cadmium, arsenic, lead are also included in the table. Additionally, trace metal analyses are reported for three source categories. However, the trace metal results are limited in that they are based on a single run during the tests.

From the limited data in Table 2-5, it appears that the air toxics species measured make up less than one percent of the total condensible emissions in most cases. The air toxics species measured include the following: arsenic, beryllium, cadmium, lead, chromium, mercury, and vanadium.

TABLE 2-4. CONTRIBUTION OF MAJOR STATIONARY POINT SOURCES TO PARTICULATE EMISSIONS

Source Category	Annual Particulate Emissions* (%)	% Condensibles**
Coal Combustion (utility)	27.2	56
Nonmetallic Minerals	7.1	12
Coal Mining	5.4	NA
Coal Combustion (industrial)	4.6	NA
Wood/Bark Combustion (industrial)	4.2	NA
Cement Manufacturing	4.1	32
Iron and Steel Plants	2.7	35
Charcoal Manufacturing	1.9	NA
Oil Combustion (industrial)	1.8	NA
Lime Manufacturing	1.7	20
Brick Manufacturing	1.5	35
Oil Combustion (utility)	1.5	NA
Petroleum Refining	1.3	39
Primary Aluminum	1.3	37
TOTAL	~65	

* Based on the 1985 NAPAP Emissions Inventory; as percent of the total U.S. stationary point source annual particulate emissions.

** As percent of annual particulate emissions for a given source category.

NA = not available.

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Asphalt Concrete	Recycle asphalt pavement	Knockout box and venturi scrubber	Total Organic Carbon	7.81 lb/hr 0.052 gr/dscf 0.041 lb/ton	3.45 lb/hr 0.023 gr/dscf 0.018 lb/ton	56	3
	Conventional	Knockout box and venturi scrubber	Total Organic Carbon	32.0 lb/hr 0.312 gr/dscf 0.139 lb/ton	11.0 lb/hr 0.107 gr/dscf 0,048 lb/ton	66	4
			Organics (ether-choloroform soluble fraction)	12.4 lb/hr 0.121 gr/dscf 0.0537 lb/ton	4.49 lb/hr 0.0445 gr/dscf 0.0191 lb/ton	64	
			Aluminum	5.0E-05 gr/dscf 2.2E-05 lb/ton	3.0E-05 gr/dscf 1.3E-05 lb/ton	40	
			Beryllium	7.2E-07 gr/dscf 2.8E-07 lb/ton	8.3E-07 gr/dscf 3.4E-07 lb/ton	(a)	
			Cadmium	4.3E-06 gr/dscf 1.8E-06 lb/ton	4.2E-06 gr/dscf 1.7E-06 lb/ton	2	
			Calcium	0.001 gr/dscf 0.0004 lb/ton	4.1E-04 gr/dscf 1.7E-04 lb/ton	59	
			Chromium	<1.2E-06 gr/dscf <4.9E-07 lb/ton	3.8E-06 gr/dscf 1.6E-06 lb/ton	(a)	
			Iron	4.0E-05 gr/dscf 2.0E-05 lb/ton	2.0E-05 gr/dscf 8.0E-06 lb/ton	50	
			Lead	<9.6E-05 gr/dscf <4.0E-05 lb/ton	NA	NA	
			Magnesium	4.0E-05 gr/dscf 2.0E-05 lb/ton	7.4E-05 gr/dscf 3.0E-05 lb/ton	(a)	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Asphalt Concrete (continued)	Conventional	Knockout box and venturi scrubber	Manganese	1.5E-06 gr/dscf 5.9E-07 lb/ton	1.6E-06 gr/dscf 6.7E-07 lb/ton	(a)	
			Mercury	<1.6E-05 gr/dscf <6.7E-06 lb/ton	1.8E-05 gr/dscf 7.4E-06 lb/ton	(a)	
			Nickel	<4.1E-06 gr/dscf <1.3E-06 lb/ton	<1.8E-06 gr/dscf <7.4E-07 lb/ton	56	
			Vanadium	<7.0E-05 gr/dscf <3.0E-05 lb/ton	3.6E-05 gr/dscf 1.5E-05 lb/ton	49	
			Zinc	1.0E-05 gr/dscf 4.4E-06 lb/ton	3.1E-06 gr/dscf 1.3E-06 lb/ton	69	
	Recycle	Knockout box and venturi scrubber	Total Organic Carbon	62.1 lb/hr 0.536 gr/dscf 0.261 lb/ton	12.4 lb/hr 0.105 gr/dscf 0.052 lb/ton	80	
			Organics (ether-chloroform soluble fraction)	14.4 lb/hr 0.123 gr/dscf 0.0605 lb/ton	4.53 lb/hr 0.0388 gr/dscf 0.0188 lb/ton	69	
			Aluminum	5.7E-05 gr/dscf 2.4E-05 lb/ton	<1.8E-05 gr/dscf <8.2E-06 lb/ton	68	
			Beryllium	1.2E-06 gr/dscf 4.9E-07 lb/ton	<1.8E-07 gr/dscf <8.3E-08 lb/ton	85	
			Cadmium	5.5E-06 gr/dscf 2.3E-06 lb/ton	<7.3E-07 gr/dscf <3.3E-07 lb/ton	87	
			Calcium	6.2E-04 gr/dscf 2.6E-04 lb/ton	1.9E-04 gr/dscf 8.7E-05 lb/ton	69	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Asphalt Concrete (continued)	Recycle	Knockout box and venturi scrubber	Chromium	5.2E-06 gr/dscf 2.2E-06 lb/ton	<3.6E-07 gr/dscf <1.7E-07 lb/ton	93	
			Iron	5.3E-05 gr/dscf 2.2E-05 lb/ton	2.5E-06 gr/dscf 1.2E-06 lb/ton	95	
			Lead	<9.4E-05 gr/dscf <4.0E-05 lb/ton	<3.1E-05 gr/dscf <1.4E-05 lb/ton	67	
			Magnesium	1.0E-04 gr/dscf 4.2E-05 lb/ton	<1.2E-05 gr/dscf <5.6E-06 lb/ton	88	
			Manganese	2.7E-06 gr/dscf 1.1E-06 lb/ton	<3.6E-07 gr/dscf <1.2E-07 lb/ton	87	
			Mercury	<3.3E-05 gr/dscf <1.4E-05 lb/ton	<1.1E-05 gr/dscf <4.9E-06 lb/ton	67	
			Nickel	2.3E-06 gr/dscf 9.8E-07 lb/ton	1.2E-06 gr/dscf 5.7E-07 lb/ton	48	
			Vanadium	<6.8E-05 gr/dscf <2.9E-05 lb/ton	<2.2E-05 gr/dscf <9.9E-06 lb/ton	68	
			Zinc	1.2E-05 gr/dscf 4.9E-06 lb/ton	2.0E-06 gr/dscf 9.0E-07 lb/ton	83	
Cadmium Sulfide Pigments	Belt dryer	Venturi scrubber	Cadmium	NA	2.8E-05 lb/hr 2.7E-06 gr/dscf 4.0E-04 lb/ton	NA	40
	Rotary calciner and vacuum pan dryer	Spray tower	Cadmium	NA	2.7E-05 lb/hr 1.3E-06 gr/dscf 1.8E-04 lb/ton	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Cadmium Sulfide Pigments (continued)	Materials handling and crushing	Fabric filter	Cadmium	NA	4.0E-06 lb/hr 1.8E-07 gr/dscf	NA	49
	Tray dryer	None	Cadmium	4.9E-06 lb/hr 4.4E-07 gr/dscf	NA	NA	
Cable Covering	Lead presses, lead pots, dross kettle	None	Lead	0.0001 lb/ton	NA	NA	8
Coke Ovens	Oven battery stack	Wet ESP	Organics (Benzene Soluble fraction)	3.7E-05 lb/hr	1.7E-05 lb/hr	54	11
	Oven battery stack	Maintenance	Sulfate	NA	3.25 lb/hr 0.02 gr/dscf	NA	84
			Organics (ether-chloroform soluble fraction)	NA	0.12 lb/hr 0.0007 gr/dscf	NA	
			Inorganics	NA	0.197 lb/hr 0.0011 gr/dscf	NA	
Iron and Steel Plants	Sintering	Cyclones and ESP	Organics (ether-chloroform soluble fraction)	NA	0.0042 gr/dscf 0.0265 lb/ton	NA	45
	Sintering	Cyclones, venturi scrubber, and demister	Organics (ether-chloroform soluble fraction)	47.6 lb/hr 0.031 gr/dscf	14.4 lb/hr 0.008 gr/dscf	70	47

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Iron and Steel Plants (continued)	BOF	Venturi scrubber	Sulfate	NA	8.1E-02 lb/hr 1.6E-04 gr/dscf 1.6E-04 lb/ton	NA	19
	BOF	ESP	Sulfate	NA	1.8E-01 lb/hr 9.8E-04 gr/dscf 7.6E-03 lb/ton	NA	18
	BOF	Venturi scrubber	Antimony	NA	<4.0E-07 lb/hr <4.0E-07 gr/dscf	NA	87
			Arsenic	NA	<6.0E-07 lb/hr <6.0E-07 gr/dscf	NA	
			Beryllium	NA	<6.1E-09 lb/hr <6.4E-09 gr/dscf	NA	
			Bismuth	NA	<6.1E-08 lb/hr <6.4E-08 gr/dscf	NA	
			Boron	NA	<6.0E-07 lb/hr <6.0E-07 gr/dscf	NA	
			Cadmium	NA	<4.0E-07 lb/hr <4.0E-07 gr/dscf	NA	
			Calcium	NA	<3.0E-06 lb/hr <3.0E-06 gr/dscf	NA	
			Chromium	NA	<6.1E-08 lb/hr <6.4E-08 gr/dscf	NA	
			Cobalt	NA	<6.1E-08 lb/hr <6.4E-08 gr/dscf	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Iron and Steel Plants (continued)	BOF	Venturi scrubber	Copper	NA	<1.2E-06 lb/hr <1.3E-06 gr/dscf	NA	
			Iron	NA	<4.0E-07 lb/hr <4.0E-07 gr/dscf	NA	
			Lead	NA	<4.0E-07 lb/hr <4.0E-07 gr/dscf	NA	
			Lithium	NA	<1.8E-06 lb/hr <1.9E-06 gr/dscf	NA	
			Magnesium	NA	<6.0E-07 lb/hr <6.0E-07 gr/dscf	NA	
			Manganese	NA	<6.1E-08 lb/hr <6.4E-08 gr/dscf	NA	
			Molybdenum	NA	<6.1E-08 lb/hr <6.4E-08 gr/dscf	NA	
			Nickel	NA	<2.0E-07 lb/hr <3.0E-07 gr/dscf	NA	
			Potassium	NA	<1.8E-06 lb/hr <1.9E-06 gr/dscf	NA	
			Silicon	NA	<6.1E-06 lb/hr <6.0E-06 gr/dscf	NA	
			Silver	NA	<6.1E-09 lb/hr <6.4E-09 gr/dscf	NA	
			Sodium	NA	<3.1E-06 lb/hr <3.0E-06 gr/dscf	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Iron and Steel Plants (continued)	BOF	Venturi scrubber	Strontium	NA	<4.0E-07 lb/hr <4.0E-07 gr/dscf	NA	
			Tin	NA	<4.0E-07 lb/hr <4.0E-07 gr/dscf	NA	
			Titanium	NA	<6.1E-08 lb/hr <6.4E-08 gr/dscf	NA	
			Vanadium	NA	<6.1E-08 lb/hr <6.4E-08 gr/dscf	NA	
			Zinc	NA	<1.2E-06 lb/hr <1.3E-06 gr/dscf	NA	
			Zirconium	NA	<6.1E-08 lb/hr <6.4E-08 gr/dscf	NA	
Lead Acid Battery	Casting furnace	None	Lead	2.0E-05 gr/dscf 6.0E-04 lb/ton	NA	NA	25
	Stacking, element burning, and casing	Fabric filter	Lead	0.005 lb/hr 4.0E-05 gr/dscf	0.0027 lb/hr 2.5E-05 gr/dscf	46	
	Paste mixer	Wet scrubber	Lead	3.0E-05 gr/dscf 3.3E-04 lb/ton	5.0E-05 gr/dscf 4.0E-04 lb/ton	(a)	
Lightweight Aggregate	Rotary kiln	Wet scrubber	Organics (ether-chloroform soluble fraction)	NA	0.13 lb/hr 0.0007 gr/dscf	NA	27
			Inorganics	NA	2.4 lb/hr 0.135 gr/dscf	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Lightweight Aggregrate (continued)	Clinker cooler	Cyclone and fabric filter	Organics (ether-chloroform soluble fraction)	0.05 lb/hr 0.0004 gr/dscf	1.77 lb/hr 0.001 gr/dscf	(a)	
			Inorganics	0.04 lb/hr 0.0003 gr/dscf	0.144 lb/hr 0.0008 gr/dscf	(a)	
	Rotary kiln	Wet scrubber	Organics (ether-chloroform soluble fraction)	6.9 lb/hr 0.021 gr/dscf	0.23 lb/hr 0.0006 gr/dscf	97	28
			Inorganics	54.4 lb/hr 0.159 gr/dscf	5.5 lb/hr 0.015 gr/dscf	90	
	Clinker cooler	Settling chamber	Organics (ether-chloroform soluble fraction)	NA	0.016 lb/hr 0.0003 gr/dscf	NA	
			Inorganics	NA	0.62 lb/hr 0.01 gr/dscf		
	Rotary kiln	Wet scrubber	Organics (ether-chloroform soluble fraction)	1.6 lb/hr 0.0075 gr/dscf	0.8 lb/hr 0.0019 gr/dscf	50	29
			Inorganics	2.9 lb/hr 0.0139 gr/dscf	3.1 lb/hr 0.0074 gr/dscf	(a)	
	Clinker cooler	Settling chamber	Organics (ether-chloroform soluble fraction)	NA	0.26 lb/hr 0.001 gr/dscf	NA	
			Inorganics		0.42 lb/hr 0.0017 gr/dscf		

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Petroleum Refining	FCCU	Venturi scrubber	Sulfate	8.3E-03 gr/dscf	1.3E-03 gr/dscf	84	53
	FCCU	ESP	Nitrate	NA	10.6 lb/hr	NA	104
			Ammonia	NA	11.2 lb/hr	NA	
Plywood Manufacturing	Veneer dryer and wood-fired boiler	None	Organics	31.0 lb/hr 0.15 gr/dscf 1.1 lb/1000ft2	NA	NA	36
	Veneer dryers	Cyclones and wet scrubber	Organics	16.6 lb/hr 0.15 gr/dscf 0.47 lb/1000ft2	11.7 lb/hr 0.081 gr/dscf 0.33 lb/1000ft2	30	37
Primary Copper	Converter, electric furnace, and fluidized bed roaster	Spray chamber and fabric filter	Arsenic	12.7 lb/hr 0.0093 gr/dscf	2.2 lb/hr 0.0016 gr/dscf	83	82
	Reverberatory furnace and multi-hearth roaster	Spray chamber and ESP	Arsenic	19.2 lb/hr 0.0128 gr/dscf	1.0 lb/hr 0.0008 gr/dscf	95	83
Primary Lead	Blast furnace	Spray chamber and fabric filter	Lead	NA	0.036 lb/hr 3.1E-05 gr/dscf	NA	38
	Blast furnace	Spray chamber and fabric filter	Lead	NA	3.0E-05 gr/dscf 0.017 lb/ton	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Secondary Lead	Blast furnace	Afterburner, settling chamber, and fabric filter	Lead	0.022 lb/hr 0.02 lb/ton	0.006 lb/hr 0.0059 lb/ton	73	44
	Refining kettles and slag tap	Venturi scrubber and wet cyclone	Lead	0.006 lb/hr	0.002 lb/hr	67	
	Blast furnace	Afterburner, cyclones, and fabric filter	Aluminum	NA	2.2E-06 gr/dscf 1.3E-04 lb/ton	NA	41
			Antimony	NA	<2.2E-06 gr/dscf <1.3E-04 lb/ton	NA	
			Arsenic	NA	<4.4E-06 gr/dscf <2.9E-04 lb/ton	NA	
			Barium	NA	<3.5E-07 gr/dscf <2.2E-05 lb/ton	NA	
			Beryllium	NA	<3.7E-08 gr/dscf <2.2E-06 lb/ton	NA	
			Boron	NA	1.4E-06 gr/dscf 8.3E-05 lb/ton	NA	
			Cadmium	NA	<2.2E-06 gr/dscf <1.3E-04 lb/ton	NA	
			Calcium	NA	1.2E-05 gr/dscf 6.8E-04 lb/ton	NA	
			Chromium	NA	<3.5E-06 gr/dscf <1.9E-04 lb/ton	NA	
			Cobalt	NA	1.1E-05 gr/dscf 5.6E-04 lb/ton	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Secondary Lead (continued)	Blast furnace	Afterburner, cyclones, and fabric filter	Copper	NA	2.2E-07 gr/dscf 1.4E-05 lb/ton	NA	
			Iron	NA	1.1E-05 gr/dscf 5.8E-04 lb/ton	NA	
			Lead	NA	<2.7E-06 gr/dscf <1.6E-04 lb/ton	NA	
			Lithium	NA	<5.9E-06 gr/dscf <3.8E-04 lb/ton	NA	
			Magnesium	NA	7.1E-07 gr/dscf 4.9E-05 lb/ton	NA	
			Manganese	NA	<1.8E-07 gr/dscf <1.1E-05 lb/ton	NA	
			Mercury	NA	<3.7E-08 gr/dscf <2.2E-06 lb/ton	NA	
			Nickel	NA	<1.9E-06 gr/dscf <1.0E-04 lb/ton	NA	
			Potassium	NA	<1.1E-05 gr/dscf <1.2E-03 lb/ton	NA	
			Strontium	NA	<1.5E-06 gr/dscf <8.8E-05 lb/ton	NA	
			Silver	NA	<3.7E-08 gr/dscf <2.2E-06 lb/ton	NA	
			Silicon	NA	2.0E-05 gr/dscf 1.1E-03 lb/ton	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Secondary Lead (continued)	Blast furnace	Afterburner, cyclones, and fabric filter	Sodium	NA	<4.3E-06 gr/dscf <2.5E-04 lb/ton	NA	
			Vanadium	NA	<3.7E-06 gr/dscf <2.2E-05 lb/ton	NA	
			Zinc	NA	<4.3E-06 gr/dscf <2.5E-04 lb/ton	NA	
	Blast furnace and refining kettles	Afterburner, fabric filter, venturi scrubber, and demister	Total Acid	NA	1.0E-03 gr/dscf 8.1E-02 lb/ton	NA	43
			Aluminum	NA	<1.7E-06 gr/dscf <1.4E-04 lb/ton	NA	
			Ammonium	NA	2.3E-03 gr/dscf 2.1E-01 lb/ton	NA	
			Antimony	NA	<2.9E-06 gr/dscf <2.4E-04 lb/ton	NA	
			Arsenic	NA	<3.6E-06 gr/dscf <3.0E-04 lb/ton	NA	
			Barium	NA	<5.7E-07 gr/dscf <4.7E-05 lb/ton	NA	
			Beryllium	NA	<5.7E-08 gr/dscf <4.7E-06 lb/ton	NA	
			Boron	NA	8.5E-07 gr/dscf 7.3E-05 lb/ton	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Secondary Lead (continued)	Blast furnace and refining kettles	Afterburner, fabric filter, venturi scrubber, and demister	Cadmium	NA	<3.6E-06 gr/dscf <3.0E-04 lb/ton	NA	
			Calcium	NA	1.6E-05 gr/dscf 1.3E-03 lb/ton	NA	
			Chlorine	NA	1.8E-04 gr/dscf 1.6E-02 lb/ton	NA	
			Chromium	NA	<1.4E-06 gr/dscf <1.1E-04 lb/ton	NA	
			Cobalt	NA	<1.3E-06 gr/dscf <1.0E-04 lb/ton	NA	
			Copper	NA	<3.6E-07 gr/dscf <3.0E-05 lb/ton	NA	
			Iron	NA	4.9E-06 gr/dscf 3.9E-04 lb/ton	NA	
			Lead	NA	<2.9E-06 gr/dscf <2.4E-04 lb/ton	NA	
			Lithium	NA	<5.7E-06 gr/dscf <4.7E-04 lb/ton	NA	
			Magnesium	NA	2.4E-06 gr/dscf 2.0E-04 lb/ton	NA	
			Manganese	NA	<2.7E-07 gr/dscf <2.3E-05 lb/ton	NA	
			Mercury	NA	5.7E-08 gr/dscf 4.7E-06 lb/ton	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Secondary Lead (continued)	Blast furnace and refining kettles	Afterburner, fabric filter, venturi scrubber, and demister	NO3	NA	1.4E-03 gr/dscf 1.3E-01 lb/ton	NA	
			Nickel	NA	<1.4E-06 gr/dscf <1.1E-04 lb/ton	NA	
			Potassium	NA	<1.4E-05 gr/dscf <1.1E-03 lb/ton	NA	
			SO3	NA	1.5E-02 gr/dscf 1.2E+00 lb/ton	NA	
			Strontium	NA	<2.0E-06 gr/dscf <1.7E-04 lb/ton	NA	
			Silicon	NA	7.1E-06 gr/dscf 6.0E-04 lb/ton	NA	
			Silver	NA	<5.7E-08 gr/dscf <4.7E-06 lb/ton	NA	
			Sodium	NA	<5.7E-06 gr/dscf <4.7E-04 lb/ton	NA	
			Sulfate	NA	1.4E-02 gr/dscf 1.2E+00 lb/ton	NA	
			Tin	NA	3.6E-06 gr/dscf 3.0E-04 lb/ton	NA	
			Vanadium	NA	<5.7E-07 gr/dscf <4.7E-05 lb/ton	NA	

(continued)

TABLE 2-5. SPECIATED CONDENSIBLES DATA BASE

Source Category	Process Type	Control Type	Condensible Species	Uncontrolled Emissions	Controlled Emissions	Control Efficiency (%)	Reference Number
Secondary Lead (continued)	Blast furnace and refining kettles	Afterburner, fabric filter, venturi scrubber, and demister	Zinc	NA	<5.7E-06 gr/dscf <4.7E-04 lb/ton	NA	
Sewage Sludge Incinerator	Fluidized bed incinerator	Venturi scrubber and demister	Lead	NA	9.0E-07 gr/dscf 9.0E-04 lb/day	NA	48

NA = Not available

(a) Due to reasons unclear from the test reports, the back-half catch at the outlet was greater than that at the inlet.

SECTION 3

CONTROLLABILITY OF CONDENSIBLE EMISSIONS

This section discusses the effectiveness of control devices in controlling condensible emissions based on the data collected in this study. It also includes a brief discussion on possible methods of optimizing controls for improved performance.

3.1 CONDENSIBLE EMISSIONS CONTROL DATA

In evaluating the effectiveneness of condensible emissions controls, emphasis is placed on control device efficiency as well as controlled emissions levels. Control efficiency data are discussed in Section 3.1.1, followed by a discussion of controlled emissions levels in Section 3.1.2.

3.1.1 Condensible Emissions Control Efficiency

Table 3-1 presents a summary of the condensible emissions control efficiency data collected in this study. This information was extracted from the Condensible Emissions Data Base presented in Table 2-1 and covers over 40 test results. The control efficiency was calculated from the back-half catch data collected before and after the control device. The efficiency data represent performance of the following particulate matter control devices:

- venturi scrubber
- wet scrubber (other)
- fabric filter
- electrostatic precipitator (ESP)
- wet ESP

In Table 3-1, efficiency of the control devices for reducing total particulate emissions range from about 30 to over 99 percent. Control efficiency for condensible emissions range from less than zero (i.e., the back-half catch at the outlet was greater than the back-half catch at the inlet) to about 90 percent. In almost all cases, the control efficiency for condensible emissions was less than that for

TABLE 3-1. CONDENSIBLE EMISSIONS CONTROL EFFICIENCY

Source Category	Process Type	Control Type	Uncontrolled Emissions			Controlled Emissions			Efficiency (%)	
			Total Particulate	Condensible	% Condensible	Total Particulate	Condensible	% Condensible	Total Particulate	Condensible
Asphalt Concrete	Conventional	Knockout box and venturi scrubber	3.41 lb/ton 7.53 gr/dscf	0.139 lb/ton 0.312 gr/dscf	4	0.073 lb/ton 0.164 gr/dscf	0.048 lb/ton 0.107 gr/dscf	66	98	66
	Recycle asphalt pavement	Knockout box and venturi scrubber	2.2 lb/ton 4.33 gr/dscf	0.261 lb/ton 0.536 gr/dscf	12	0.065 lb/ton 0.13 gr/dscf	0.052 lb/ton 0.105 gr/dscf	80	97	80
	Recycle asphalt pavement	Knockout box and venturi scrubber	4.41 lb/ton 5.71 gr/dscf	0.041 lb/ton 0.052 gr/dscf	1	0.115 lb/ton 0.153 gr/dscf	0.018 lb/ton 0.023 gr/dscf	16	97	56
Carbon Black	Process line vent (via off-gas boiler)	Fabric filter	0.0056 lb/lb	0.0024 lb/lb	43	0.0016 lb/lb	0.0007 lb/lb	44	71	71
Coke Oven	Oven battery stack	Wet ESP	0.47 lb/ton 0.0135 gr/dscf	0.18 lb/ton 0.005 gr/dscf	38	0.08 lb/ton 0.002 gr/dscf	0.03 lb/ton 0.0008 gr/dscf	38	83	83
	Oven battery stack	Fabric Filter	25.88 lb/hr 0.085 gr/dscf	2.21 lb/hr 0.007 gr/dscf	9	8.6 lb/hr 0.027 gr/dscf	1.71 lb/hr 0.005 gr/dscf	20	67	23
Ferroalloy	Ferro-chrome electric arc furnace	ESP	1312 lb/hr 1.87 gr/dscf	19 lb/hr 0.0271 gr/dscf	1	24.1 lb/hr 0.0183 gr/dscf	3.6 lb/hr 0.0027 gr/dscf	15	98	81
	Silicon metal electric arc furnace	Fabric filter	2360 lb/hr 0.706 gr/dscf	151 lb/hr 0.045 gr/dscf	6	27.65 lb/hr 0.0053 gr/dscf	12.13 lb/hr 0.0023 gr/dscf	44	99	92
	Silico-manganese electric arc furnace	Venturi scrubber and demister	230 lb/hr 1.65 gr/dscf	3.6 lb/hr 0.0259 gr/dscf	2	14.21 lb/hr 0.0856 gr/dscf	1.42 lb/hr 0.0085 gr/dscf	10	94	60
Fertilizer (Phosphate)	Dryer kiln and cooler	Fabric filter	133.2 lb/ton 14.78 gr/dscf	0.6 lb/ton 0.06 gr/dscf	<1	0.346 lb/ton 0.05 gr/dscf	0.302 lb/ton 0.043 gr/dscf	87	>99	50
	Ammoniator	Venturi scrubber and demister	4.67 lb/ton 3.14 gr/dscf	0.1 lb/ton 0.07 gr/dscf	2	0.24 lb/ton 0.123 gr/dscf	0.12 lb/ton 0.062 gr/dscf	50	95	(a)

(continued)

TABLE 3-1. CONDENSIBLE EMISSIONS CONTROL EFFICIENCY

Source Category	Process Type	Control Type	Uncontrolled Emissions			Controlled Emissions			Efficiency (%)	
			Total Particulate	Condensible	% Condensible	Total Particulate	Condensible	% Condensible	Total Particulate	Condensible
Grey Iron Foundry	Electric Arc Furnace (EAF)	Fabric filter	195 lb/hr 0.33 gr/dscf	9.9 lb/hr 0.0173 gr/dscf	5	3.86 lb/hr 0.0058 gr/dscf	1.27 lb/hr 0.0019 gr/dscf	33	98	87
Incinerators	Municipal Solid Waste (MSW) fired	ESP	393 lb/hr 1.09 gr/dscf	21 lb/hr 0.06 gr/dscf	5	19 lb/hr 0.005 gr/dscf	4.7 lb/hr 0.01 gr/dscf	25	95	78
	MSW and industrial SW-fired	ESP	460 lb/hr 1.473 gr/dscf	3.75 lb/hr 0.012 gr/dscf	1	22.4 lb/hr 0.073 gr/dscf	1.53 lb/hr 0.005 gr/dscf	7	95	59
	MSW and ISW fired	ESP	557 lb/hr 1.744 gr/dscf	3.52 lb/hr 0.011 gr/dscf	<1	18.5 lb/hr 0.056 gr/dscf	2.31 lb/hr 0.007 gr/dscf	12	97	34
Iron and Steel Plants	EAF	Fabric filter	0.0537 gr/dscf	0.0019 gr/dscf	4	0.0027 gr/dscf	0.0013 gr/dscf	48	95	32
	Sintering	Cyclones, venturi scrubber, and demister	619 lb/hr 0.403 gr/dscf	99 lb/hr 0.065 gr/dscf	16	72.3 lb/hr 0.042 gr/dscf	40.2 lb/hr 0.023 gr/dscf	56	88	59
Kraft Pulp Mills	Smelt-dissolving tank	Wet packed scrubber	1.79 lb/ton 0.492 gr/dscf	0.09 lb/ton 0.025 gr/dscf	5	0.285 lb/ton 0.0708 gr/dscf	0.018 lb/ton 0.0047 gr/dscf	6	84	80
Lead Acid Battery	Stacking, element burning, and casing	Fabric filter	1.469 lb/hr 0.0149 gr/dscf	0.713 lb/hr 0.0072 gr/dscf	49	1.029 lb/hr 0.0096 gr/dscf	0.543 lb/hr 0.0051 gr/dscf	53	30	24
	Paste mixer	Wet scrubber	0.545 lb/ton 0.0614 gr/dscf	0.021 lb/ton 0.0027 gr/dscf	4	0.124 lb/ton 0.0142 gr/dscf	0.037 lb/ton 0.0043 gr/dscf	30	77	(a)
Lead Oxide Plant	Calcining furnace	Cyclones and fabric filter	86.7 lb/hr 11.64 gr/dscf	0.1 lb/hr 0.014 gr/dscf	<1	0.084 lb/hr 0.0121 gr/dscf	0.017 lb/hr 0.0021 gr/dscf	20	>99	83
	Materials handling and grinding	Fabric filter	49.32 lb/hr 1.0893 gr/dscf	0.03 lb/hr 0.0007 gr/dscf	<1	0.054 lb/hr 0.001 gr/dscf	0.022 lb/hr 0.0005 gr/dscf	41	>99	27

(continued)

TABLE 3-1. CONDENSIBLE EMISSIONS CONTROL EFFICIENCY

Source Category	Process Type	Control Type	Uncontrolled Emissions			Controlled Emissions			Efficiency (%)	
			Total Particulate	Condensible	% Condensible	Total Particulate	Condensible	% Condensible	Total Particulate	Condensible
Lightweight Aggregate	Clinker cooler	Cyclone and fabric filter	12.09 lb/hr 0.0825 gr/dscf	0.09 lb/hr 0.0007 gr/dscf	1	2.36 lb/hr 0.0047 gr/dscf	1.91 lb/hr 0.0018 gr/dscf	81	81	(a)
	Rotary kiln	Wet scrubber	9190 lb/hr 26.28 gr/dscf	61.3 lb/hr 0.18 gr/dscf	1	21.13 lb/hr 0.0586 gr/dscf	5.73 lb/hr 0.0156 gr/dscf	27	>99	91
	Rotary kiln	Wet scrubber	3699 lb/hr 17.421 gr/dscf	4.5 lb/hr 0.0214 gr/dscf	<1	123.3 lb/hr 0.29 gr/dscf	3.9 lb/hr 0.0093 gr/dscf	3	97	13
Petroleum Refining	FCCU	Venturi scrubbers	0.0213 gr/dscf	0.0083 gr/dscf	39	0.0129 gr/dscf	0.0013 gr/dscf	10	61	84
Phosphate Rock Processing	Fluid bed dryer	Cyclone and wet cyclonic scrubber	2.81 lb/ton 1.677 gr/dscf	0.069 lb/ton 0.038 gr/dscf	2	0.102 lb/ton 0.058 gr/dscf	0.026 lb/ton 0.015 gr/dscf	25	96	62
	Roller mill and ball mill	Cyclones and fabric filter	201 lb/hr 3.21 gr/dscf	0.15 lb/hr 0.0024 gr/dscf	<1	0.146 lb/hr 0.003 gr/dscf	0.042 lb/hr 0.001 gr/dscf	29	>99	72
Plywood Manufacturing	Veneer dryers	Cyclones and wet scrubber	0.525 lb/1000 0.164 gr/dscf	0.472 lb/1000 0.148 gr/dscf	90	0.43 lb/1000 0.103 gr/dscf	0.338 lb/1000 0.081 gr/dscf	79	18	28
Primary Aluminum	Anode prebake	Fabric filter	99.3 lb/ton 0.1401 gr/dscf	1.3 lb/ton 0.0019 gr/dscf	1	1.8 lb/ton 0.0022 gr/dscf	0.57 lb/ton 0.0007 gr/dscf	32	98	56
	Horizontal Soderburg	ESP	81.8 lb/ton 0.0875 gr/dscf	15.2 lb/ton 0.0163 gr/dscf	19	5.95 lb/ton 0.0064 gr/dscf	2.99 lb/ton 0.0032 gr/dscf	50	93	80
Primary Copper	Reverberatory furnace	Settling chamber and ESP	398.5 lb/hr 0.597 gr/dscf	103.5 lb/hr 0.155 gr/dscf	26	138.8 lb/hr 0.157 gr/dscf	61.7 lb/hr 0.07 gr/dscf	44	65	69
	Converter, electric furnace, and fluidized bed roaster	Spray chamber and fabric filter	8678 lb/hr 6.264 gr/dscf	122.2 lb/hr 0.088 gr/dscf	1	111.3 lb/hr 0.078 gr/dscf	82.5 lb/hr 0.058 gr/dscf	74	99	33

(continued)

TABLE 3-1. CONDENSIBLE EMISSIONS CONTROL EFFICIENCY

Source Category	Process Type	Control Type	Uncontrolled Emissions			Controlled Emissions			Efficiency (%)	
			Total Particulate	Condensible	% Condensible	Total Particulate	Condensible	% Condensible	Total Particulate	Condensible
Primary Copper (continued)	Reverberatory furnace and multi-hearth roaster	Spray chamber and ESP	2415 lb/hr 2.207 gr/dscf	51.4 lb/hr 0.047 gr/dscf	2	104.9 lb/hr 0.055 gr/dscf	22.9 lb/hr 0.012 gr/dscf	22	96	55
Primary Lead	Blast furnace	Spray chamber and fabric filter	174 lb/ton 3.16 gr/dscf	2 lb/ton 0.05 gr/dscf	1	2.5 lb/ton 0.0275 gr/dscf	1.2 lb/ton 0.0133 gr/dscf	48	99	40
Residential Woodheaters	Catalytic	Catalyst	NA	45.3 lb/ 1000 lb wood	NA	NA	3.1 lb/ 1000 lb wood	NA	NA	93 - 94
	Non-catalytic	Design modification	NA	45.3 lb/ 1000 lb wood	NA	NA	5.7 lb/ 1000 lb wood	NA	NA	87 - 89
	Pellet-fired	Controlled air & fuel delivery	NA	45.3 lb/ 1000 lb wood	NA	NA	5.7 lb/ 1000 lb wood	NA	NA	87 - 89
Secondary Lead	Blast furnace	Afterburner, settling chamber, fabric filter	1506 lb/hr 3610 lb/ton	15.72 lb/hr 400 lb/ton	1	13.67 lb/hr 3.3 lb/ton	12.54 lb/hr 3 lb/ton	92	99	20
	Refining kettles and slag tap	Venturi scrubber and wet cyclone	34.7 lb/hr	1.67 lb/hr	5	5.53 lb/hr	0.95 lb/hr	17	84	43
Soap & Detergent Manufacturing	Spray tower	Cyclones and fabric filter	273 lb/hr 1.09 gr/dscf	6 lb/hr 0.02 gr/dscf	2	1.88 lb/hr 0.0087 gr/dscf	1.59 lb/hr 0.0074 gr/dscf	85	99	74

(a) Due to reasons unclear from the test reports, the back-half catch at the outlet was greater than that at the inlet.

total particulate emissions. As indicated earlier, a large fraction of condensible particulate matter falls in the very fine size range. The decreased efficiency for condensible emissions is likely due to the increased difficulty of collecting very fine particles.

Since condensible emissions are collected at a lower efficiency than total particulate, one would expect to see an enrichment in the condensible fraction of the reported controlled particulate emissions. This behavior is exhibited in Table 3-1 in all but six cases. The fraction of condensible particulates in the total catch collected after the control device shows a significant increase in most cases.

3.1.2 Control Device-Specific Performance

Table 3-2 summarizes the control efficiency data for condensible emissions by control device type and identifies the source category and process type. For venturi scrubbers, the control efficiency ranges from less than zero for a phosphate fertilizer plant to 84 percent for a fluid catalytic cracking unit. The range for wet scrubbers is from less than zero for a lead acid battery manufacturing facility to 91 percent for a lightweight aggregate plant. The control efficiency range for ESP's is from 34 to 81 percent, for an incinerator and a ferroalloy manufacturing plant, respectively. The widest range of performance is for fabric filters, from less than zero at a lightweight aggregate plant to 92 percent at a ferroalloy plant.

The increase in condensible emissions after the control device, as indicated by the negative control efficiencies, may result from a number of factors. The negative efficiency for the venturi scrubber was probably due to the entrainment of scrubber solution containing soluble species. For the wet scrubber and fabric filter, the increased condensible emissions may be explained by changes in waste gas conditions such as a temperature drop followed by increased condensation across the control device.

The wide variation in condensible emissions control efficiencies for a given control device type is an indication of the differences in processes and operating conditions involved. Within a given source category and process type, however, a greater degree of consistency in control efficiency is observed for a specific control device. This is indicated in Table 3-3 for a number of categories.

It is difficult to determine which devices are more effective in controlling condensible emissions from similar sources. This would depend on the specific process characteristics of the source in question. The limited control efficiency data where a comparison can be made are presented in Table 3-4.

TABLE 3-2. CONTROL DEVICE-SPECIFIC PERFORMANCE

Control Device	Source Category	Process Type	Condensible Emissions Control Efficiency (%)
Venturi Scrubber			
	Asphalt concrete	Conventional	66
		Recycle asphalt pavement	80
		Recycle asphalt pavement	56
	Ferroalloy	Silico-manganese electric arc furnace	60
	Fertilizer (phosphate)	Ammoniator	<0
	Iron and steel	Sintering	59
	Petroleum refining	Fluid catalytic cracking unit	84
	Secondary lead	Refining kettles and slag tap	43
Wet Scrubber			
	Kraft pulp	Smelt disolving Tank	80
	Lead acid battery	Paste mixer	(a)
	Lightweight aggregate	Rotary kiln	91
		Rotary kiln	13
	Phosphate rock	Fluid bed dryer	62
	Plywood manufacturing	Veneer dryer	28
ESP			
	Ferroalloy	Ferrochrome electric arc furnace	81
	Incinerator	MSW-fired	78
		MSW and ISW-fired	59
		MSW and ISW-fired	34
	Primary aluminum	Horizontal Soderburg	80
	Primary copper	Reverberatory furnace	69
		Reverberatory furnace and roaster	55
Wet ESP			
	Coke ovens	Oven battery stack	83

(continued)

TABLE 3-2. CONTROL DEVICE-SPECIFIC PERFORMANCE
(Continued)

Control Device	Source Category	Process Type	Condensible Emissions Control Efficiency (%)
Fabric Filter			
	Carbon black	Process line vent	70
	Coke oven	Oven battery stack	23
	Ferroalloy	Silicon metal electric arc furnace	92
	Fertilizer	Dryer kiln and cooler	50
	Grey iron foundry	Electric arc furnace	87
	Iron and steel	Electric arc furnace	32
	Lead acid battery	Stacking, element burning, and casing	24
	Lead oxide	Calcining furnace	83
		Materials handling and grinding	27
	Lightweight aggregate	Clinker cooler	(a)
	Phosphate rock	Roller mill and ball mill	72
	Primary aluminum	Anode prebake	56
	Primary copper	Converter, furnace, and roaster	33
	Primary lead	Blast furnace	40
	Secondary lead	Blast furnace	20
	Soap and detergent	Spray tower	74

(a) Due to reasons unclear from the test reports, the back-half catch at the outlet was greater than that at the inlet.

3.1.3 Controlled Condensible Emissions

In several of the test reports included in this study, emissions data were collected only at the control device outlet. Therefore, no control efficiency calculations were made for these tests. As Table 3-1 shows, the emission rates are expressed in different units (lb/ton, lb/hr, etc.) depending on the available information. This makes it difficult to identify possible trends in the data with respect to control device type or source category/process type.

Table 3-5 summarizes controlled condensible emissions levels for a number of source categories where similar emission sources are controlled by the same type of control device. For a given source category, the emission levels for wet scrubbers, settling chambers, venturi scrubbers, and fabric filters vary within a factor of 10-11. For ESP's, the variation is greater than two orders of magnitude. As indicated earlier, these variations reflect the differences in the specific source characteristics.

Table 3-6 presents performance of different control devices for similar process sources in a given emission category. Higher control efficiencies are not always associated with lower outlet emissions levels. For example, controlled emissions from an electric arc furnace were 1.4 lb/hr, equivalent to 60 percent control with a venturi scrubber. For the same type of source, the emissions after a 92 percent controlled fabric filter were 12.4 lb/hr. Similar behavior is observed for the primary copper and asphalt concrete (Table 3-5) categories.

Due to the effect of lower temperatures on condensation, wet control technologies such as wet scrubbers, venturi scrubbers, and wet ESP's would be expected to be more effective in collecting condensible emissions. Based on the data shown in Table 3-6, it is difficult to distinguish between the performance of ESP's and fabric filters. However, in almost all cases, wet scrubbers and venturi scrubbers are associated with lower condensible emission levels than ESP's or fabric filters.

3.2 SPECIATED CONDENSIBLE EMISSIONS CONTROL DATA

Data collected in this study on the controllability of specific components within the condensible fraction were very limited. As Table 2-5 shows, the most common breakdown of condensible emissions involved expressing the back-half catch in terms of the organic and inorganic fractions. Results from tests conducted to characterize emissions of specific species such as lead, arsenic, sulfuric acid, and cadmium are also included. In addition, trace metal analysis of the back-half catch is reported for three source categories. These analyses are based on a single run during the tests.

Any organic compound that is emitted as a vapor and is normally a solid at ambient conditions will condense once the critical temperature and pressure are reached for that compound. Higher

TABLE 3-3. VARIATION IN CONTROL DEVICE EFFECTIVENESS FOR SELECTED CATEGORIES

Source Category	Process Type	Control Type	Condensible Emissions Control Efficiency (%)
Asphalt concrete	Conventional	Venturi scrubber	66
	Recycle asphalt pavement	Venturi scrubber	80
	Recycle asphalt pavement	Venturi scrubber	56
Incinerator	MSW and ISW-fired	ESP	59
	MSW and ISW-fired	ESP	34
Lightweight aggregate	Rotary kiln	Wet scrubber	91
	Rotary kiln	Wet scrubber	13
Primary copper	Reverberatory furnace	ESP	69
	Reverberatory furnace	ESP	55

TABLE 3-4. COMPARISON OF CONTROL DEVICE EFFECTIVENESS FOR SELECTED CATEGORIES

Source Category	Process Type	Control Type	Condensible Emissions Control Efficiency (%)
Coke ovens	Oven battery	Wet ESP	83
	Oven battery	Fabric filter	23
Ferroalloy	Electric arc furnace	ESP	81
	Electric arc furnace	Fabric filter	92
	Electric arc furnace	Venturi scrubber	60
Primary copper	Reverberatory furnace	ESP	69
	Converter, furnace, roaster	Fabric filter	33
	Furnace and roaster	ESP	55

TABLE 3-5. VARIATION IN CONTROLLED CONDENSIBLE EMISSIONS FOR SELECTED CATEGORIES

Source Category	Process Type	Control Type	Controlled Condensible Emissions	Condensible Emissions Control Efficiency (%)
Asphalt concrete	Conventional	Venturi scrubber	.05 lb/ton	66
	Recycle asphalt	Venturi scrubber	.05 lb/ton	80
	Recycle asphalt	Venturi scrubber	.02 lb/ton	56
Coal prep. plants	Fluid bed dryer	Venturi scrubber	1.8 lb/hr	
	Thermal dryer	Venturi scrubber	13.1 lb/hr	
Glass manufacturing	Melting furnace	Fabric filter	20.87 lb/hr	
	Melting furnace	Fabric filter	2.64 lb/hr	
	Melting furnace	Scrubber	.04 lb/hr	
	Melting furnace	Scrubber	.29 lb/hr	
Grain processing	Grain elevator	Fabric filter	.20 lb/hr	
	Grain elevator	Fabric filter	.04 lb/hr	
Incinerator	MSW and ISW-fired	ESP	1.53 lb/hr	59
	MSW and ISW-fired	ESP	2.31 lb/hr	34
Iron and steel	BOF	Venturi scrubber	.0212 lb/ton	
	BOF	Venturi scrubber	.0035 lb/ton	
	BOF	Venturi scrubber	.0019 lb/ton	
Kraft-pulp	Smelt dissolving tank	Wet scrubber	1.95 lb/hr	
	Smelt dissolving tank	Wet scrubber	1.5 lb/hr	
	Smelt dissolving tank	Wet scrubber (packed)	.018 lb/ton	80
	Smelt dissolving tank	Wet scrubber (packed)	.021 lb/ton	
Lead oxide	Materials handling	Fabric filter	.08 lb/hr	
	Materials handling	Fabric filter	.02 lb/hr	
Lightweight aggregate	Clinker cooler	Settling chamber	.64 lb/hr	
	Clinker cooler	Settling chamber	.66 lb/hr	
	Rotary kiln	Wet scrubber	5.7 lb/hr	
	Rotary kiln	Wet scrubber	3.9 lb/hr	13
Petroleum refining	FCCU	ESP	116 lb/hr	
	FCCU	ESP	85 lb/hr	
	FCCU	ESP	3.21 lb/hr	
	FCCU	ESP	13.66 lb/hr	
	FCCU	ESP	16.06 lb/hr	
	FCCU	ESP	14.61 lb/hr	
	FCCU	ESP	1.53 lb/hr	
	FCCU	ESP	11.54 lb/hr	
	FCCU	ESP	.52 lb/hr	
	FCCU	ESP	1.24 lb/hr	
	FCCU	ESP	2.64 lb/hr	
	FCCU	ESP	20.15 lb/hr	
	FCCU	ESP	2.25 lb/hr	
	FCCU	ESP	2.46 lb/hr	

(continued)

TABLE 3-5. VARIATION IN CONTROLLED CONDENSIBLE EMISSIONS FOR SELECTED CATEGORIES (Continued)

Source Category	Process Type	Control Type	Controlled Condensible Emissions	Condensible Emissions Control Efficiency (%)
Portland cement	Rotary kiln	Fabric filter	.11 lb/ton	
	Rotary kiln	Fabric filter	.43 lb/ton	
	Rotary kiln	Fabric filter	.12 lb/ton	
Primary copper	Furnace	ESP	61.7 lb/hr	69
	Furnace	ESP	22.9 lb/hr	55
Secondary lead	Blast furnace	Fabric filter	2.98 lb/ton	
	Blast furnace	Fabric filter	3 lb/ton	20

TABLE 3-6. COMPARISON OF CONDENSIBLE EMISSIONS FOR SELECTED CATEGORIES

Source Category	Process Type	Control Type	Controlled Condensible Emissions	Condensible Emissions Control Efficiency (%)
Coke ovens	Oven battery stack	Maintenance	1.4 lb/hr	
	Oven battery stack	Fabric filter	1.7 lb/hr	23
	Oven battery stack	Maintenance	2.1 lb/hr	
Ferroalloy	Electric arc furnace	ESP	3.6 lb/hr	81
	Electric arc furnace	Fabric filter	12.1 lb/hr	92
	Electric arc furnace	Venturi scrubber	1.4 lb/hr	60
Glass manufacturing	Furnace	Fabric filter	20.9 lb/hr	
	Furnace	Venturi scrubber	2.3 lb/hr	
	Furnace	Scrubber	.04 lb/hr	
	Furnace	ESP	.42 lb/hr	
	Furnace	Scrubber	.29 lb/hr	
	Furnace	Fabric filter	2.64 lb/hr	
	Furnace	Scrubber/ESP	.49 lb/hr	
Iron and steel	BOF	ESP	.0593 lb/ton	
	BOF	Venturi scrubber	.0212 lb/ton	
	BOF	Venturi scrubber	.0035 lb/ton	
	BOF	Venturi scrubber	.0019 lb/ton	
	BOF	ESP	.0303 lb/ton	
	Sintering	Fabric filter	17.9 lb/hr	
	Sintering	Venturi scrubber	40.2 lb/hr	59
Lightweight aggregate	Clinker cooler	Fabric filter	1.91 lb/hr	(a)
	Clinker cooler	Settling chamber	.64 lb/hr	
	Clinker cooler	Settling chamber	.54 lb/hr	
Lime manufacturing	Rotary kiln	ESP	.26 lb/ton	
	Rotary kiln	Fabric filter	.04 lb/ton	
Phosphate rock	Dryer	Wet scrubber/wet ESP	.04 lb/ton	
	Dryer	Wet scrubber	.03 lb/ton	62
Portland cement	Rotary kiln	ESP	.09 lb/ton	
	Rotary kiln	Fabric filter	.11 lb/ton	
	Rotary kiln	Fabric filter	.43 lb/ton	
	Rotary kiln	Fabric filter	.12 lb/ton	
Primary copper	Furnace	Fabric filter	61.7 lb/hr	69
	Furnace	ESP	82.5 lb/hr	33
	Furnace	ESP	22.9 lb/hr	55
Secondary lead	Blast furnace	Fabric filter	2.98 lb/ton	
	Blast furnace	Venturi scrubber	.04 lb/ton	
	Blast furnace	Fabric filter	3 lb/ton	
Soap and detergent	Spray tower	Wet scrubber/wet ESP	.51 lb/ton	
	Spray tower	Wet scrubber	.25 lb/ton	

(a) Due to reasons unclear from the test reports, the back-half catch at the outlet was greater than that at the inlet.

molecular weight compounds such as polycyclic organic matter would more readily condense than lower molecular weight compounds. Therefore, one would expect such species to make up the organic fraction of condensibles collected in the back-half of the EPA Method 5 sampling train. Based on component vapor pressures and temperatures, metallic oxides, sulfates, and chlorides would be expected to make up the inorganic condensibles fraction. Sulfates are believed to make up a large proportion of the inorganic condensible emissions. However, in a number of cases in Table 2-5, the inorganic fraction may contain sulfates formed from absorption of SO_2/SO_3 in the back-half of the sampling train, in addition to the sulfates emitted from the process.

A comparison of the available control efficiency data based on specific condensible components and the total back-half catch is shown in Table 3-7. This comparison is possible for eight source categories and covers six distinct species - organics, inorganics, total organic carbon, lead, arsenic, and sulfate. There are no clear trends that indicate a correlation between the condensible species control efficiency, control device type or condensible emissions control efficiency. This behavior is attributed to the wide variety of processes represented in this data set. For example, the organic fraction appears to be better controlled than the organic and inorganic fractions combined in the lightweight aggregate and iron and steel industries. For asphalt concrete plants and coke ovens, however, the opposite appears to be true.

3.3 CONDENSIBLE EMISSIONS CONTROL IMPROVEMENT

The most obvious method for optimizing condensible particulate emissions control is to force condensation of the emissions upstream of or within the control device. Theoretically, this can be accomplished by lowering the flue gas temperature, increasing the gas pressure, or both. Although gas compression may not be a practical approach, methods of lowering the flue gas temperatures are available. Heat exchanger designs or direct water sprays can be used to lower flue gas temperatures and volume, thus improving both condensible and total particulate removal.

Addition of a precooler/presaturation section will facilitate condensation before the control device and increase the collection efficiency. For example, venturi scrubbers are very efficient in removing very fine particles when the particles form ahead of the venturi throat. Increased control efficiency for condensible emissions may also be achieved in wet scrubber applications by adding an ionizing section before the scrubber. The ionizer, which functions like an ESP, enhances collection efficiency of the fine fraction.[128]

In wet scrubber applications, entrainment of the scrubbing liquor in the exit waste gas is quite common. Dissolved species in the entrained liquid droplets also contribute to the condensible

TABLE 3-7. CONTROL EFFECTIVENESS FOR SPECIATED CONDENSIBLE EMISSIONS

Source Category	Process Type	Control Type	Condensible Species	Species Control Efficiency (%)	Condensible Emissions Control Efficiency (%)
Asphalt concrete	Recycle	Venturi scrubber	Total organic carbon	56	56
	Conventional	Venturi scrubber	Total organic carbon	66	66
			Organics	64	66
	Recycle	Venturi scrubber	Total organic carbon	80	80
			Organics	69	80
Coke ovens	Oven battery stack	Wet ESP	Organics		83
				54	
Iron and steel	Sintering	Venturi scrubber	Organics		59
Lead acid battery	Stacking, element burning, casing	Fabric filter	Lead	70	24
	Paste mixer	Wet scrubber	Lead	46	(a)
				(a)	
Lightweight aggregate	Clinker cooler	Fabric filter	Organics		<0
	Clinker cooler	Fabric filter	Inorganics		<0
	Rotary kiln	Wet scrubber	Organics	<0	91
	Rotary kiln	Wet scrubber	Inorganics	<0	91
	Rotary kiln	Wet scrubber	Organics	97	13
	Rotary kiln	Wet scrubber	Inorganics	90	13
				50	
Petroleum refining	FCCU	Venturi scrubber	Sulfate	<0	84
Primary copper	Converter, electric furnace, and fluidized bed roaster	Spray chamber and fabric filter	Arsenic	84	33
				83	
	Reverberatory furnace and multihearth roaster	Spray chamber and ESP	Arsenic		55
			Lead	95	20
	Blast furnace	Fabric filter	Lead		43
Secondary lead	Refining kettles and slag tap	Venturi scrubber		73	
				67	

(a) Due to reasons unclear from the test reports, the back-half catch at the outlet was greater than that at the inlet.

emissions. Therefore, application of high-efficiency mist eliminators following venturi or other types of wet scrubbers improves condensible emission removal.

In ESP applications, gas conditioning agents are used to improve performance by altering particle resistivity. Conditioning agents may also enhance performance by particle agglomeration, thus effecting an increased control of condensible emissions. However, care must be taken to prevent condensation of corrosive species in the ductwork or device internals.

A technology used with ESP's that is currently in the demonstration phase is the cold-pipe precharger.[116] This technology combines precharging and heat exchange designs. The cold-pipe precharger consists of discharge wires interspersed with grounded pipes through which cooling water flows. When applied at the ESP entrance, the temperature and volume of gas treated by the ESP are decreased, and the particles are pre-charged. This technology could be promising as a condensible emission control.

Optimization of fabric filters for condensible emission control is not straightforward. Excessive moisture in the flue gas can cause undesirable filter cake properties, resulting in unacceptably high pressure drops or bag blinding. Some of the currently available filter bag coatings, such as Nomex® or Goretex®, have demonstrated effective control of fine particulates. Thus, they may also enhance condensible control.

SECTION 4

REFERENCES

1. U.S. Environmental Protection Agency. PM_{10} SIP Development Guide. Report No. EPA-450/2-86-001 (NTIS PB87-206488). June 1987.

2. U.S. Environmental Protection Agency. Estimation of the Importance of Condensed Particulate Matter to Ambient Particulate Levels, Report No. EPA-450/4-83-012. April 1983.

3. U.S. Environmental Protection Agency. Emission Test Report No. 84-ASP-8. Sloan Construction Company Asphalt Concrete Plant. Cocoa, Florida. November 1984.

4. U.S. Environmental Protection Agency. Emission Test Report No. 83-ASP-4. T. J. Campbell Asphalt Concrete Plant. Oklahoma City, Oklahoma. Revised May 1984.

5. U.S. Environmental Protection Agency. EPA Test Number 71-C1-26. R. L. Lavin & Sons, Inc. Chicago, Illinois. March 1972.

6. U.S. Environmental Protection Agency. EPA Test Number 71-C1-27. American Smelting and Refining Co. San Francisco, California. February 1971.

7. U.S. Environmental Protection Agency. Building Brick and Structural Clay Industry. EMB Report No. 80-BRK-1. Lee Brick and Tile Company. Sanford, North Carolina. 1980.

8. U.S. Environmental Protection Agency. Emissions Sampling Report EMB Project Report Number 73-CCC-1. General Electric Company Wire and Cable Division. Bridgeport, Connecticut. June 1973.

9. U.S. Environmental Protection Agency. Phillips Petroleum Company, Carbon Black Division. Toledo, Ohio. EMB Test No. 73-CBK-1. September 1974.

10. U.S. Environmental Protection Agency. Coke Oven Emission Testing Bethlehem Steel Corporation. Sparrows Point, Maryland. Report No. 79-CKO-15. July 1979.

11. U.S. Environmental Protection Agency. Emission Testing at a By-Product Coke Oven Battery. Wisconsin Steel Division. Chicago, Illinois. EMB Report No. 77-CKO-11. May 1977.

12. U.S. Environmental Protection Agency. EMB Report No. 73-ELC-1. Electric Arc Furnace. Babock and Wilcox Company, Beaver Falls, Pennsylvania. 1973.

13. U.S. Environmental Protection Agency. EMB Report. Number 72-PC-02. Union Carbide Corporation Ferroalloys Division. Alloy, West Virginia. June 1972.

14. U.S. Environmental Protection Agency. Emission Testing Report. EMB Test No. 73-FRT-6. Swift Agricultural Chemicals, Inc. Birmingham, Alabama. May 1973.

15. U.S. Environmental Protection Agency. EPA Report Number 73-FRT-7. U.S.S. Agri-Chemicals. Nashville, Tennessee. November 1974.

16. U.S. Environmental Protection Agency. Emission Testing Report No. 73-FRT-14. International Minerals and Chemicals Inc. Winston-Salem, North Carolina. March 1973.

17. U.S. Environmental Protection Agency. Source Testing Study at an Iron Ore Beneficiation Facility. Report No. 76-IOB-1. Hanna Mining Company Groveland Mine. Iron Mountain, Michigan. October 1975.

18. U.S. Environmental Protection Agency. Emission Test Report No. 71-MM-23. Alan Wood Steel Co. Conshohocken, Pennsylvania. March 1972.

19. U.S. Environmental Protection Agency. Emission Test Report No. 71-MM-24. United States Steel Corporation. Lorain, Ohio. March 1972.

20. U.S. Environmental Protection Agency. Source Testing Report No. 71-MM-01. Bethlehem Steel Corporation, Basic Oxygen Furnace. Bethlehem, Pennsylvania. April 1972.

21. U.S. Environmental Protection Agency. Air Pollution Emission Test. Report No. 74-KPM-4. Escanaba Paper Company. Escanaba, Michigan. September 1973.

22. U.S. Environmental Protection Agency. Air Pollution Emission Test. Report No. 74-KPM-5. Champion International. Courtland, Alabama. November 1973.

23. U.S. Environmental Protection Agency. Particulate Emission Measurements From Kraft Pulp Mills Report No. 74-KPM-9. Crown Zellerbach Corporation. Camas, Washington. October 1973.

24. U.S. Environmental Protection Agency. Air Pollution Emission Test. Report No. 74-KPM-10. Weyerhaeuser Company Kraft Mill. Everett, Washington. October 1973.

25. U.S. Environmental Protection Agency. Emission Test Report No. 74-BAT-1. ESB Incorporated. Milpitas, California. March 1974.

26. U.S. Environmental Protection Agency. Report No. 74-PBO-1. Particulate and Lead Emission Measurements From A Lead Oxide Plant. Gould Incorporated Metals Division. St. Paul, Minnesota. August 1973.

27. U.S. Environmental Protection Agency. Method Development and Testing for Clay, Shale, and Slate Aggregate Industry. Emission Test Report No. 80-LWA-3. Texas Industries, Inc. Clodine, Texas. May 1981.

28. U.S. Environmental Protection Agency. Method Development and Testing for Clay, Shale, and Slate Aggregate Industry. Emission Test Report No. 80-LWA-4. Vulcan Materials Company. Bessemer, Alabama. March 1982.

29. U.S. Environmental Protection Agency. Method Development and Testing for Clay, Shale, and Slate Aggregate Industry. Emission Test Report No. 80-LWA-6. Galite Corporation. Rockmart, Georgia. April 1982.

30. U.S. Environmental Protection Agency. Emissions From Dry Process Cement Kiln. Emission Test Report No. 71-MM-05. Oregon Cement Company. Northampton, Pennsylvania. 1971.

31. U.S. Environmental Protection Agency. Emissions From Wet Process Cement Kiln. Emission Testing Report No. 71-MM-13. Oregon Portland Cement. Lake Oswego, Oregon. 1971.

32. U.S. Environmental Protection Agency. Emission Test Report No. 72-MM-12. Alcoa Aluminum. Baldin, North Carolina. March 1972.

33. U.S. Environmental Protection Agency. Emission Test Report No. 72-MM-06. Alcoa Aluminum. Wenatchee, Washington. October 1972.

34. U.S. Environmental Protection Agency. Emission Test Report No. 72-MM-08. Reynolds Aluminum. Longview, Washington. May 1972.

35. U.S. Environmental Protection Agency. Emission Test Report No. 77-CUS-4. Kennecott Copper Company. Hayden, Arizona. 1977.

36. U.S. Environmental Protection Agency. Emission Test Report No. 81-PLY-2. Champion Plywood Plant. Lebanon, Oregon. May 1982.

37. U.S. Environmental Protection Agency. Emission Test Report No. 81-PLY-4. Georgia-Pacific Plywood Plant. Springfield, Oregon. December 1981.

38. U.S. Environmental Protection Agency. Emissions From A Primary Lead Smelter Blast Furnace. Emission Test Report No. 72-MM-14. American Smelting and Refining Company. Glover, Missouri. May 1972.

39. U.S. Environmental Protection Agency. Emission Test Report No. 73-PLD-1. American Smelting and Refining Company. Glover, Missouri. July 1973

40. U.S. Environmental Protection Agency. Emission Test Report No. 86-CAD-2. Cadmium Sulfide Pigments. Harshaw/Filtrol Partnership, Louisville, Kentucky. November 1986.

41. U.S. Environmental Protection Agency. Secondary Lead Plant Stack Emission Sampling. Emission Test Report No. 71-CI-29. N. L. Industries Plant. Beech Grove, Indiana. August 1972.

42. U.S. Environmental Protection Agency. Secondary Lead Plant Stack Emission Sampling. Emission Test Report No. 71-CI-33. Revere Smelting and Refining Plant. Newark, New Jersey. August 1972.

43. U.S. Environmental Protection Agency. Secondary Lead Plant Stack Emission Sampling. Emission Test Report No. 71-CI-34. General Battery Corporation. Reading, Pennsylvania. July 1972.

44. U.S. Environmental Protection Agency. Emission Test Report No. 74-SLD-1. Selco. Columbus, Georgia. July 1974.

45. U.S. Environmental Protection Agency. Emission Test Report No. 75-SIN-5. Colorado Fuel & Iron. Pueblo, Colorado. February 1976.

46. U.S. Environmental Protection Agency. Emissions Source Test From A Baghouse Serving an Iron and Steel Sintering Plant. Emission Test Report No. 75-SIN-3. Kaiser Steel Corporation. Fontana, California. November 1975.

47. U.S. Environmental Protection Agency. Air Pollution Emissions Test. Emission Test Report No. 75-SIN-4. National Steel Corporation. Granite City, Illinois. May 1975.

48. U.S. Environmental Protection Agency. Sewage Sludge Incinerator Emissions Test. Emission Test Report No. 74-SS1-3. Piscataway Sewage Sludge Incinerator. Accokeek, Maryland. February 1974.

49. U.S. Environmental Protection Agency. Emission Test Report No. 86-CAD-3. Cadmium Sulfide Pigments. SCM Corporation, Baltimore, Maryland. November 1986.

50. U.S. Environmental Protection Agency. Source Sampling of Fluid Catalytic Cracking Plant. Emission Test Report No. 71-PC-20. Standard Oil of California. Richmond, California. July 1972.

51. U.S. Environmental Protection Agency. Emission Test Report No. 71-PC-21. Standard Oil of California Company. El Segundo, California. 1971.

52. U.S. Environmental Protection Agency. Emission Test Report No. 72-PC-1. Atlantic Richfield Company. Wilmington, California. 1972.

53. U.S. Environmental Protection Agency. Fluid Catalytic Cracking Unit Monitoring Of A Wet Gas Scrubber. Emission Test Report No. 80-CAT-8. Marathon Oil Company. Garyville, Louisiana. April 1982.

54. U.S. Environmental Protection Agency. Stationary Source Testing Of a FiberGlass. Emission Test Report No. 78-GLS-1. Owens-Corning Fiberglas Corporation. Kansas City, Kansas. February 1978.

55. U.S. Environmental Protection Agency. Stack Emission Sampling. Emission Test Report No. 78-GLS-2. Glass Containers Corporation. Vernon, California. January 1978.

56. U.S. Environmental Protection Agency. Stationary Source Testing Of Coal-Fired Steam Generator. Emission Test Report No. 76-SPP-14. The Navajo Power Plant. Page, Arizona. December 1976.

57. U.S. Environmental Protection Agency. Stationary Source Testing Of An Electric Power Plant. Emission Test Report No. 77-SPP-16. The Pacific Power and Light Company Centralia No. 1 Steam Plant. Centralia, Washington. August 1977.

58. U.S. Environmental Protection Agency. Coal Preparation Plant Emission Test. Emission Test Report No. 72-Cl-13. Eastern Associates Coal Company. Keystone, West Virginia. February 1972.

59. U.S. Environmental Protection Agency. Emission Test Report No. 72-Cl-19. Consolidation Coal Company. Bishop, West Virginia. November 1972.

60. U.S. Environmental Protection Agency. Emission Test Report No. 73-CCL-2. Island Creek Coal Company. Van Sant, Virginia. October 1972.

61. U.S. Environmental Protection Agency. Emissions From the Grain Drying Facility. Emission Test Report No. 73-GRN-4. Quaker Oats Company. Chattanooga, Tennessee. April 1973.

62. U.S. Environmental Protection Agency. Emission Test Report No. 74-GRN-6. Kansas City Terminal Elevator. Kansas City, Missouri. October 1973.

63. U.S. Environmental Protection Agency. Emission Test Report No. 72-CI-28. Cargill, Inc. Sioux City, Iowa. June 1972.

64. U.S. Environmental Protection Agency. A Study Of Gaseous and Particulate Emissions From Lime Kilns. Emission Test Report No. 74-LIM-6. Dow Chemical Corporation. Freeport, Texas. May 1974.

65. U.S. Environmental Protection Agency. Emission Test Report No. 74-LIM-4. Bethlehem Mines Corporation. Annville, Pennsylvania. 1974.

66. U.S. Environmental Protection Agency. Emission Test Report No. 74-LIM-5. U.S. Lime Division of Flintkote Company. City of Industry, California. October 1974.

67. U.S. Environmental Protection Agency. Emission Test Report No. 76-LIM-9. Martin-Marietta. Calera, Alabama. September 1975.

68. U.S. Environmental Protection Agency. Emission Test Report No. 74-HAS-1. Prepared for Reserve Mining Company. Silver Bay, Minnesota. June 1974.

69. U.S. Environmental Protection Agency. Emission Test Report No. 75-PRP-1. W. R. Grace Chemical Company. Bartow, Florida. January 1976.

70. U.S. Environmental Protection Agency. Emission Test Report No. 73-ROC-1. International Minerals and Chemical Corporation. Kingsford, Florida. February 1973.

71. U.S. Environmental Protection Agency. Emission Test Report No. 75-PRP-2. The Royster Company Phosphate Rock Facility. Mulberry, Florida. January 1976.

72. U.S. Environmental Protection Agency. Emission Test Report No. 73-DET-7. Colgate Palmolive. Jeffersonville, Indiana. June 1973.

73. U.S. Environmental Protection Agency. Emission Test Report No. 73-DET-4. Procter and Gamble. Long Beach California. April 1973.

74. U.S. Environmental Protection Agency. Emission Test Report No. 73-DET-2. Lever Brothers. Los Angeles, California. April 1976.

75. U.S. Environmental Protection Agency. Emission Test Report No. 75-STN-2. Essex Bituminous Concrete Corporation. Dracut, Massachusetts. December 1974.

76. U.S. Environmental Protection Agency. Emission Test Report No. 75-STN-4. Caldwell Stone Company. Danville, Kentucky. 1975.

77. U.S. Environmental Protection Agency. Emission Test Report No. 74-GFE-1. John Deere Tractor Works. Waterloo, Iowa. June 1974.

78. South Coast Air Quality Management District. Emission Test Report No. 88-0043. Shell Oil Company. Carson, California. January 1988.

79. South Coast Air Quality Management District. Emission Test Report No. 88-0372. Mobil Oil Corporation. Torrance, California. October 1988.

80. U.S. Environmental Protection Agency. Emission Test Report No. 79-CKO-14. Kaiser Steel Corporation. Fontana, California. 1979.

81. U.S. Environmental Protection Agency. Emission Test Report No. 72-PC-05. Chromium Mining and Smelting Corporation. Memphis, Tennessee. 1972.

82. U.S. Environmental Protection Agency. Particulate and Arsenic Emission Measurements From a Copper Smelter. Emission Test Report No. 77-CUS-5. Anaconda Mining Company. Anaconda, Montana. April 1977.

83. U.S. Environmental Protection Agency. Particulate and Arsenic Emission Measurements From a Copper Smelter. Emission Test Report No. 77-CUS-6. Asarco. El Paso, Texas. June 1977.

84. U.S. Environmental Protection Agency. Emission Testing at a By-Product Coke Plant. Emission Test Report No. 79-CKO-16. C. F. & I. Steel Corporation. Pueblo, Colorado. August 1979.

85. U.S. Environmental Protection Agency. Emission Test Report No. 71-PC-16. AIRCO Alloys and Carbide. Charleston, South Carolina. 1971.

86. U.S. Environmental Protection Agency. Emission Test Report No. 71-MM-26. Weirton Steel Division National Steel Corporation. Weirton, West Virginia. March 1972.

87. U.S. Environmental Protection Agency. Emission Test Report No. 72-MM-02. United States Steel Corporation. Lorain, Ohio. June 1972.

88. U.S. Environmental Protection Agency. Emissions From Wet Process Cement Kiln and Finish Mill Systems. Emission Test Report No. 71-MM-04. Ideal Cement Company. Castle Hayne, North Carolina. April 1971.

89. U.S. Environmental Protection Agency. Emissions From Wet Process Cement Kiln and Clinker Cooler. Emission Test Report No. 71-MM-03. Ideal Cement Company. Seattle, Washington. 1971.

90. Battelle. Schuly, E.J., et al., Battelle. Final Report on Harrisburg Municipal Incinerator Evaluation to the Harrisburg Incinerator Authority. December 17, 1973.

91. Allen, R. N., Resources Research, Inc. Chicago Northwest Incinerator. Chicago, Illinois. Test No. 71-CI-11. McLean, Virginia. March 1972.

92. Doerflein, W.S. and H.R. Horn, York-Shipley, Inc. Fluid Flame Solid Waste Converter, Particulate Emission Test. H&B Lumber Company. Marion, North Carolina. August 1977.

93. The Mogul Corporation. Emission Test Report for Champion International Corporation in Dee, Oregon. March 1978.

94. Applied Energy Systems, Inc. Design Handbook for Solid Fuel Heaters. East Greenwich, Rhode Island. 1981.

95. Federal Register, Vol. 53, No. 38, pp. 5860, 5861. February 1988.

96. McCrillis, R. and R. Merrill, U.S. Environmental Protection Agency. Emission Control Effectiveness of a Woodstove Catalyst and Emission Measurement Methods Comparison. APCA paper 85-43.5. June 1985.

97. Burnett, P. and P. Tiegs, Omni Environmental Services, Inc. Woodstove Emissions as a Function of Firebox Size. Presented at 21st Meeting of the Pacific Northwest International Section of the APCA. November 12-14, 1984. Portland, Oregon.

98. South Coast Air Quality Management District. Emission Test Report No. 88CST089. Brockway Glass Company, Pomona, California. March 1989.

99. U.S. Environmental Protection Agency. Emission Test Report No. 71-MM-15. Oregon Portland Cement. Lake Oswego, Oregon. 1971.

100. South Coast Air Quality Management District. Emission Test Report No. C-79-39. Kerr-McGee Chemical Corporation, Trona, California. September 1979.

101. South Coast Air Quality Management District. Emission Test Report No. C-79-62. Interstate Engineering, Anaheim, California. December 1979.

102. South Coast Air Quality Management District. Emission Test Report No. C-80-68. Kaiser Steel Corporation, Fontana, California. July 1980.

103. South Coast Air Quality Management District. Emission Test Report No. 87CST007. Ball Corporation, El Monte, California. August 1987.

104. South Coast Air Quality Management District. Emission Test Report No. 87-0019. Chevron USA, Inc., El Segundo, California. January 1987.

105. South Coast Air Quality Management District. Emission Test Report No. 87CST024. AAA Glass Corporation, Los Angeles, California. September 1987.

106. South Coast Air Quality Management District. Emission Test Report No. 87CST032. GNB, Inc., Vernon, California. September 1987.

107. South Coast Air Quality Management District. Emission Test Report No. 87CST049. Latchford Glass Company, Los Angeles, California. October 1987.

108. South Coast Air Quality Management District. Emission Test Report No. 87CST059. Harshaw/Filtrol Partnership, Los Angeles, California. November 1987.

109. South Coast Air Quality Management District. Emission Test Report No. 87CST072. Alco Pacific, Inc., Gardena, California. November 1987.

110. South Coast Air Quality Management District. Emission Test Report No. 87CST110. Lever Brothers Company, Inc., Los Angeles, California. January 1988.

111. South Coast Air Quality Management District. Emission Test Report No. 87CST135. Owens-Illinois, Inc., Vernon, California. February 1988.

112. South Coast Air Quality Management District. Emission Test Report No. 87CST136. Owens-Illinois, Inc., Vernon, California. February 1988.

113. South Coast Air Quality Management District. Emission Test Report No. 87-0322. Golden West Refining Company, Santa Fe Springs, California. October 1987.

114. South Coast Air Quality Management District. Emission Test Report No. 87-0356. Atlantic Richfield, Company, Watson Refinery, Carson, California. November 1987.

115. South Coast Air Quality Management District. Emission Test Report No. 87-0370. Gold Bond Building Products, Long Beach, California. November 1987.

116. Emmel, T. et al. U.S. Environmental Protection Agency. Cost of Controlling Directly Emitted Acidic Emissions from Major Industrial Sources. Report No. EPA-600/7-88-012 (NTIS PB88-234190). July 1988.

117. South Coast Air Quality Management District. Emission Test Report No. 88CST046. National Can Corporation, Foster Forbes Division, Maywood, California. January 1989.

118. South Coast Air Quality Management District. Emission Test Report No. 88CST102. Aluminum Company of America, Vernon, California. April 1989.

119. South Coast Air Quality Management District. Emission Test Report No. 88-0161. Shell Oil Company, Carson, California. August 1988.

120. South Coast Air Quality Management District. Emission Test Report No. 88-0212. Blair Paving, Inc., Anaheim, California. July 1988.

121. South Coast Air Quality Management District. Emission Test Report No. 88-0259. Fletcher Oil and Refinery Company, Carson, California. July 1988.

122. South Coast Air Quality Management District. Emission Test Report No. 88-0310. Texaco Refining and Marketing, Inc., Wilmington, California. September 1988.

123. South Coast Air Quality Management District. Emission Test Report No. 88-0316. Powerline Oil Company, Santa Fe Springs, California. August 1988.

124. Saeger, M. et al. U.S. Environmental Protection Agency. The 1985 NAPAP Emissions Inventory (Version 2). Development of the Annual Data and Modelers' Tapes. Report No. EPA-600/7-89-012a. November 1989.

125. South Coast Air Quality Management District. Emission Test Report No. 88-0432. Fletcher Oil and Refining Company, Carson, California. January 1989.

126. U.S. Environmental Protection Agency. Control Techniques for Particulate Emissions from Stationary Sources. Volume 1. Report No. EPA-450/3-81-005a (NTIS PB83-127498). September 1982.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/8-90-075	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Assessment of the Controllability of Condensible Emissions		5. REPORT DATE October 1990
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) G. S. Shareef and J. T. Waddell		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Radian Corporation P. O. Box 13000 Research Triangle Park, North Carolina 27709		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-4286, Tasks 67/105
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air and Energy Engineering Research Laboratory Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final report
		14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Carlos M. Nunez, Mail Drop 61, 919/541-1156.

16. ABSTRACT The report gives results of a study to gain insights into the condensible emissions area from an air toxics perspective, with emphasis on controllability and chemical composition of these emissions. The study: compiled existing data on condensible emissions; determined the chemical composition of condensible emissions, where possible; identified source categories that are major emitters of condensibles; evaluated the effectiveness of various control devices in reducing condensible emissions; and evaluated how the performance of currently available control technologies can be improved to better control condensible emissions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Emission	Stationary Sources	14G
Condensing	Condensible Emissions	07D
Chemical Composition	Particulate	
Particles		
Toxicity		06T

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 71
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE