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Update and Analysis of Current Boiler Operations Used for the Generation of Steam Heat and Electricity

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Abstract

According to the U.S. Environmental Agency, the number of boilers in the U.S. devoted to the production of steam, electricity, and heat is approximately 1.5 million. This study will focus on major source boilers burning natural gas, coal, wood, oil, or other fuels to recover thermal energy in the form of steam or hot water to produce electricity or heat. The focus of this research paper will be to assess the compliance status of the boilers which were in the original EPA major source Boiler MACT group to provide insight into the current operating status of these boiler units.

Keywords: boiler, MACT, fuels, combustors, boiler operations, control devices, utilities

1. Introduction

1.1 EPA MACT Standard

According to the US. Environmental Protection Agency (EPA), the number of boilers in the United States (U.S.) is approximately 1.5 million (EPA, 2016). In this study, a boiler refers to an enclosed device burning natural gas, coal, wood, oil, or some other type of fuel to recover thermal energy in the form of steam or hot water to produce electricity or heat (CIBO, 2016). To control the air emissions from the combustion of fuels in those boilers, EPA has set a series of standards to protect the environment under Section 112 of the Clean Air Act (EPA, Emissions Standards for Boilers and Process Heaters and Commercial / Industrial Solid Waste Incinerators – Basic Information (EPA, 2016). The Maximum Achievable Control Technology (MACT) Standards were developed by EPA with specific emissions limits to reduce the effects of Hazardous Air Pollutants (HAPs) generated by industrial, commercial, and institutional (ICI) boilers (National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters; Final Rule., 2015). These limits are based on the lowest level of HAPs emissions achieved by such facilities. To clarify, the control technology may include: (1) the measures, (2) processes, (3) methods, (4) systems, or (5) techniques, instead of expensive control devices, being used to control HAPs (EPA, 2002).

However, MACT Compliance only applies to "major source" HAP facilities who produce one or more pollutants that appear on the list of HAPs in significant quantities (aggregately emitting at least 10 tons of any single HAP or 25 tons of multiple HAPs annually, or 10/25 tpy (tons per year)) (EPA, 2016). A "major source" must lower its emissions amount below these quantities (10/25 tpy) (EPA, 2016) to comply with the rule by January 31, 2016 (National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters; Final Rule., 2015). We provided a list of the 185 HAPs regulated by the United States Environmental Protection Agency as of year 2017 in the Appendix B at the end of this paper (EPA, 2017). Though MACT applies to boilers in a wide range of industrial facilities and institutions, less than one percent of the approximately 1.5 million boilers, or 15,000 boilers, in the United States are required to meet the final MACT rule signed on May 11, 2015. This is due to the fact that the majority, for instance, hotels, hospitals, and commercial buildings, are emitting only small amounts of air pollutants, which can be regulated by the Area Source Boiler Rule (Energy, 2015).

1.2 CIBO Boiler MACT Project Overview

The original EPA major source Boiler MACT regulated the HAPs by controlling the emission from the combustion of three major fuel types, coal, biomass, and liquid (EPA, 2017). The final rule issued on November 20, 2015 adopted “work practices” achieved by the best emissions performers in the industry between the startup and shutdown of boilers. It required boilers be equipped with any possible control devices to meet the MACT standards within 4 hours after startup of producing useful energy. In addition, the first burning of coal fuel, biomass fuel, heavy liquid fuel and other gases (gas 2) within 1 hour must be accompanied by the particulate matter (PM) control. A written startup and shutdown plan (SSP) should be provided for any public inspection (National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters; Final Rule., 2015).

The primary focus of the project referenced in this research paper was to assess the compliance status of the boilers which were in the original EPA major source Boiler MACT with emission limits that could require control or conversion to other fuels. In this case, this amounted to 1,742 units. The EPA’s database was searched and a survey via emails or phone calls was undertaken for these 1,742 individual units during the fourth quarter of year 2015. The total response rate from this effort was 39 percent, approximately 671 units. Eighty percent of the boiler respondents were affiliated with the Council of Industrial Boiler Owners (CIBO), a broad-based trade association with a mission of maintaining the competitiveness of the nation’s economy by ensuring the safety, cost-efficiency and reliability of energy from non-utility industrial, commercial and institutional energy producers. Its members are mostly from manufacturers and suppliers of boilers, firing equipment, gas clean-up systems, and related products and services (CIBO, 2016).

1.3 Main Findings Overview

According to the survey results, natural gas turned out to be the primary type of fuel burned by most boilers after achieving Boiler MACT compliance. This represented approximately 76 percent of the responding boiler systems. In retrospect, when comparing this result to the original EPA boiler units, natural gas did not exist as a fuel sub-category at that point in time. Coal was the second largest fuel type used by 14 percent of the boiler units. Among all the replies received, approximately seven percent of the units reported that they recently had made a change in the type of fuel being used.

2. Project Description

2.1 Data Collection

The original 1,742 EPA major source Boiler MACT units were contacted and asked specific information about the current status of their boilers. The survey content was shown in Appendix A, which can be categorized into three areas: (1) Basic information about the company, including company name, address, manager’s name and contact information; (2) Basic information about the boiler, including the type of boiler, capacity and operating hours, fuel type, combustor design, and the type facility; (3) Compliance operations, including their active or decommissioned status, any fuel type changes, and the addition of HAP control devices. The survey results were compiled into an Excel spreadsheet database for further analysis. The physical location distribution of facilities responded to our survey was listed in Appendix C. As our survey only got responses from 30 states, the analysis results might be biased if seeing as a nationwide picture.

2.2 Data Analysis

The major area boilers are generally subcategorized in four aspects: boiler combustion design type, type of fuel burned, new or existing units with and without limited use and boiler size/capacity. Here are some definitions that should be clarified. The new or existing boilers differed by a certain construction date. The new units were built after June 4, 2010. Any units built before June 4, 2010 were seen as the existing units. ‘‘Limited-use units’’ are those operating 10% of their full annual capacity or 30% of their one-third full annual capacity. Boilers were characterized into large source units or small sources according to their capacity. The large source units would have a heat input capacity no less than 10 million British thermal units per hour (mmbtu/hr) and the small source units would have a heat input capacity no larger than 10 mmbtu/hr (EPA, 2017).

The project focused on the active 571 responding individual boilers of the total 671 responses. The remaining 100 responding individual units had been decommissioned, about 14.9 percent of the total 671 responses. (See Figure 1)

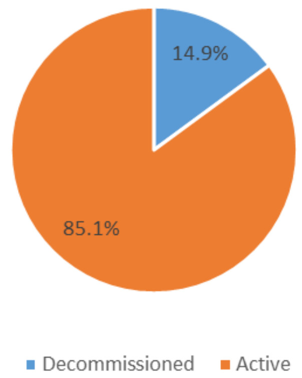

Figure 1. Percentages of Active and Decommissioned Boilers

An analysis of the data was performed on the following five main areas:

2.2.1 Boiler Combustion Design Analysis

Coal-fired boilers were divided into three subclasses based on the combustion technology used, namely, pulverized-coal (PC) fired, stoker-fired, and fluidized-bed (FB) combustion boilers. The survey results indicated that coal, as the second most used type of fuel, was used by 80 facilities out of the 571 active responses. Out of those 80 responses, 18 (or 22.5%) indicated "PC" as the technology in use, 41 (or 51.25%) indicated "Stoker" as the technology in use, 20 (or 25.0%) indicated "FB" as the technology in use, and the remaining 1.25% did not respond. (See Figure 2)

To make a compliance with the major source Boiler MACT, facility owners/ operators have to assess the air pollution effects of the type of combustion design of their boilers and consider about redesign if the current technology cannot help meet the major source Boiler MACT standards.

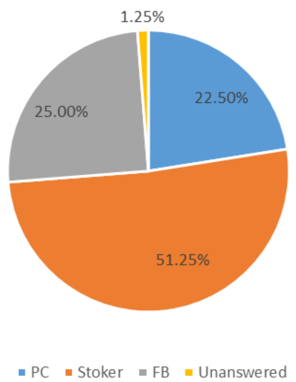

Figure 2. Percentage of Coal Boilers by Combustion Design

2.2.2 Utility Analysis

The utility analysis was directed at the 131 active non-CIBO boilers since, as mentioned earlier, CIBO members are non-utility facilities. The survey indicated that 11 facilities were part of a utility (or 16.9%), 5 facilities were part of an independent power producer (IPP) (or 7.7%), 12 facilities were part of an industrial facility (or 18.5%), and 3 facilities were part of a municipal facility (or 4.6%). The other 28 facilities were categorized as "Miscellaneous", which were listed in the column entries as "Institutional Non-profit Utility", "Piedmont Natural Gas", etc. The remaining six responses listed "No", which might indicate that their boiler was not one of the types listed in the column headings. (See Figure 3)

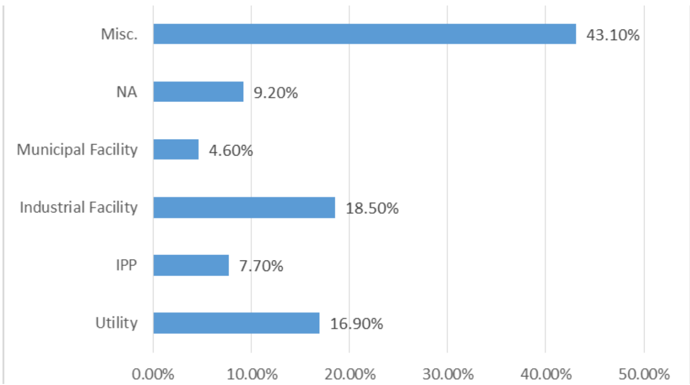

Figure 3. Percentage of Non-CIBO Boiler Utility Answers

2.2.3 Fuel Type Analysis

The type of fuel fed in a boiler has great influence on its amount and type of air toxics emissions. The main type of fuel for boiler combustion for the non-CIBO members was coal (including coal refuse, petroleum coke, or synthetic fuels derived from coal), oil or other liquid fuel, biomass and non-waste materials (EPA, 2016). The original EPA database was searched and compared to the current study's survey results to show any updated information in recent years concerning fuel type changes among those boilers. Among the 571 active boiler responses, 433 responses (or 75.83%) indicated the fuel source was "gas" and 80 responses (or 14.01%) indicated the fuel source was "coal". Another 41 responses (7.18%) were listed as liquid fuel, with "light liquid" and "heavy liquid" each accounting for about 3.5%. The remaining 20 responses (3.5%) indicated biomass as the primary fuel source, with 17 listing "wet biomass" and 3 listing "dry biomass". (See Figure 4) Gas was shown to be a main fuel source among boilers with a growth from zero percent in the original EPA database. The percentage of coal and liquid fuel usage reflected very few changes between the original EPA database and this survey study. Biomass showed a slight decline as a fuel.

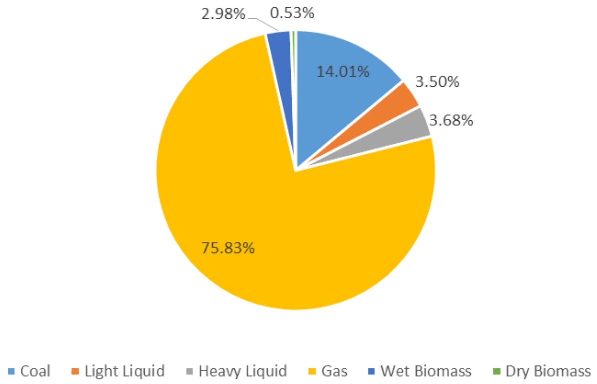

Figure 4. Percentage of Boilers Using a Particular Type of Fuel

2.3.4 Control Device Analysis

Control devices might be added to limit certain type of air toxics so as to comply with the major source Boiler MACT (National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters; Final Rule., 2015). When asked about the addition of control devices in the last five years (this question only applies for "Non-CIBO" member boilers), 93 responses out of the 131 active boilers responded to this item. The majority (92.5%) of the units indicated that they did not add any control devices during that time period. Five units indicated that they added control devices to comply with the MACT standards: (1) two responded that they had added "dry sorbent injection control devices", (2) one indicated the addition of a "dry ESP (Electrostatic Precipitator) control device", (3) indicated the addition of a "continuous O2 trim control device", and (4) one indicated the addition of a "combustion control device". The remaining two indicated "N/A" as a response to this question. (See Figure 5).

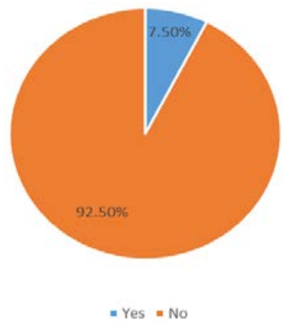

Figure 5. Percentage of Non-CIBO Units That Had Added Control Devices in Last Five Years

2.2.5 Operational Change Analysis

This project also surveyed the operating conditions of these 671 boilers that responded to this study's data collection efforts. In the last five years, 100 out of the 671 responding units have been decommissioned (approximately 14.9% of the total responses) to meet the major source Boiler MACT rules. In another perspective, major source boilers could merge themselves to area boilers by decreasing operations so as to get rid of the major source Boiler MACT rules (EPA, 2016). From our survey, 522 out of the 571 active boilers indicated that no operation changes occurred during that time period. Six indicated that they were new boilers. One indicated an "increase in operation" and two indicated a "decrease in operation". Finally, 40 units reported having a change in type of fuel being used.

The current Boiler MACT compliance date was January 31, 2016, which could be extended to January 31, 2017, in a case-by-case condition (National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters; Final Rule., 2015). When the "Non-CIBO" member boilers were asked the question, "Has a one-year compliance extension been obtained for their unit(s)", 103 responses were received out of the 131 "Non-CIBO" companies. Most units indicated a "No" result. Approximately 11% responded "Yes" and one indicated that the "boiler was operating under 112 (j) case by case MACT".

3. Conclusion

3.1 Project Summary

From the data analysis above, approximately 15% of the total responding units have been decommissioned over the last five years. For the remaining 85% active boilers, natural gas turned out to be the most popular type of fuel, followed by coal. Among all the active units, only about 7% of the units indicated a fuel change and the majority of the boilers did not make any operational changes in recent years.

3.2 U.S. Boiler Future Development Trends

EPA issued the final revisions of Boiler MACT on November 5, 2015, to limit air pollutant emissions from industrial, commercial, and institutional boilers and process heaters (EPA, 2016). The type of fuel for the boilers affected by the new MACT standards are contained in four categories: (1) coal (including coal refuse, petroleum coke, or synthetic fuels derived from coal), (2) oil or other liquid fuel, (3) biomass, and (4) non-waste materials.6 With more and more attention on air emission control through government regulation, some boilers will experience decommissioning in the future and others might have to perform operational changes in order to meet the MACT standards, such as fuel changes, decreasing operations, combustor redesign, etc.

References

CIBO. (2016). Retrieved from Council of Industrial Boiler Owners: https://www.cibo.org/

Energy, O. O. (2015, 4). *Boiler Maximum Achievable Control Technology (MACT) Technical Assistance – Fact Sheet (April 2015).* Retrieved from Office of Energy Efficiency and Renewable Energy,: http://energy.gov/eere/amo/downloads/boiler-maximum-achievable-control-technology-mact-technical-assistance-fact-sheet

EPA. (16, 1 14). *Boiler MACT, 40 CFR Part 63, Subpart DDDDD (5D) Question and Answers (Revised 1/14/16).* Retrieved from United States Environmental Protection Agency (EPA): https://www.epa.gov/sites/production/files/2016-09/documents/boilermactqanda.pdf

EPA. (2002, 2). *Guidelines for MACT Determinations under Section 112(j) Requirements*. Retrieved from United States Environmental Protection Agency: https://www3.epa.gov/ttn/atw/112j/guidance.pdf

EPA. (2016, 8). *Air Quality Planning and Standards - Emissions Standards for Boilers and Process Heaters and Commercial / Industrial Solid Waste Incinerators (August 2016).* Retrieved from Environmental Protection Agency (EPA): https://www3.epa.gov/airq

EPA. (2016, 8). *Boiler Compliance at Area Sources*. Retrieved from United States Environmental Protection Agency (EPA): https://www3.epa.gov/boilercompliance/

EPA. (2016, 8). *Emissions Standards for Boilers and Process Heaters and Commercial / Industrial Solid Waste Incinerators – Basic Information (August 2016).* Retrieved from United States Environmental Protection Agency: https://www3.epa.gov/airquality/combustion/basic.html

EPA. (2017). *National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters, Small Entity Compliance Guide For Major Source Boilers And Process Heaters*. Retrieved from Clean Air Act Standards and Guidelines for Energy, Engines, and Combustion: https://www.epa.gov/stationary-sources-air-pollution/clean-air-act-standards-and-guidelines-energy-engines-and

EPA. (2017, 3). *Industrial, Commercial, and Institutional Boilers and Process Heaters: National Emission Standards for Hazardous Air Pollutants (NESHAP) for Major Sources*. Retrieved from United States Environmental Protection Agency (EPA): https://www.epa.gov/stationary-sources-air-pollution/industrial-commercial-and-institutional-boilers-and-process-heaters#additional-resources

EPA. (2017, 3). Initial List of Hazardous Air Pollutants with Modifications. Retrieved from United States Environmental Protection Agency (EPA): https://www.epa.gov/haps/initial-list-hazardous-air-pollutants-modifications#mods

National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters; Final Rule., 40-CFR-Part-63 (Federal Register, Vol. 80, No. 224, Rules and Regulations 11 20, 2015). Retrieved from Federal Register, Vol. 80, No. 224, November 20, 2015, Rules and Regulations, 40-CFR-Part-63, National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters; Final Rule.

Appendix A

Survey Content

Facility Information	Facility ID
	Facility Name
	Physical Location (Detailed Address, City, States, Zip Code)
	Contact Information (Contactor Name, Telephone, Fax, E-mail)
Unit Information	Unit ID
	Unit Count
	Boiler or Process Heater
	Capacity in MMBtu/br
	Operation Hours per Year
	Limited Use or Not
	Fuel Category
Boiler MACT Compliance	Combustion Design
	Coal Type
	With or Without HAP APCD Control Device
	Will unit operate after Boiler MACT Compliance date?
	What controls, if any, have been added to comply with Boiler MACT?
	Describe any fuel switching to comply with Boiler MACT.
	Describe any replacement boilers/process heaters.

Appendix B

List of 185 HAPs as of year 2017

Initial Letter	Number	Items
A	14	Acetaldehyde, Acetamide, Acetonitrile, Acetophenone, 2-Acetylaminofluorene, Acrolein, Acrylamide, Acrylic acid, Acrylonitrile, Allyl chloride, 4-Aminobiphenyl, Aniline, o-Anisidine, Asbestos
B	9	Benzene (including benzene from gasoline), Benzidine, Benzotrichloride, Benzyl chloride, Biphenyl, Bis(2-ethylhexyl)phthalate (DEHP), Bis(chloromethyl)ether, Bromoform, 1,3-Butadiene
C	22	Calcium cyanamide, Captan, Carbaryl, Carbon disulfide, Carbon tetrachloride, Carbonyl sulfide, Catechol, Chloramben, Chlordane, Chlorine, Chloroacetic acid, 2-Chloroacetophenone, Chlorobenzene, Chlorobenzilate, Chloroform, Chloromethyl methyl ether, Chloroprene, Cresols/Cresylic acid (isomers and mixture), o-Cresol, m-Cresol, p-Cresol, Cumene
D	27	2,4-D, salts and esters, DDE, Diazomethane, Dibenzofurans, 1,2-Dibromo-3-chloropropane, Dibutylphthalate, 1,4-Dichlorobenzene(p), 3,3-Dichlorobenzidene, Dichloroethyl ether (Bis(2-chloroethyl)ether), 1,3-Dichloropropene, Dichlorvos, Diethanolamine, N,N-Dimethylaniline, Diethyl sulfate, 3,3-Dimethoxybenzidine, Dimethyl aminoazobenzene, 3,3'-Dimethyl benzidine, Dimethyl carbamoyl chloride, Dimethyl formamide, 1,1-Dimethyl hydrazine, Dimethyl phthalate, Dimethyl sulfate, 4,6-Dinitro-o-cresol, and salts, 2,4-Dinitrophenol, 2,4-Dinitrotoluene, 1,4-Dioxane (1,4-Diethyleneoxide), 1,2-Diphenylhydrazine
E	13	Epichlorohydrin (l-Chloro-2,3-epoxypropane), 1,2-Epoxybutane, Ethyl acrylate, Ethyl benzene, Ethyl carbamate (Urethane), Ethyl chloride (Chloroethane), Ethylene dibromide (Dibromoethane), Ethylene dichloride (1,2-Dichloroethane), Ethylene glycol, Ethylene imine (Aziridine), Ethylene oxide, Ethylene thiourea, Ethylidene dichloride (1,1-Dichloroethane)
F	1	Formaldehyde
H	12	Heptachlor, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclopentadiene, Hexachloroethane, Hexamethylene-1,6-diisocyanate, Hexamethylphosphoramide, Hexane, Hydrazine, Hydrochloric acid, Hydrogen fluoride (Hydrofluoric acid), Hydroquinone
I	1	Isophorone
L	1	Lindane (all isomers)
M	15	Maleic anhydride, Methanol, Methoxychlor, Methyl bromide (Bromomethane), Methyl chloride (Chloromethane), Methyl chloroform (1,1,1-Trichloroethane), Methyl hydrazine, Methyl iodide (Iodomethane), Methyl isobutyl ketone (Hexone), Methyl isocyanate, Methyl methacrylate, Methyl tert butyl ether, 4,4-Methylene bis(2-chloroaniline), Methylene chloride (Dichloromethane), Methylene diphenyl diisocyanate (MDI), 4,4'-Methylenedianiline
N	8	Naphthalene, Nitrobenzene, 4-Nitrobiphenyl, 4-Nitrophenol, 2-Nitropropane, N-Nitroso-N-methylurea, N-Nitrosodimethylamine, N-Nitrosomorpholine
P	17	Parathion, Pentachloronitrobenzene (Quintobenzene), Pentachlorophenol, Phenol, p-Phenylenediamine, Phosgene, Phosphine, Phosphorus, Phthalic anhydride, Polychlorinated biphenyls (Aroclors), 1,3-Propane sultone, beta-Propiolactone, Propionaldehyde, Propoxur (Baygon), Propylene dichloride (1,2-Dichloropropane), Propylene oxide, 1,2-Propylenimine (2-Methyl aziridine)
Q	2	Quinoline, Quinone
S	2	Styrene, Styrene oxide
T	16	2,3,7,8-Tetrachlorodibenzo-p-dioxin, 1,1,2,2-Tetrachloroethane, Tetrachloroethylene (Perchloroethylene), Titanium tetrachloride, Toluene, 2,4-Toluene diamine, 2,4-Toluene diisocyanate, o-Toluidine, Toxaphene (chlorinated camphene), 1,2,4-Trichlorobenzene, 1,1,2-Trichloroethane, Trichloroethylene, 2,4,5-Trichlorophenol, 2,4,6-Trichlorophenol, Triethylamine, Trifluralin, 2,2,4-Trimethylpentane
V	4	Vinyl acetate, Vinyl bromide, Vinyl chloride, Vinylidene chloride (1,1-Dichloroethylene)
X	4	Xylenes (isomers and mixture), o-Xylenes, m-Xylenes, p-Xylenes
Compounds	17	Antimony Compounds, Arsenic Compounds (inorganic including arsine), Beryllium Compounds, Cadmium Compounds, Chromium Compounds, Cobalt Compounds, Coke Oven Emissions, Cyanide Compounds, Glycol ethers, Lead Compounds, Manganese Compounds, Mercury Compounds, Fine mineral fibers, Nickel Compounds, Polycyclic Organic Matter, Radionuclides (including radon), Selenium Compounds.
Total	**185**	

Appendix C

Physical Distribution of Facilities

Number	State	Facilitiy Count
1	IA	69
2	IL	63
3	TN	52
4	IN	45
5	TX	44
6	OH	33
7	NE	27
8	MN	20
9	WV	19
10	PA	18
11	NC	18
12	VA	16
13	SC	15
14	AL	12
15	LA	10
16	MI	10
17	MS	10
18	MO	9
19	GA	8
20	ND	8
21	MA	8
22	KS	7
23	CA	7
24	DE	6
25	NJ	5
26	NY	4
27	AR	3
28	KY	3
29	PR	1
30	ME	1
Not Identified		23
Total Facilities		574