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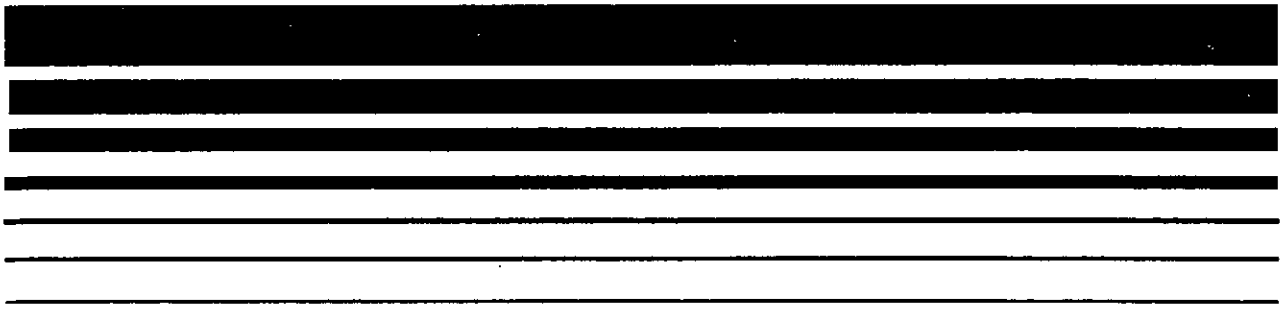
Review of New Source Performance Standards for Lead-Acid Battery Manufacture

Preliminary Draft



NSPS

Review of New Source Performance Standards for Lead-Acid Battery Manufacture

Preliminary Draft

Emissions Standards Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711
October 1989

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1.0 SUMMARY

The new source performance standards (NSPS) for lead-acid battery manufacturing plants were promulgated by the U.S. Environmental Protection Agency (EPA) on April 16, 1982, under Section 111 of the Clean Air Act. The standards limit emissions of lead from new, modified, and reconstructed facilities at any lead-acid battery manufacturing plant which has the design capacity to produce in one day batteries which would contain, in total, an amount of lead equal to or greater than 5.9 Mg (6.5 tons). These standards apply to any affected facility which commences construction or modification after January 14, 1980. The affected facilities included in this source category are the grid casting facility, paste mixing facility, three-process operation facility, lead oxide manufacturing facility, lead reclamation facility, and other lead emitting operations.

The objective of this report is to document the review of the NSPS for lead-acid battery manufacture, and to assess the need for revision on the basis of developments that have occurred since the standards were promulgated. This review is required under Section 111(b) of the Clean Air Act, as amended. The following paragraphs summarize the findings of this review.

1.1 INDUSTRY TRENDS

Two major types of lead-acid storage batteries are manufactured in the United States: starting-lighting-ignition (SLI) batteries, and industrial storage batteries. SLI units by far account for the majority of the North American Battery Industry. In 1986, United States SLI battery shipments reached 75.7 million units; in 1987, SLI shipments were valued at $2.10 billion (1982 $). As of 1985, the industrial battery sector accounted for approximately $375 million in annual sales.

Growth is expected in the future for both the SLI and industrial battery markets. SLI battery shipments are expected to increase 4.5 percent annually between 1987 and 2000. In 1985, it was estimated that the industrial battery market would experience annual growth of 2 to 5 percent through 1989. The trend is toward fewer, larger plants, with the already small number of small plants decreasing.

1.2 CONTROL TECHNOLOGY

The lead-acid battery industry applies various air pollution controls, including: baghouses, low energy wet scrubbers, and more recently, cartridge collectors and secondary high efficiency particulate air filters (HEPA). Manufacturers often vent a number of processes to the same control device via a collection system of ducts and hoods. The control systems used at individual plants depend upon plant layout, applicable OSHA regulations, and economics of product recovery. The emissions data collected during this review show no major difficulties in meeting the allowable NSPS limits.

2.0 INTRODUCTION

2.1 SCOPE OF THE REVIEW

The Clean Air Act Amendments of 1977 require that the Administrator of EPA review and, if appropriate, revise established standards of performance for new stationary sources (NSPS) at least every 4 years.[1] The purpose of this report is to document this review and to assess the need for revisions of the existing standards for lead-acid battery manufacture, based on developments that have occurred or are expected to occur within the industry. The information presented in this report was obtained from reference literature, discussions with industry representatives, trade organizations, process and control equipment vendors, EPA Regional Offices, and State and local agencies. Additional information was obtained from plant surveys, and responses to information requests under Section 114 of the Clean Air Act.[2]

The review conducted to assess the current NSPS for lead-acid battery manufacture included several areas, such as:

- new manufacturing processes (production of low maintenance or maintenance free batteries)
- technologies being used for compliance
- enforcement and compliance experiences.

2.2. NEW SOURCE PERFORMANCE STANDARDS

This section presents the current federal regulations for new sources of lead and visible emissions from lead-acid battery manufacture. A summary of the NSPS is first presented, followed by detailed discussions of the requirements, definitions, and specifications of the NSPS.

2.2.1 Background.

New source performance standards regulate emissions of air pollutants from new, modified, and reconstructed facilities in various industrial categories. The authority for the NSPS regulations is granted to the U.S. Environmental Protection Agency (EPA) under Section 111 of the Clean Air Act.[3]

The regulation for lead-acid battery manufacture is listed in Subpart KK of 40 CFR 60, (Code of Federal Regulations; Title 40-Protection of Environment; Part 60-Standards of Performance for New Stationary Sources; Subpart KK - Standards of Peformance for Lead-Acid Battery Manufacturing Plants). Subpart KK addresses specific requirements for this source category, but Subpart KK also incorporates the general requirements for any NSPS. These general requirements are listed in Subpart A (General Provisions) of 40 CFR 60.

2.2.2. Summary of the NSPS for Lead-Acid Battery Manufacture.

New source performance standards were promulgated by the EPA on April 16, 1982, limiting emissions of lead from new, modified, and reconstructed facilities at any lead-acid battery manufacturing plant which has the design capacity to produce in one day batteries which would contain, in total, an amount of lead equal to or greater than 5.9 Mg (6.5 tons). These standards apply to any affected facility which commences construction or modification after January 14, 1980.

The affected facilities for this standard are the grid casting facility, paste mixing facility, three-process operation facility, lead oxide manufacturing facility, lead reclamation facility, and other lead emitting operations. The emission limits are defined as follows:

Facility	Lead Emission Limit	Opacity
Lead oxide production	5.0 mg/Kg (0.010 lb/ton)*	0%
Grid casting	0.40 mg/dscm (0.000176 gr/dscf)	0%
Paste mixing	1.00 mg/dscm (0.00044 gr/dscf)	0%
Three-process operation	1.00 mg/dscm (0.00044 gr/dscf)	0%
Lead reclamation	4.50 mg/dscm (0.00198 gr/dscf)	5%
Other lead emitting operations	1.00 mg/dscm (0.00044 gr/dscf)	0%

* The emission limit for lead oxide production is expressed in terms of lead emissions per kilogram of lead processed.

Compliance is demonstrated by an initial performance test using EPA Reference Methods 9 and 12. The regulation includes monitoring and record keeping requirements, which will be discussed in detail in section 2.2.4.

2.2.3. Applicability of the Standards.[4]

2.2.3.1. Affected Facilities. The affected facilities included in this source category are the grid casting facility, paste mixing facility, three-process operation facility, lead oxide manufacturing facility, lead reclamation facility, and other lead emitting operations. These devices are defined as follows:

- The grid casting facility is the facility which includes all lead melting pots and machines used for casting the grid used in battery manufacturing.
- The paste mixing facility is the facility which includes lead oxide storage, conveying, weighing, metering, and charging operations; paste blending, handling, and cooling operations; and plate pasting, take-off, cooling, and drying operations.

- The three-process operation facility is the facility which includes those processes involved with plate stacking, burning or strap casting, and assembly of elements into the battery case.
- The lead oxide manufacturing facility is the facility which produces lead oxide from lead, including product recovery.
- The lead reclamation facility is the facility which remelts lead scrap and casts it into lead ingots for use in the battery manufacturing process, and which is not a furnace affected under Subpart L.
- Other lead emitting operations are any lead-acid battery manufacturing plant operations from which lead emissions are collected and ducted to the atmosphere and which are not part of a grid casting, lead oxide manufacturing, lead reclamation, paste mixing, or three-process operation facility, or a furnace affected under Subpart L.

2.2.3.2 Applicability Date. The NSPS applies if the construction or modification commenced after January 14, 1980, (the date of the original proposal of the regulation) for any affected facility. The term "commenced" is defined in the General Provisions to 40 CFR 60, (Section 60.2);

"Commenced means that an owner or operator has undertaken a continuous program of construction or modification or that an owner or operator has entered into a binding agreement or contractual obligation to undertake and complete, within a reasonable time, a continuous program of construction or modification."

2.2.3.3. Modification. While NSPS are intended primarily for newly constructed facilities, existing sources can become subject to an NSPS

through either "modification" or "reconstruction." These terms are defined in detail in the General Provisions for Part 60, (40 CFR 60.14 and 40 CFR 60.15).

An existing facility becomes subject to the NSPS under the modification provisions if there is any physical or operational change that causes an increase in the emission rate. A number of clarifications, exemptions, and exceptions to the modification provision are listed. The following actions by themselves are not considered to be modifications:

- routine maintenance, repair, and replacement
- production increases achieved without any capital expenditure
- production increases resulting from an increase in the hours of operation
- use of an alternative fuel if the existing facility was originally designed to accommodate such an alternative use
- addition or replacement of equipment for emission control (as long as the replacement does not increase emissions)
- relocation or change of ownership of an existing facility.

Also, the addition or modification of one facility at a source will not cause other unaltered facilities at that source to become subject to the NSPS.

2.3.3.4. Reconstruction. An existing facility becomes subject to the NSPS upon reconstruction regardless of any change in the rate of emissions. Reconstruction is defined as the replacement of components of an existing facility to the extent that the cumulative fixed capital cost of the new components exceeds 50 percent of the cost that would be required to construct a comparable entirely new facility.

2.2.4. Testing and Monitoring Requirements.[5]

The owner or operator of a facility subject to NSPS is required to conduct performance tests within a specified period after start-up, and thereafter from time to time as may be specified by the EPA. These performance tests are required in order to demonstrate that the standards are being met by the new device. General testing, monitoring, and reporting requirements are listed in the General Provisions for 40 CFR Part 60, (Sections 60.7, 60.8, and 60.13), while details specific to this source category ar found in Subpart KK, (Section 60.374).

The initial test of performance of a facility must be conducted within 60 days after the facility first achieves its maximum intended rate of operation, but not later than 180 days after the initial startup. Thirty days must be allowed for prior notice to the EPA, to allow the Agency to designate an observer to witness the test.

To demonstrate compliance with the standards limiting lead emissions, EPA Reference Method 12 is used to measure lead concentrations. The sampling time for each run shall be at least 60 minutes and the sampling rate shall be at least 0.85 dscm/h (0.53 dscf/min). Lead emissions from lead oxide manufacturing facilities, expressed in terms of mass emissions per mass of lead charged, is determined using the concentration of lead in the exhaust stream, the volumetric flow rate of the exhaust stream, and the lead feed rate to the facility. EPA Reference Method 9 is used to demonstrate compliance with the opacity regulations.

For any affected facility controlled by a scrubbing system, the pressure drop across the scrubbing system is to be measured and recorded at least once every 15 minutes. These records must be kept on file for at least two years. Pressure drop monitoring and recording is also required during all performance testing.

2.3 REFERENCES

1. Clean Air Act as Amended, August 1977. 42 U.S.C. Title I -- Air Pollution Prevention and Control. Part A -- Air Quality and Emission Limitations: Section 111 -- Standards of Performance for New Stationary Sources. Washington, DC.

2. Reference 1, Section 114 -- Inspections, Monitoring, and Entry.

3. Reference 1.

4. U.S. Environmental Protection Agency. Code of Federal Regulations. Title 40, Part 60. Office of the Federal Register. Washington, DC July 1, 1985.

5. Reference 4.

3.0 THE LEAD-ACID BATTERY INDUSTRY

3.1 GENERAL

The largest single use of lead in the United States is in the manufacture of lead-acid, or secondary, storage batteries. There are approximately 90 lead-acid battery manufacturing facilities in the United states, scattered throughout the country.[1,2] These facilities are generally located in highly urbanized areas near markets for their batteries, and can range in size from one small plant producing a single type of battery, to a large complex of several plants producing many different types of batteries. Some of the larger facilities have secondary smelting operations, or lead oxide production facilities, or both; smaller firms tend to purchase the lead constituents from outside vendors. Table 3-1 lists U.S. lead-acid battery manufacturing facilities as of October, 1988.

3.1.1 Industry Profile

Two major types of lead-acid storage batteries are manufactured in the United States: 1) starting-lighting-ignition (SLI) batteries, used in automobiles, golf carts, and aircraft, SIC (Standard Industrial Classification) 36911, and 2) industrial storage batteries for low-voltage power systems, industrial fork-lift trucks, and the like, SIC 36912.

SLI units by far account for the majority of the North American Battery Industry.[8] SLI battery shipments in 1987 were valued at $2.10 billion (1982$)[9], accounting for 0.055 percent of the 1987 gross national product (GNP) of $3808 billion (1982 $)[9].

The battery industry receives lead from two sources: mines and secondary lead smelters. United States mine production of recoverable lead in 1985 was 413,955 Mg (456,303 tons).[10] Secondary lead recovery in 1985 was 594,200 Mg (654,987 tons).[10] The storage battery industry consumed 853,824 Mg (941,164 tons) of lead in 1986.[11] Lead consumption by individual products in the years 1982 through 1986 is summarized in Table 3-2.

TABLE 3-1. UNITED STATES LEAD ACID BATTERY MANUFACTURING FACILITIES [1,2,3,4,5,6,7]

COMPANY	MANUFACTURING LOCATIONS
Acme Battery Manufacturing Co. St. Louis, MO	St. Louis, MO
Alaska Husky Battery, Inc. Anchorage, AK	Anchorage, AK
AMP King Battery Co. San Francisco, CA	San Francisco, CA
Atlantic Battery Company, Inc. Watertown, MA	Watertown, MA
Battery Builders, Inc. Naperville, IL	Naperville, IL
Bell City Battery Manufacturing Co. Belleville, IL	Belleville, IL
C&D Power Systems, Inc. Plymouth Meeting, PA	Conyers, GA Huguenot, NY, Leola, PA
Car-Go Battery Company Denver, CO	Denver, CO
Continental Battery Manufacturing Co. Dallas, TX	Dallas, TX
Crown Battery Manufacturing Co. Fremont, OH	Fremont, OH
Daniell Battery Manufacturing Co. Baton Rouge, LA	Baton Rouge, LA
Delco Remy Division of G.M. Anderson, IN	Anaheim, CA Fitzgerald, GA Muncie, IN Olathe, KS New Brunswick, NJ
Douglas Battery Manufacturing Co. Winston-Salem, NC	Winston-Salem, NC
Dyno Battery Co. Seattle, WA	Seattle, WA

TABLE 3-1. UNITED STATES LEAD ACID BATTERY MANUFACTURING FACILITIES (Continued)

COMPANY	MANUFACTURING LOCATIONS
East Penn Manufacturing Co., Inc. Lyon Station, PA	Lyon Station, PA
Electro-Lite Battery Co. Chattanooga, TN	Chattanooga, TN
Estee Battery Co. Commerce, CA	Commerce, CA
Exide Corporation Reading, PA	City of Industry, CA Visalia, CA Burlington, IA Manchester, IA Frankfort, IN Logansport, IN Salina, KS Richmond, KY Allentown, PA Hamburg, PA Reading, PA Greer, SC Sumter, SC
Farmland Industries, Inc. Kansas City, MO	Kansas City, MO
Gates Energy Products, Inc. Denver, CO	Denver, CO Warrensburg, MO
GNB Incorporated St. Paul, MN	Ft. Smith, AR City of Industry, CA Sun Valley, CA Orlando, FL Columbus, GA Kankakee, IL Kansas City, KS Leavenworth, KS Shreveport, LA Florence, MS Salem, OR Dunmore, PA Memphis, TN Dallas, TX Lynchburg, VA

TABLE 3-1. UNITED STATES LEAD ACID BATTERY MANUFACTURING FACILITIES (Continued)

COMPANY	MANUFACTURING LOCATIONS
Interspace Battery Co. West Covina, CA	West Covina, CA
Johnson Controls, Inc. Milwaukee, WI	Fullerton, CA Middletown, DE Tampa, FL Geneva, IL Louisville, KY Owosso, MI St. Joseph, MO Winston-Salem, NC Holland, OH Canby, OR Garland, TX Bennington, VT Milwaukee, WI
K.W. Battery Company Skokie, IL	Skokie, IL
Miami Battery Manufacturing Co. Miami, FL	Miami, FL
Mule Battery Company, Inc. Providence, RI	Providence, RI
New Castle Battery Manufacturing Co. New Castle, PA	New Castle, PA
Norton Battery Manufacturing, Inc. Rialto, CA	Rialto, CA
Old Ironsides, Inc. Campbellsport, WI	Campbellsport, WI
Pilot Batteries, Inc. Kankakee, IL	Kankakee, IL
Powerstone Batteries Inc./Keystone Batteries Fairfield, CA	Fairfield, CA
Prime Battery Manufacturing Co. Anderson, IN	Anderson, IN
Prime Battery Mfg. Co./West Kentucky Battery Benton, KY	Benton, KY

TABLE 3-1. UNITED STATES LEAD ACID BATTERY MANUFACTURING FACILITIES (Continued)

COMPANY	MANUFACTURING LOCATIONS
Ray Glass Batteries, Inc. Thomasville, GA	Thomasville, GA
Sound Battery Company, Inc. Tacoma, WA	Tacoma, WA
Standard Industries San Antonio, TX	San Antonio, TX
Standard Storage Battery Co. St. Paul, MN	St. Paul, MN
Surrette Storage Battery Co. Tilton, NH	Tilton, NH
Teledyne Battery Products Redlands, CA	Redlands, CA
Trojan Battery Co. Santa Fe Springs, CA	Santa Fe Springs, CA Lithonia, GA
U.S. Battery Manufacturing Co. Signal Hill, CA	Signal Hill, CA Evans, GA
Voltmaster Company, Inc. Corydon, IA	Corydon, IA

TABLE 3-2

CONSUMPTION OF LEAD IN UNITED STATES[11] BY PRODUCT CATEGORY

Lead Content – Short Tons

	1982	1983	1984	1985	1986
Metal Products Total	**965,436**	**1,068,093**	**1,131,327**	**1,104,437**	**1,102,160**
Ammunition – shot & bullets	48,763	48,168	52,721	55,372	48,923
Bearing metals total	6,761	6,442	5,155	5,943	6,089
Machinery except electrical	1,340	1,414	985	366	640
Electrical & electronic equipment	106	155	280	274	295
Motor vehicles & equipment	2,227	3,095	3,194	4,271	4,174
Other transportation equip.	3,088	1,778	696	1,032	980
Brass & bronze – billets & ingots	12,513	12,103	7,665	8,623	9,241
Cable covering – power & communication	16,734	11,580	13,525	17,087	18,807
Calking lead – building construction	4,471	3,937	4,372	2,522	2,021
Casting metals total	27,626	17,907	17,422	21,399	11,319
Electrical machinery & equipment	884	1,408	1,818	2,030	1,321
Motor vehicles & equipment	724	761	840	1,124	1,496
Other transportation and equipment	26,018	6,214	8,723	12,285	7,485
Nuclear radiation shielding	(c)	9,524	6,041	5,960	1,017
Pipes, traps & other extruded products total	9,567	14,348	15,055	13,068	13,825
Building construction	9,100	14,078	12,534	12,629	13,117
Storage tanks, process vessels, etc.	467	270	2,521	439	708
Sheet lead total	16,710	15,702	16,165	16,349	19,043
Building construction	11,011	12,058	14,746	12,562	13,858
Storage tanks, process vessels, etc.	138	143	176	1,766	2,247
Medical radiation shielding	5,561	3,501	1,243	2,021	2,938
Solder total	31,416	31,405	26,941	23,560	23,482
Building construction	7,430	8,327	7,212	4,926	4,975
Metal cans & shipping containers	8,223	5,667	3,610	3,190	2,258
Electronic components & accessories	6,577	6,255	5,909	4,615	4,776
Other electrical machinery & equipment	2,978	2,681	2,454	2,863	2,421
Motor vehicles & equipment	6,208	8,475	7,756	7,966	9,052
Storage battery grids, posts, etc. total	344,562	421,453	469,915	516,703	538,955
Storage batteries – SLI automotive	313,891	(b)	(b)	(b)	(b)
Storage batteries – industrial & traction	30,671	(b)	(b)	(b)	(b)
Storage battery oxides total	431,820	468,000	484,181	410,273	402,209
Storage batteries – SLI automotive	410,150	(b)	(b)	(b)	(b)
Storage batteries – industrial & traction	21,670	(b)	(b)	(b)	(b)
Terne metal – motor vehicles & equipment	3,624	5,574	6,695	5,609	3,855
Type metal – printing & allied industries	3,049	2,800	2,383	1,789	337
Other metal products (a)	7,820	8,674	9,132	6,140	4,054
Other Oxides Total	**67,093**	**75,722**	**84,666**	**80,208**	**76,640**
Paints	14,743	17,022	19,136	15,494	15,873
Glass & ceramic products	38,059	43,729	50,819	48,663	44,953
Other pigments	14,291	14,971	14,711	16,051	15,814
Gasoline Additives	**131,433**	**98,236**	**87,009**	**50,369**	**31,461**
Miscellaneous Uses	**21,471**	**23,938**	**27,521**	**30,764**	**29,671**
Total	**1,185,433**	**1,265,989**	**1,330,523**	**1,265,778**	**1,239,932**

Total United States battery shipments reached 75.7 million SLI units in 1986.[12] Figures 3-1 and 3-2 show the shipments of SLI units (replacement, original equipment, and exports) since 1942. Shipments of replacement units have shown steady growth over the past ten years, accounting for nearly 80 percent of the 1986 SLI battery shipments.[12] Tables 3-3 and 3-4 summarize SLI battery use from 1982 to 1986. Approximately 80 percent of the SLI units are used in automobiles.[13] Preliminary values for 1987 United States battery shipments (not including exports) are 59.5 million replacement units and 13.1 million original equipment units.[14]

The other major type of lead-acid storage battery manufactured in the United States is industrial storage batteries. There are two major categories of industrial batteries, motive power and stationary. As of 1985, the motive power sector accounted for annual sales in the range of $200 million, with approximately $175 million in annual sales being attributed to the stationary sector.[18] At that time, over 85 percent of the motive power category market was for forklifts and material handling equipment, and over 75 percent of the stationary market was for telecommunications and UPS (uninterrupted power source).[18]

Growth is expected in the future for both the SLI and industrial battery markets. SLI battery shipments are expected to increase 4.5 percent annually between 1987 and 2000.[19] In 1985, it was estimated that the industrial battery market would experience annual growth of two to five percent through 1989.[18] The trend is toward fewer, larger plants, with the already small number of small plants decreasing.[20]

3.1.2. Process Description

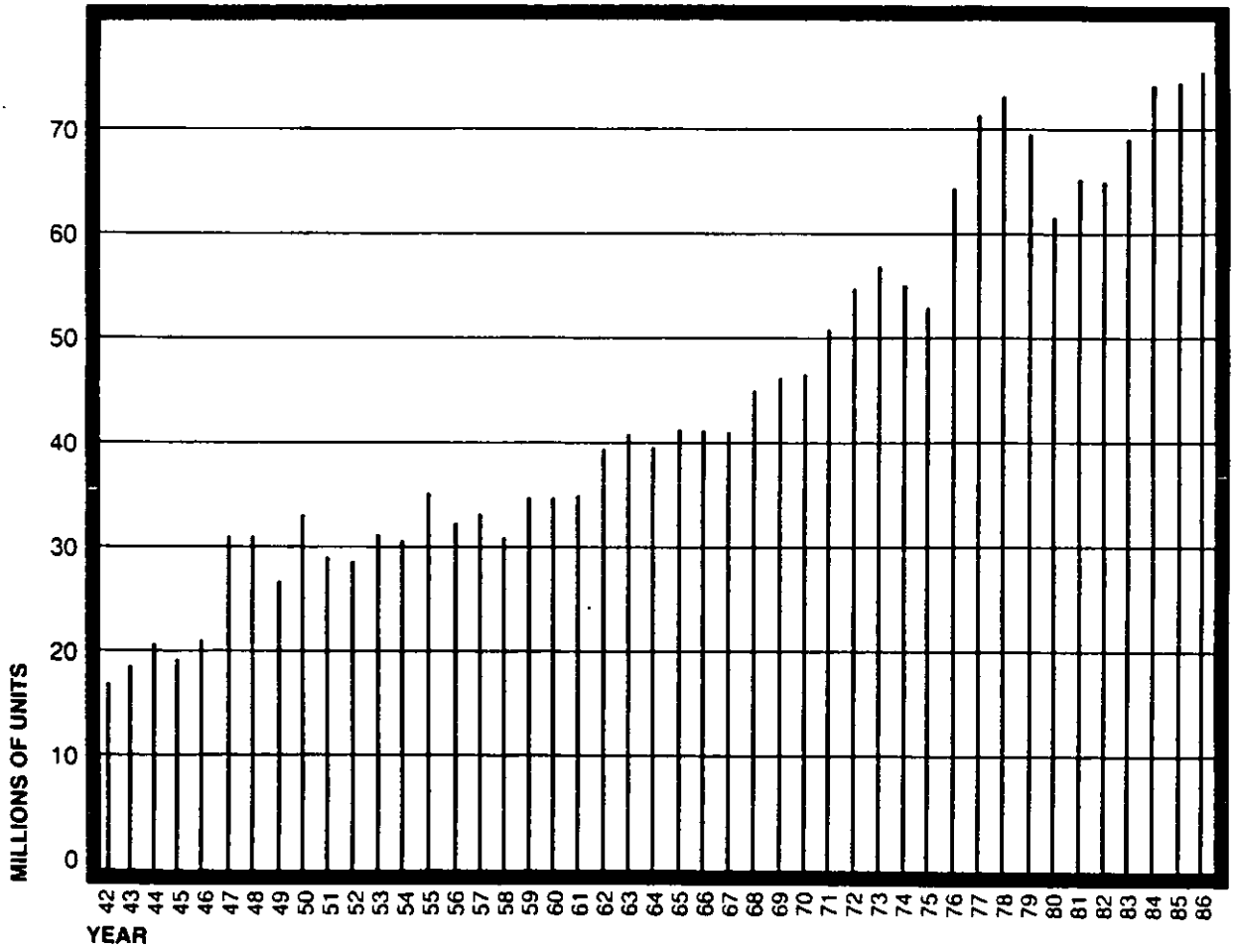
A lead-acid battery consists of any number of cells, depending on the voltage of the battery. Stationary batteries contain up to 120 cells (240 volts), whereas automobile batteries generally contain 3 or 6 cells (6 or 12 volts). Lead acid storage batteries range in size and weight. The electrodes are made of lead, and the electrolyte consists of a solution of sulfuric acid and water. The cathode consists of lead peroxide and the anode consists of porous or spongy lead. Both the anode and the cathode are converted to lead sulfate when the battery is discharging. Many complicated chemical reactions take place inside a lead-oxide battery during discharge, resulting in

FIGURE 3-1

U.S. TOTAL SHIPMENTS* OF S.L.I. BATTERIES[15]

MILLIONS OF UNITS

1942	16.5	**1951**	29.7	**1960**	34.4	**1969**	46.4	**1978**	73.2
1943	18.1	**1952**	28.4	**1961**	35.2	**1970**	46.9	**1979**	69.3
1944	20.4	**1953**	31.3	**1962**	39.0	**1971**	50.6	**1980**	61.7
1945	19.0	**1954**	30.8	**1963**	41.0	**1972**	55.5	**1981**	65.5
1946	21.0	**1955**	35.4	**1964**	39.1	**1973**	57.1	**1982**	64.6
1947	31.2	**1956**	32.3	**1965**	40.8	**1974**	55.6	**1983**	69.0
1948	31.0	**1957**	33.4	**1966**	41.6	**1975**	52.9	**1984**	74.7
1949	26.2	**1958**	30.6	**1967**	40.2	**1976**	64.1	**1985**	74.4
1950	32.9	**1959**	34.4	**1968**	45.0	**1977**	70.7	**1986**	75.7



* Shipments represent rounded sum of replacement, original equipment, and export shipments.

FIGURE 3-2

BREAKDOWN OF U.S. BATTERY SHIPMENTS (1942-86)[16]

YEAR	REPLACEMENT	ORIGINAL EQUIPMENT	EXPORT 12V, 6V	YEAR	REPLACEMENT	ORIGINAL EQUIPMENT	EXPORT 12V, 6V
	MILLIONS OF UNITS			1964	29.6	9.3	.2
1942	15.2	1.0	.3	1965	29.5	11.1	.2
1943	17.0	.7	.4	1966	31.1	10.3	.2
1944	19.1	.7	.6	1967	31.0	9.0	.2
1945	17.6	.7	.7	1968	33.8	10.7	.5
1946	17.5	3.1	.4	1969	35.5	10.1	.8
1947	25.8	4.8	.6	1970	37.9	8.2	.8
1948	25.1	5.3	.6	1971	39.1	10.6	.9
1949	19.4	6.3	.5	1972	43.2	11.3	1.0
1950	24.4	8.0	.5	1973	43.5	12.6	1.0
1951	22.2	6.8	.7	1974	44.4	10.1	1.1
1952	22.5	5.5	.4	1975	42.6	9.0	1.3
1953	23.6	7.3	.4	1976	49.2	13.4	1.5
1954	23.8	6.6	.4	1977	54.6	14.7	1.4
1955	25.8	9.2	.4	1978	56.4	15.2	1.6
1956	25.0	6.9	.4	1979	53.7	14.4	1.2
1957	25.9	7.2	.3	1980	50.1	10.0	1.6
1958	25.3	5.1	.2	1981	53.6	10.0	1.9
1959	27.5	6.7	.2	1982	54.2	8.4	2.0
1960	26.3	7.9	.2	1983	56.1	10.8	2.1
1961	28.3	6.7	.2	1984	59.3	12.8	2.6
1962	30.5	8.2	.3	1985	58.7	13.5	2.2
1963	31.7	9.1	.2	1986	60.3	13.3	2.1

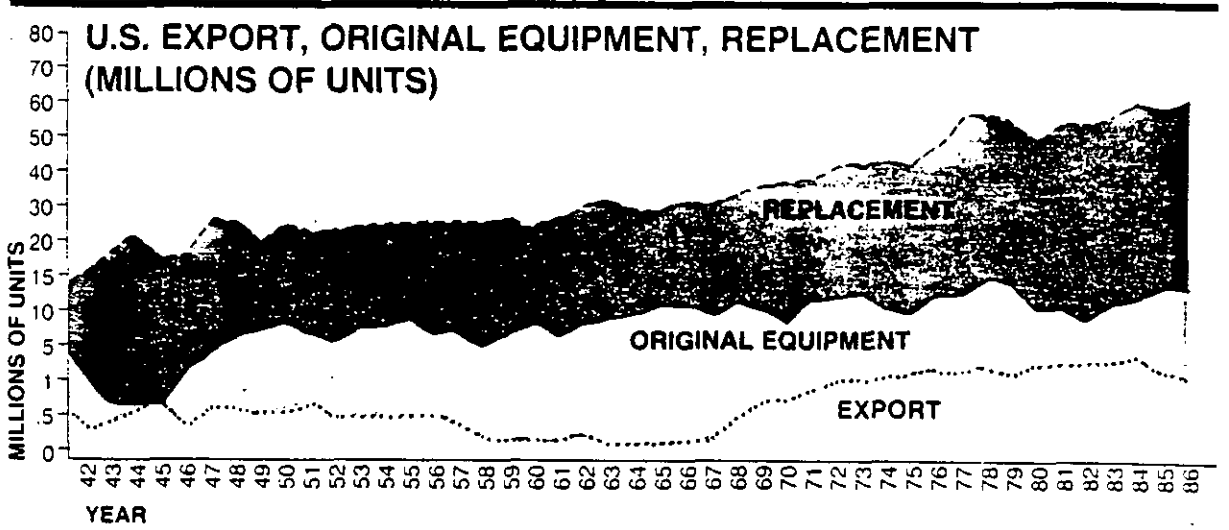
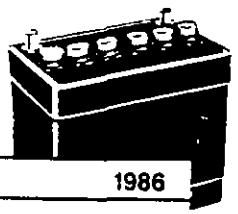


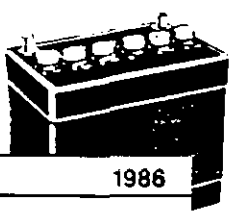
TABLE 3-3

UNITED STATES REPLACEMENT BATTERY SHIPMENTS: PRODUCT CATEGORY (000's) [13]



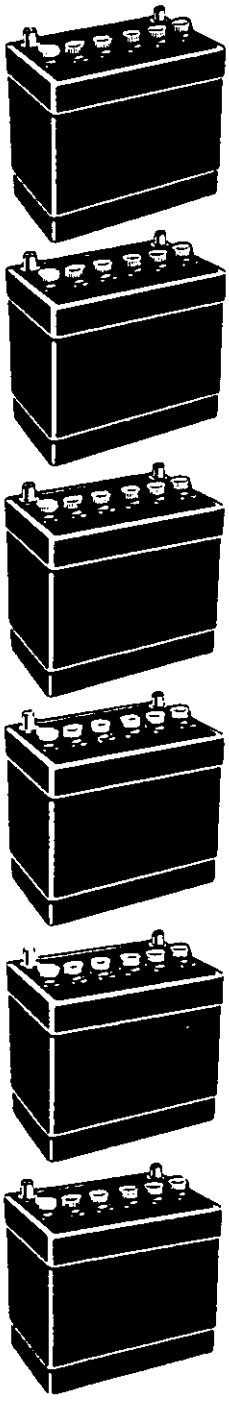
PRODUCT CATEGORY	1982	1983	1984	1985	1986
Passenger Car:					
12 Volt	44,207.8	45,080.0	47,354.5	46,685.6	47,682.1
6 Volt	1,460.7	1,282.7	1,234.0	1,095.0	960.8
Heavy Duty:					
12 Volt	2,002.9	2,379.6	2,757.6	2,766.0	3,031.1
6 Volt	1,719.7	1,705.0	1,775.2	1,656.8	1,557.5
Special Tractor	751.3	853.8	878.8	785.6	842.5
Marine	1,414.4	1,770.5	2,003.9	2,097.3	2,442.5
General Utility	1,156.2	1,395.7	1,477.2	1,591.4	1,748.4
Golf Car	866.2	915.0	1,175.7	1,270.9	1,303.3
Miscellaneous	255.7	329.7	260.2	324.1	315.6
Total	53,834.9	55,712.0	58,917.1	58,272.7	59,883.8

UNITED STATES ORIGINAL EQUIPMENT BATTERY SHIPMENTS: PRODUCT CATEGORY (000's)



PRODUCT CATEGORY	1982	1983	1984	1985	1986
Passenger Car:					
12 Volt	7,384.5	9,576.6	10,936.0	11,656.9	11,320.1
6 Volt	31.2	34.5	12.3	12.1	7.7
Heavy Duty:					
12 Volt	451.1	499.9	838.2	667.0	716.0
6 Volt	80.9	44.7	52.5	42.6	33.8
Special Tractor	28.8	32.0	43.1	29.5	16.8
Marine	9.7	4.6	5.3	6.7	28.9
General Utility	319.5	473.8	669.7	748.1	778.0
Golf Car	67.6	150.2	208.1	303.6	370.7
Miscellaneous	0.0	0.0	0.0	0.0	0.0
Total	8,373.3	10,816.3	12,765.2	13,466.5	13,272.0

TABLE 3-4



U.S. BATTERY SHIPMENTS [17]

REPLACEMENT AND ORIGINAL EQUIPMENT SHARES BY PRODUCT CATEGORY (%'s)

	1982	1983	1984	1985	1986
PRODUCT CATEGORY	%R / %OE	%R / %OE	%R / %OE	%R / %OE	%R / %OE
Passenger Car, Light Commercial – 12 V	86/14	82/18	81/19	80/20	81/19
6 V	98/2	97/3	99/1	99/1	99/1
Heavy Duty Commercial 12 V	82/18	83/17	77/23	81/19	81/19
6 V	96/4	97/3	97/3	97/3	98/2
Special Tractor	96/4	96/4	95/5	96/4	98/2
Marine	99/1	100/0	100/0	100/0	99/1
General Utility	78/22	75/25	69/31	68/32	69/31
Golf Car	93/7	86/14	85/15	81/19	78/22

neutralization of the two plates and weakening of the electrolytic solution by formation of water. Figure 3-3 shows the components of a battery.

The electrodes, or plates, consist of two parts: (1) an inactive lead grid, which provides mechanical support for the active portion (the plate) and a conductive path for the electric current, and (2) a lead oxide sulfate paste, which is applied and bonded to the grids. Other materials in the lead-acid battery include plastic separators or envelopes, and the outer case materials, which are usually vulcanized rubber, polypropylene, nylon, or acrylics. Figure 3-4 shows the arrangement of battery components in an element.

Consumer attention has recently been directed toward the waterless or "maintenance free" batteries. These batteries are typically supplied without vent plugs or provisions for adding water. Though they appear to be totally sealed, they are always vented in some way, usually by small holes in the top of the battery case. These batteries are practically identical to the conventional battery except in appearance; they all use lead-lead peroxide plates in a sulfuric acid electrolite. There are subtle differences in the lead alloy used in some of the plates (usually a substitution of calcium for the antimony) and generally they do consume so little water during normal operation that water addition is usually unnecessary during the life of the battery. However, manufacturing processes for these batteries, and the attendant emissions, are for all practical purposes identical to those for the conventional battery. Therefore, this document makes no distinction between this style of battery and conventional batteries.

Lead oxide (gray or black lead) is used in preparing the active materials. Many battery plants prepare the oxide in-house, and several processes are used.

A process flow diagram for the manufacture of lead-acid storage batteries is shown in Figure 3-5. As the figure indicates, this study encompasses only the battery manufacturing process and production of lead oxide (PbO); it does not include lead smelting operations, which are covered by separate new source performance standards.

Battery manufacturing begins with grid casting and paste mixing. The grids are generally cast in doublets (two grids per casting) from molten lead to which calcium or antimony has been added to provide hardness. These grids

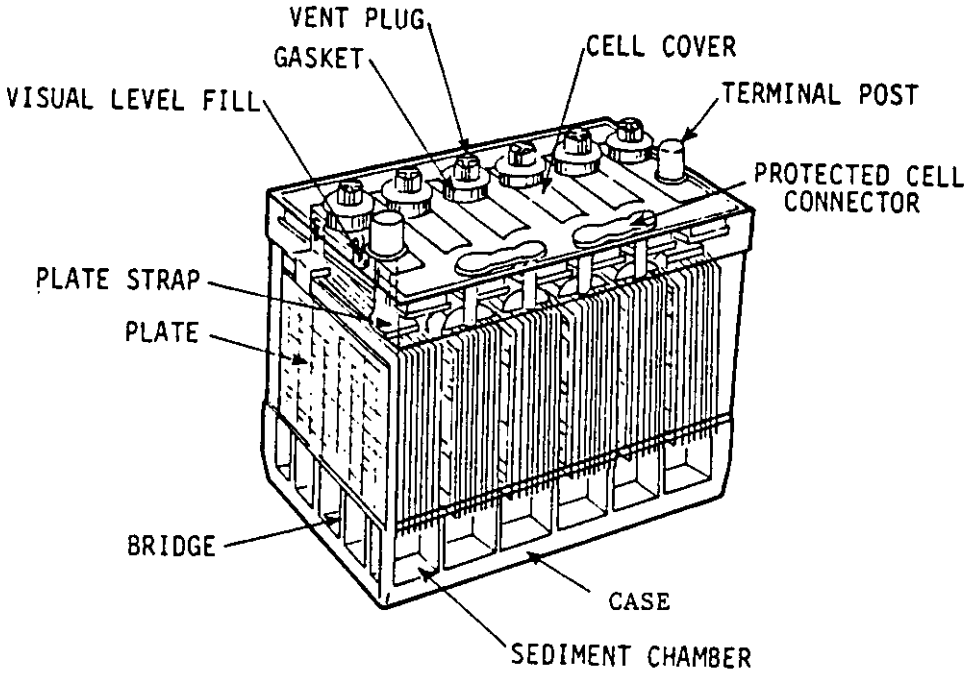


FIGURE 3-3. A lead-acid storage battery. [21]

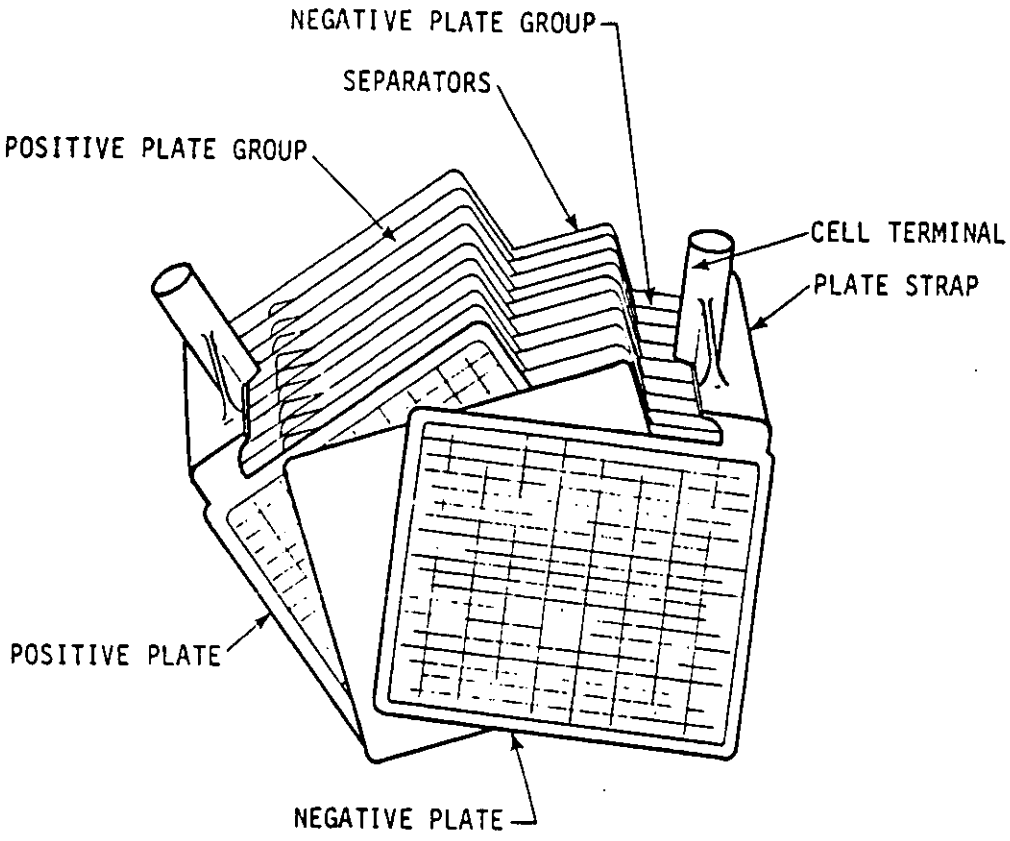


FIGURE 3-4. Components of a battery element [22] (shown pulled apart).

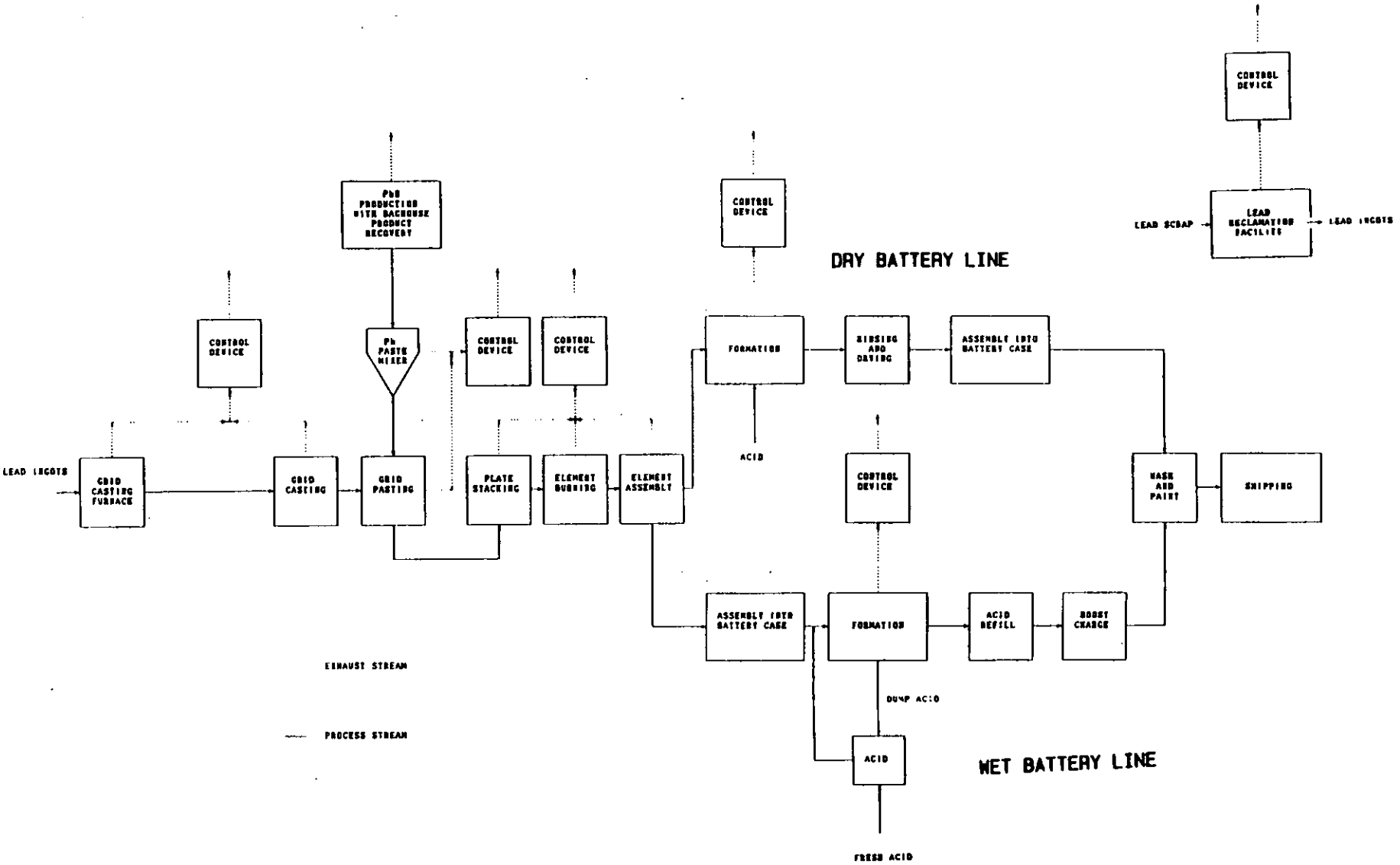


FIGURE 3-5. Process Flow Diagram

are coated with either positive or negative paste, formed (a process discussed later), cured, cut into two separate grids (a process called slitting) and then sent to be assembled into batteries.

Except for the lead oxide manufacturing facility, the particulate pollutant catch from the pollution control systems, whether wet or dry, is reclaimed by a lead smelter. The particulate captured from the lead oxide manufacturing operation is used in the paste mixer.

3.2 GRID CASTING

Techniques for casting of grids vary with the alloy used, the type of molds, and mold preparation before casting. Molten lead alloy ingots are melted in electric or gas-fired lead pots at approximately 370°C (700°F).[23] The furnace is often equipped with a hood to vent the fumes to a control device or to the atmosphere.

In some grid casting operations, melting pots are attached directly to the casting machines. The molten lead flows from the pots directly into the molds, where the grids are formed and then are ejected, trimmed, and stacked. A newer type of casting machine produces a continuous strip of grids, rather than individual 2-grid panels, which is wound on a reel, or fed directly into the pasting line.[24, 25, 26] Some facilities feed the casting machines from a central pot furnace, from which the molten lead is either pumped or fed by gravity. Pumping may cause air to be entrained in the molten lead, resulting in problems at the molding machines. Entrained air is not a problem with grid casting machines that are fed by gravity flow.

Emissions from the grid casting operations are lower than emissions from some of the other facilities in a battery manufacturing plant. Some manufacturers control emissions from this operation and others do not. Exhausts from the grid casting furnace are usually vented to the atmosphere to protect workers from the lead emissions. The areas around the casting machines are generally unvented. Testing of a grid casting facility during the original NSPS development project indicated uncontrolled lead concentrations ranging from 0.00039 gr/dscf to 0.0026 gr/dscf.[27]

Another process for grid production is called "expanded metal." A thin, narrow strip of lead "sheet" first has small slits punched into it, and then is expanded into a continuous strip of grids.[28] This strip often feeds directly into a pasting line.

3.3 PASTE MIXING

The paste mixing operation, a batch-type process, is done with a muller, Day, or dough-type mixer. From 272 to 1361 kg (600 to 3000 lb) of lead oxide is added to the mixer; water and sulfuric acid are then added, and the mixture is blended to form a stiff paste.[27] Because reactions of the process are exothermic, mixers are usually water-jacketed and air-cooled to prevent excessive temperature buildup which causes the paste to become stiff and difficult to apply to the grids. Approximately 1 weight percent of expander (generally a mixture of barium sulfate, carbon black, and organics) is added to batches of paste for negative plates.[27] Carbon black also provides color identification for the negative paste. A duct system vents the moisture-laden exhaust gases from the mixer. The duration of the mixing cycle depends on the type of mixer, ranging from 15 minutes to an hour.[27] Typical formulas for positive and negative pastes are shown in Table 3-5.

TABLE 3-5. TYPICAL FORMULAS FOR POSITIVE AND NEGATIVE BATTERY PASTES[29]

Ingredient	Positive	Negative
Lead oxide, kg (lb)	272 (600)	272 (600)
Dynel fiber, kg (lb)	0.068 (0.15)	0.068 (0.15)
Expander, kg (lb)	None	1.90 (4.2)
Water, liter (quart)	23 (25)	26 (28)
H_2SO_4 (1.375-1.400 s.g.), liter (quart)	25 (26)	21 (22)

The major emissions from paste mixing occur during charging of the dry ingredients to the mixer. The high-emissions phase is about the first 10 minutes of a 60-minute mixing cycle. The emissions are in the form of lead oxide, with small amounts of other paste constituents such as Dynel, organics, and carbon black.

Source tests were performed during the original NSPS development project at a facility where the mixer was vented to a baghouse during materials charging and to a low energy impingement entrainment scrubber during mixing. The baghouse also controlled the plate slitting operation, and the scrubber also controlled the grid casting operation. Two tests run at the baghouse inlet during charging showed uncontrolled lead emissions of 0.050 and 0.015 gr/dscf. A single test to determine emissions from the slitting process indicated uncontrolled lead emissions of 0.0188 gr/dscf.[29]

The paste is next applied to the grids, they are flash dried, and then stacked and sent to curing ovens. These ovens most often operate under conditions of high humidity, but occasionally supply only dry heat, depending upon the desired plate characteristics. Grids produced by continuous casting or expanded metal are pasted while still in strip form, and cut into individual grids prior to drying and curing. Some facilities apply a layer of tissue paper to each side of the continuous wet pasted strips of grids before cutting them. This tissue paper helps hold the paste in place, and decreases emissions.[28]

3.4 THREE-PROCESS OPERATION - STACKING/BURNING/ASSEMBLY

After the plates are cured, they are normally sent to the three-process operation, which includes plate stacking, burning, and assembly of elements into the battery case. Most plants are equipped with an associated plate slitter, which cuts the double plates apart. Depending upon the individual plant's design, the plate slitter can be considered part of the paste mixing facility, three-process facility, or the "other lead emitting" facility. At some plants the plates are parted by hand, after which they are stacked in an alternating positive and negative block formation with plastic separators sandwiched between each plate to insulate the oppositely charged plates while permitting free ionic flow. Many plants now insert the positive plates in envelopes, and then stack, rather than using separators. These envelopes are

made of several materials, one of which is PVC. Machines have been designed to stack the plates and separators automatically, or envelope and stack, but hand stacking is still done at some plants. In some instances, the battery plates are wrapped in a fiberglass mat before stacking. This mat will absorb the acid in the battery, and help minimize spilling or leakage should the unit overturn.

Leads (pronounced leeds) are welded to the tabs of each positive plate and each negative plate, fastening the assembly (element) together. Then a positive and a negative terminal are welded to the element. This is the burning operation. A more common alternative to the welding or burning process is the cast-on-strap process, in which molten lead is poured around and between the plate tabs to form the connections and terminals. The completed elements are then assembled into battery cases either before wet formation or after dry formation. The difference between wet and dry formation is explained in Section 3.5.

Most lead emissions are generated during plate stacking and burning or casting operations. Handling of plates between process steps also generates considerable lead emissions. Typically, operators straighten stacks by striking them against a grated surface. Upon impact, particles of paste become airborne. Work areas are generally vented to collect these particles and to protect the health of the workers.

Source tests during the original NSPS development project indicated that uncontrolled lead emissions from the three-process operation ranged from 0.0087 to 0.023 gr/dscf.[30] These tests indicated total three-process emissions, since testing of each process step in the facility was not feasible.

The post building operation is often included in the three-process facility. This is the attachment of the positive and negative terminal posts to the outside of the battery case. Depending upon the individual plant's design, this operation can be considered part of either the three-process facility, or the "other lead emitting" facility.

3.5 FORMATION

During formation, the inactive lead oxide-sulfate paste is chemically converted into an active electrode. Formation is essentially an oxidation-reduction reaction, in which the lead oxide in the positive plates is oxidized to lead peroxide and in the negative plates is reduced to metallic lead. This

is accomplished by placing the unformed plates in a dilute (10-25 percent)[30] sulfuric acid solution and connecting the positive plates to the positive pole of a direct current (dc) source and the negative plates to the negative pole of the dc source.

During the formation process, hydrogen is released in the form of small bubbles, which carry sulfuric acid with them as they break through the surface of the solution and enter the atmosphere above the container. The process, therefore, is a source of sulfuric acid mist emissions.

Charging rate and temperature affect the emissions of sulfuric acid mist, which generally increase with increasing temperature and rate of charge. Also, as the process nears the end of the formation cycle, the release of hydrogen bubbles increases. Emissions therefore increase with time.

3.5.1 Wet Formation Process

In the manufacture of lead-acid batteries using the wet (or "jar") formation process, the elements are assembled into the case before forming. It is common practice to place the cells in the battery case, place the lid on the battery, and add sulfuric acid. The plates are then formed within the battery case. After formation, additional acid is added to completely fill the battery, or the spent acid is dumped from the battery and new acid is added. Often, the units require an additional boost charge. Then the unit is ready for use, requiring only decoration and manufacturer's markings.

Wet formation generally takes 1 to 4 days. Most plants use a 36- to 48-hour forming cycle. The charging rate is high during the first 24 to 36 hours and lower during the remaining 12 hours. The ampere rates depend on the battery size.[31]

Sulfuric acid mist emissions from wet formation processes are usually not controlled or ducted to a stack. Therefore, no data are available on quantitative emissions from the wet formation process. However, because of the slow charging rate, the fact that there is a lid or cap on the battery during formation, and the absence of a strong acid odor at wet formation processes, emissions from the process are believed to be small.

3.5.2 Dry Formation Process

The dry (or "tank") formation process can be performed in several ways. In some cases, the plates are individually formed in tanks of sulfuric acid and

then assembled. Most often, however, the plates are assembled into elements before formation. The completed elements are then formed by placing the elements in large tanks of sulfuric acid and making an electrical connection to form the elements. Some manufacturers place the assembled elements directly in the battery case for formation. Thereafter, they remove the formed elements, dump the acid, rinse and dry the cases and elements, and reassemble them. The batteries are shipped dry, or refilled with acid at this point. Dry formation typically lasts 16 hours, with the plates or elements loaded into tanks during the day shift, and formed during the evening and night shifts. Occasionally, following dry formation, the plates or elements are cured in dry charge ovens prior to reassembly.[32] This process, however, is becoming less prevalent within the battery industry.

When forming batteries by the dry formation process, the acid mist can be controlled by the use of mist eliminators or scrubbers, or by some sort of cover over the acid bath or receptable. The cover is often a surface foaming agent such as Alkonol or Dupanol.

Two dry formation processes were sampled by EPA during the original NSPS development process. The first test did not yield any valid results because the process was not operating properly (one of the three formation circuits was inoperative). Also, acid mist emissions from the control device were not detectable when EPA Reference Method 8 was used to collect emissions over a two hour sampling period. The second EPA test showed uncontrolled acid mist emissions toward the end of the cycle to average 66 mg/m^3 (0.029 gr/dscf, 0.70 lb/hr).[33]

3.6 LEAD OXIDE PRODUCTION

The lead monoxide used in battery paste production is called lead oxide, black oxide, or battery oxide. The typical lead oxide contains approximately 70 percent PbO.[33] The balance is free metallic lead. Lead oxide is produced either by the ball mill process or Barton process.

Each of the lead oxide manufacturing processes incorporates a baghouse for product recovery, since the value of the product is relatively high. Air-to-cloth ratios of these fabric filters generally are about 3/1, whether the filters are designed for product recovery or for emissions control. As a result, emissions from the lead oxide production facility are lower than emissions from some of the other facilities at a battery manufacturing plant.

3.6.1 Ball Mill Process

In the ball mill process, oxidation is initiated by heat generated by tumbling pure lead pigs (ingots) in a mill. During the tumbling action the lead oxide that forms on the surface of the lead pigs and fine particles of unoxidized lead are broken off, forming a fine dust that is removed from the mill by a circulating air stream. The larger fraction is ground further in a hammermill. Air flow through the mill, the temperature of the charge, and the weight of the charge are controlled to produce a specified ratio of lead oxide to finely divided metallic lead. The product is conveyed by totally enclosed screw conveyors, or pneumatic systems, to storage bins. Enough product is entrained in the mill exhaust gases to justify gas cleaning for product recovery. Fabric filtration is also a part of the process.

Tests performed during the original NSPS development project yielded average lead emissions of 0.475 g/kg (0.0095 lb/ton) of lead input.[34] This plant operated two ball mill production lines equipped with fabric filters, one with an air-to-cloth ratio of 2/1 and the other with a ratio of 4/1. The filters were vented to a common stack.

3.6.2 Barton Process

In the Barton process, molten lead is fed to a circular pot and stirred rapidly. A series of baffles within the pot atomize the lead into extremely small droplets, which are then oxidized by an air stream directed over the surface of the molten lead. The resulting lead oxide is conveyed by the air stream to a fabric filter where the product is removed. The particle-size distribution, apparent density, and reactivity of the oxide are controlled by the temperature maintained in the pot and by the volume and speed of the air stream that carries away the reacted products. The larger particles are captured in a cyclone prior to the fabric filter and pulverized in a hammermill. They are then conveyed and collected by the fabric filter.

3.7 LEAD RECLAMATION

Lead reclamation is the process whereby relatively clean lead scrap is remelted and cast into pigs for use in the process. The melting is generally done in a pot-type furnace. Scrap, in the form of small parts or defective grids, is charged to the furnace. This is often done sporadically, only when enough material is available for charging. Emissions from pot-type furnaces

tend to be minimal. The lead is melted at relatively low temperatures and emissions usually are visible only when oily scrap or floor sweepings are charged. Source tests performed during the original NSPS development project on a lead recovery process show uncontrolled lead emissions averaging 298 g/kg (5.9 lb/ton) of scrap input.[35] Many of the smaller plants have no lead reclamation facilities and send out the scrap for reclamation.

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4.0 EMISSION CONTROL TECHNOLOGY

The lead-acid battery industry applies various particulate controls, including baghouses, low energy wet scrubbers, and more recently, cartridge collectors and secondary high efficiency particulate air filters (HEPA). Manufacturers often vent a number of processes to the same control device via a collection system of ducts and hoods. The control systems used at individual plants depend upon plant layout, applicable OSHA regulations, and economics of product recovery. The following sections describe emission control technology applicable to facilities in the lead-acid battery industry.

4.1 GRID CASTING MACHINES AND FURNACES

Emissions from grid casting facilities are often uncontrolled, and many plants vent this facility directly to the outside air. Some plants have used low-energy wet scrubbers to control these exhausts. There are also some applications of fabric filters on this facility.[1-6]

4.1.1 Scrubbers

An impingement and entrainment scrubber, such as the type N Roto-Clone,™ is a common device for controlling grid casting emissions. These units are relatively small, with moderate power requirements (1245 Pa or 5 in. W.G. pressure drop) and low water requirements (makeup water typically less than 0.134 l/m³ or 1 gal./1000 acf). The liquid-to-gas ratio is typically about 2.6 l/m³ (20 gal./1000 acf) of exhaust. Collection efficiency is generally about 90 percent.[7]

Multiwash centrifugal or cascade scrubbers are also used. These units typically accommodate up to 1415 m³/min (50,000 acfm) with a liquid to gas ratio as low as 0.4 l/m³ (3 gal./1000 acf).[7]

Frequently, grid casting machines and furnaces are vented along with other operations, such as small parts casting and lead reclamation, to a single low-energy scrubber.

4.1.2 Fabric Filters

During the original NSPS development project, there were no known applications of fabric filters on this facility, primarily due to the anticipation of bag blinding and fire hazards caused by hydrocarbons and mold release agents. Due to the increased use of spark arresters, better bag fabrics, and better hygiene practices, the incidence of fires has decreased. Therefore, fabric filters are now being used to control grid casting emissions in some cases (most often, this baghouse is controlling other facilities at the plant as well).[1-6,8]

At least one facility is still having some difficulties with bag blinding due to hydrocarbon build-up.[8,9] This is believed to be due to the incomplete combustion of fuel for the melt pots, and the open flame in the ladle area of the casting machines.[8,9] Some proposed solutions to this problem include the use of Goretex™ bags with a lime precoat, and higher baghouse operating temperatures.[9]

4.2 PASTE MIXER

Both baghouses and scrubbers are used to control paste mixing emissions. Some plants vent the mixer to a baghouse during the material charging phase and then to a wet collector during the final "wet" mixing and application phase.

Typically when two control devices are used, other operations are controlled by the same devices. Use of a scrubber during the wet mixing cycle prevents possible blinding of the bags by the moist exhaust. The exhaust stream is transferred from one control device to the other via an automatically operated damper located at the mixer hood. Emissions from the pasting lines (where the paste is applied to the grids) are generally controlled by one of the mixer control devices.

4.2.1 Scrubbers

An impingement entrainment scrubber such as the Type N Roto-Clone™ is frequently used to control mixing operations. These units are relatively small, (in the range of 30 to 300 m^3/min [1,000 to 10,000 acfm]) with a pressure drop of approximately 1245 Pa (5 in. W.G.). Makeup water is generally less than 0.134 l/m^3 (1 gal./1000 acf) and liquid-to-gas ratios generally are about 2.6 l/m^3 (20 gal./1000 acf) of exhaust.[10] Most of the

water loss is due to evaporation; about 20 percent results from recirculation tank blowdown. Collection efficiency is approximately 90 percent.[10]

4.2.2 Fabric Filters

Fabric filters with air-to-cloth ratios ranging from 4/1 to 8/1 are used to control particulate and lead emissions from the charging phase of paste mixing. The bags are typically made from orlon felt, polyester, cotton sateen, dacron, wool, or Goretex.™ Pressure drops across the bags are 249 to 1494 Pa (1 to 6 inches W.G.).[11]

In some cases, fabric filters are used to control emissions from the entire mixing cycle.[12-15] However, preventing condensation of moisture in the fabric filters usually involves insulation of the baghouse and all ductwork leading to it, and often requires the installation of a small auxiliary heater to keep the gas temperature above its dew point. This auxiliary heat is sometimes needed only during startup or shutdown of the facility. To provide a margin of safety, it is recommended that the gas temperature be maintained 50-75°F above its dew point.[16] A properly maintained baghouse controlling this process can reduce lead emissions by at least 98 percent.[17]

4.3 THREE-PROCESS OPERATION (STACKING, BURNING AND ASSEMBLY)

Lead-acid battery plants use fabric filters or scrubbers to control the three-process operation. Most plants vent the stacking, burning, and assembly operations into a common duct prior to cleaning the gases. Other plants clean exhausts from the three-process operation and various other facilities with a common system.

4.3.1 Fabric Filters

Based on plants surveyed by EPA, the industry typically uses shaker-type or pulse-jet fabric filters having air-to-cloth ratios of 6/1 to 7/1 to control three-process emissions. The lead removal efficiencies are greater than 97 percent.[18] Hood design is very important because of the large number of emission points (stacking, burning, and assembly usually are performed at several stations).

4.3.2 Scrubbers

Impingement type scrubbers are sometimes used to control three-process emissions. These scrubbers typically operate with a pressure drop of

approximately 1245 Pa (5 inches W.G.) with lead collection efficiencies ranging about 90 percent.[18] Makeup water requirements for this type of scrubber are usually less than 0.134 l/m ^{3} (1 gal./1000 acf) at a liquid-to-gas ratio of 2.6 l/m^3 (20 gal./1000 acf) of exhaust.[18]

4.4 LEAD OXIDE PRODUCTION

Lead oxide in the form of fine particulate matter is manufactured in a ball mill or a Barton pot. Most lead oxide facilities of both types use mechanical collectors followed by a baghouse to capture the lead oxide production after it leaves the ball mill or Barton pot. Most of the product is separated in a settling chamber or cyclone, and the baghouse serves to increase the product collection efficiency. The baghouse is considered as both process equipment and air pollution control equipment. Therefore, for economic reasons, wet collection devices are not used. Air-to-cloth ratios of baghouses for collection of lead oxide range from 2/1 to 4/1.[18]

During the original NSPS development project, emissions tests were conducted only at a well controlled ball mill system. At that time, it was determined that a well controlled Barton system could achieve a similar emissions level (as the air flow rates per unit production rate are similar).[19] Since then, several Barton systems have indeed demonstrated compliance with the NSPS, as will be shown in Chapter 5.

4.5 LEAD RECLAMATION

The exhaust gas stream from the lead reclamation process is similar to the grid casting and small parts casting exhaust gases in that both are characterized by high temperatures and lead fumes. Since these gas streams are similar in character it is not uncommon to vent these processes to a common control device.

4.5.1 Scrubbers

Lead reclamation facilities are generally controlled with low-energy wet scrubbers. Low-energy multistage or impingement-entrainment type wet collectors are used most frequently, with pressure drops less than 2 kPa (8 inches W.G.) and liquid-to-gas ratios of 0.4 to 0.7 l/m^3 (3 to 5 gal./1000 acf).[20] Lead collection efficiencies have been shown to be above 98 percent.[21]

4.5.2 Fabric Filters

As was the case for grid casting, there were no known applications of fabric filters on this facility during the original NSPS development project. Once again the reason being anticipated bag blinding and fire hazards due to hydrocarbons and mold release agents contained with the scrap. As was discussed earlier, the use of spark arresters, better bag fabrics, and better hygiene practices have reduced the incidence of fires. Therefore, fabric filters are now being used to control lead reclamation emissions in some cases (most often, this baghouse is controlling other facilities at the plant as well).[22-24] It is estimated that a collection efficiency in excess of 98 percent is achievable for these facilities using fabric filters with air-to-cloth ratios between 3/1 and 6/1.[25]

4.6 FORMATION

As explained in Chapter 3, formation processes are divided into two categories, those which form in the battery case and those which form in open tanks (a practice which is decreasing within the industry). Formation processes do not emit lead, but are a source of sulfuric acid mist. Battery plates formed inside the battery case are formed slowly (1 to 4 days), and those formed in open tanks are formed more rapidly (usually 16 hours). The type of emissions control for these processes depends on whether or not the formation area is enclosed.

Very little data on emissions from formation processes are available from any source. However, based on observations during plant inspections, the processes which appear to generate much higher emissions are those which form the plates in open vats.[25] This is also evidenced by the fact that most companies which form the battery plates inside the assembled battery have no ductwork to remove emissions from the work area. Plants which do duct the emissions from the work area (those which form in an open vat) have a more acute emission problem. These plants typically use either foam, scrubbers, mist eliminators, or combinations of these control techniques to minimize emissions to the production area and the outside air. Following are emission control practices used for formation processes.

4.6.1. Good Work Practice

When the formation area is not vented to a control device, such as when the battery is formed after complete assembly, the operator should form the batteries slowly and keep every battery filler cap on the battery at all times during the formation period.[26] This minimizes emissions to the work area, and hence to the atmosphere. Some facilities leave the top of the battery case off during the assembly process and do not install the top until after formation is complete. During formation, a dummy, reusable cover is placed on top of the batteries being formed. This helps to reduce emissions since much of the sulfuric acid mist impinges on the slave cover and condenses back into the battery.[26]

4.6.2 Water Sprays

Many plants which form in the battery case (wet formation) spray the batteries with water during the formation process. The spray may absorb some sulfuric acid mist but is primarily used to keep the temperature of the batteries lower than it would normally be since sulfuric acid mist emissions increase proportionally with acid temperature during formation.[26]

4.6.3 Foam Covers

Some companies which form the batteries in open tanks (dry formation) cover the tanks with a layer of foam. The foaming agent controls sulfuric acid mist by collecting the mist particles from the surface of the sulfuric acid solution before they can escape into the formation room. Three formation processes using foam were surveyed by EPA during the original NSPS development project. Subjective measurements of the mist cloud above forming tanks and the characteristic acid odor in the forming room suggested a decrease in acid mist emissions when foam is used.[27]

4.6.4 Scrubbers

The scrubbers used to control formation emissions are typically low energy type scrubbers, such as the Heil™ fume washer (a scrubber and mist eliminator), and several non-commercial designs. Plants which use scrubbers either enclose the formation tanks and duct the emissions to the scrubber, or they form the battery in a room which can be closed off. The emissions in the room are then ducted to the scrubber.[27]

4.6.5 Mist Eliminators

Some companies use mist eliminators rather than scrubbers to control formation emissions. A popular brand used by this industry is the Tri-Mer™ scrubber. This mist eliminator catches the mist particles as they go through a fan separator followed by a packed tower. The packing is then periodically washed or flushed on a schedule ranging from once per day to two or three times per shift.[28]

4.7 CENTRAL VACUUM SYSTEMS

Many lead-acid battery manufacturing plants use central vacuum systems for general housekeeping practices. These units have, in several cases, been determined as subject to the NSPS as an "other lead emitting" source.[29-32] Based on plants surveyed by EPA, the industry typically uses fabric filters to control exhaust emissions from these vacuum systems. The fabric filters encountered were generally pulse-jet or reverse air units, with air-to-cloth ratios of approximately 4/1 to 7/1.[29-31]

4.8 NEW CONTROL TECHNIQUES

Since the original NSPS development project, fabric filters have become an accepted method for controlling emissions from grid casting and lead reclamation. Also, there have been two new lead control techniques applied to various facilities in the lead-acid battery manufacturing process. These are the use of cartridge dust collectors as primary control devices, and the use of HEPA filters for secondary collection.

4.8.1 Cartridge Collectors

Cartridge collectors are similar to baghouses, but they have rigid, pleated cellulose cartridges rather than bags, allowing more filter surface area per total volume of the collector. These pulse-jet units have an air-to-filter surface ratio of approximately 1.5/1, and operate at a pressure drop between 1 and 2 inches W.G.[33] Due to very fine pore size, cartridge filtration media will remove particles as small as one micron.[33] Another advantage of these units is ease and safety of maintenance; the cartridges can be changed quickly without entering, or even leaning into, the collector. There is still some question over the successful application of these systems to moist exhausts. However, there have been reported cases of a cartridge collector controlling the entire paste mixing cycle, including the wet

portion.[34,35] Also, at least one firm manufactures a filter cartridge that is reported to be applicable for filtering particulate in moist streams.[36]

4.8.2 High Efficiency Particulate Air Filters

High efficiency particulate air filters (HEPA filters) are used primarily as a secondary control device following a fabric filter or cartridge collector.[37-39] Use of a HEPA filter makes it possible to recirculate the exhaust to the plant; recirculation helps reduce make-up air costs, as well as heating costs during colder weather. OSHA requires HEPA filters for recirculation systems, and this requirement is currently the primary reason for use of such units.[40]

The HEPA filter is constructed of an extended-pleated dry filter medium, enclosed in a rigid casing the full depth of the pleats.[41] The collection efficiency is a minimum of 99.97 percent for 0.3 um particles, and a clean unit has a maximum pressure drop of 0.25 kPa (1.0 in. W.G.).[38,41] Large airflows are controlled by banks of several filters. The filters are generally replaced when the pressure drop reaches 0.5 kPa (2.0 in. W.G.).[41] Used filters must be disposed of as a hazardous waste material.[42]

4.9 REFERENCES

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21. Reference 7, p. 4-29.

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23. Reference 4.

24. Reference 8.

25. Reference 7, p. 4-32.

26. Reference 7, p. 4-33.

27. Reference 7, p. 4-34.

28. Reference 7, p. 4-35.

29. Reference 9.

30. Reference 15.

31. Reference 18.

32. Memo from Michelitsch, D.M., EPA:ISB, to Durkee, K.R., EPA:ISB. December 6, 1988. Report on July 27, 1988, trip to East Penn Manufacturing Company, Lyon Station, Pennsylvania.

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5.0 COMPLIANCE STATUS

5.1 AFFECTED FACILITIES

Thirty-one plants have been identified as having facilities subject to the new source performance standards (NSPS) for lead-acid battery manufacture. Table 5-1 lists these plants. Emissions data were received from 30 of the 31 plants reported as subject to the NSPS. Information concerning these plants was obtained from EPA's Stationary Source Compliance Division (SSCD), Regional and State agencies, and responses to several Section 114 Information Requests.

5.2 EMISSIONS DATA

Emissions testing is required to demonstrate compliance with the NSPS emission limits, which are summarized as follows:

Facility	Lead Emission limit	Opacity
Lead oxide production	5.0 mg/kg (0.010 lb/ton)*	0%
Grid casting	0.40 mg/dscm (0.000176 gr/dscf)	0%
Paste mixing	1.00 mg/dscm (0.00044 gr/dscf)	0%
Three-process operation	1.00 mg/dscm (0.00044 gr/dscf)	0%
Lead reclamation	4.50 mg/dscm (0.00198 gr/dscf)	5%
Other lead emitting operations	1.00 mg/dscm (0.00044 gr/dscf)	0%

* The emission limit for lead oxide production is expressed in terms of lead emissions per kilogram of lead processed.

The lead mass emissions are determined using EPA Reference Method 12, and opacity is determined using EPA Reference Method 9. The compliance emissions data collected during this review are presented and discussed in the following sections.

TABLE 5-1

LEAD-ACID BATTERY PLANTS WITH SUBJECT FACILITIES*

Battery Builders, Incorporated
- Naperville, IL

C&D Power Systems, Incorporated
- Conyers, GA
- Hugeunot, NY
- Leola, PA
- Conshohocken, PA (recently closed)

Douglas Battery Manufacturing Company
- Winston-Salem, NC

East Penn Manufacturing Company
- Lyon Station, PA

Exide Corporation
- City of Industry, CA
- Visalia, CA
- Logansport, IN
- Burlington, IA
- Manchester, IA
- Salina, KS
- Allentown, PA
- Muhlenberg/Laureldale, PA
- Greer, SC
- Sumter, SC

Gates Energy Products, Incorporated
- Warrensburg, MO

GNB Incorporated
- Fort Smith, AR
- Columbus, GA
- Zanesville, OH (recently closed)

Johnson Controls, Incorporated
- Middletown, DE
- Tampa, FL
- St. Joseph, MO
- Winston-Salem, NC
- Holland, OH
- Milwaukee, WI

Trojan Battery Company
- Santa Fe Springs, CA
- Lithonia, GA

TABLE 5-1, CON'T.

LEAD-ACID BATTERY PLANTS WITH SUBJECT FACILITIES*

U.S. Battery Manufacturing Company
- Evans, GA

West Kentucky Battery, Incorporated
- Benton, KY

*Note: References listed in Section 5.3

5.2.1 Grid Casting

Emissions data for grid casting facilities were received from 14 plants. This information is shown in Figure 5-1.

Data from Plant B includes the casting fume exhaust system vent and the general casting area vent. Both of these exhaust streams are uncontrolled. Opacity data were not included with the test reports.

Plant C includes emissions data from the grid casting area vent and a cast-on-strap facility, which has, in this case, been interpreted as a casting facility rather than the usual definition as part of the three-process operation (the emissions would also be below the limit for three-process facilities). Emissions from the casting area are controlled by a baghouse, and a cartridge collector is used to control the emissions from the cast-on-strap facility. Opacity data were not included with the test reports.

The five casting facilities tested at Plant E are all uncontrolled, with 0 percent opacity. These tests include the combined exhaust of four carousel casters, a general casting area vent, an annealing oven, a fifth carousel caster, and a small parts die caster. All of these units had emissions below the allowable limit.

The data for Plant I are for the exhaust from the entire casting operation. These average uncontrolled emissions are above the standard; however, the allowable limit stated in the test report is incorrect, making the facility appear below the NSPS limit. The local enforcement agency is currently taking actions to correct this permitting error. The opacity for this facility was measured at 0 percent.

The two tests presented for Plant K are both for the same uncontrolled general casting area vent. The first test shows the emissions are above the level of the standard. The second, later test shows the emissions are now below allowable limits. There were no opacity data included with these reports.

The data for Plant N are for the combined exhaust from the grid casting and small parts casting operations. This exhaust stream is controlled by a baghouse, and the opacity was measured at 0 percent.

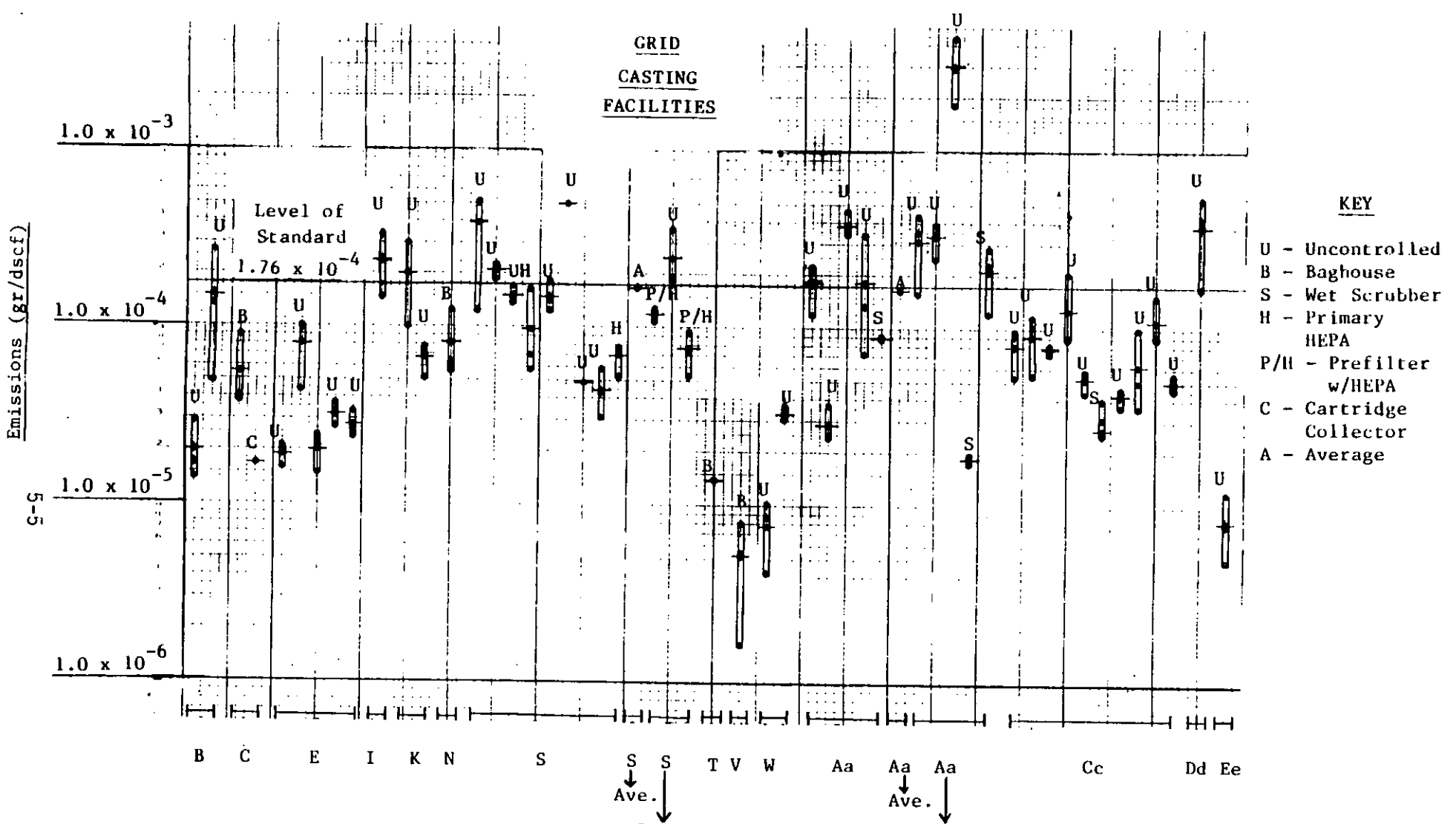


Figure 5-1. Emissions Data for Grid Casting Facilities

NOTE: References shown in Section 5.3.

The first nine tests presented for Plant S are for the following facilities:

- Casting Machine #1 - Uncontrolled
- Casting Machine #2 - Uncontrolled
- Casting Machine #3 - Uncontrolled
- Casting Machine #4 - HEPA Filter
- Casting Machine #5 - Uncontrolled
- Antimony/lead Melt Pot - Uncontrolled
- Calcium/lead Melt Pot - Uncontrolled
- Industrial Casting - Uncontrolled
- Casting Machine #6 - HEPA Filter

Although several of these units have emissions above the allowable NSPS, the local enforcement agency for this plant interpreted the regulation such that compliance with the grid casting standard is determined by taking a weighted average of the emissions from all grid casting related operations at the plant. This average (denoted on Figure 5-1 by "Ave.") is below the allowable limit. Test information was also received for further modifications to some of the facilities noted above (these tests are marked "later Mod." on Figure 5-1). HEPA filters were added to both lead melt pots (bringing the antimony/lead pot within the allowable limits), and the controls were removed from Casting Machine #6, causing its emissions to rise slightly above the NSPS limit. Opacity data were included with five of these test reports, and all were 0 percent.

The data from Plant T and Plant V are both for general grid casting area vents. These facilities are each controlled by a baghouse. No opacity data were included with the emissions information.

The two facilities at Plant W are both uncontrolled lead melt furnaces; one for antimony/lead and one for calcium/lead. Opacity data were not included.

The first five tests presented for Plant Aa are all for grid casting machines. The first four tests are for single units (#1-#4) with uncontrolled exhaust streams, and the fifth test is for two units (#5, #6) with the exhaust stream combined and controlled by a wet scrubber. All of these tests included opacity readings of 0 percent. Although several of these units have emissions

above the NSPS allowable, the local enforcement agency for this plant interpreted the regulation such that compliance with the grid casting standard is determined by taking a weighted average of the emissions from all the grid casting machines. This average (denoted on Figure 5-1 by "Ave.") is below the allowable limit. Test information was also received for several earlier tests on machine #5 individually and one for the combined (#5, #6) exhaust stream. (These tests are marked "Earlier Tests" on Figure 5-1). The first three of these earlier reports for machine #5 show emissions above the NSPS limit, with the single unit at that time being uncontrolled; the forth test reflects the addition of a wet scrubber resulting in emissions below allowable. The last of the earlier tests is for the addition of the exhaust from machine #6 to the wet scrubber controlling machine #5, and it exceeds the standard. The later emissions test for this unit combined (which was used to compute the weighted average) shows that subsequent modifications were made to bring the units emissions below the allowable limit.

The data presented for Plant Cc are for the following facilities:

- Casting Machine #1 - Uncontrolled
- Casting Machine #2 - Uncontrolled
- Casting Machine #4 - Uncontrolled
- Casting Machine #3 - Uncontrolled
- Casting Machine #6 - Uncontrolled
- Casting Machines #5 & 7 - Wet scrubber
- Post Pouring Station - Uncontrolled
- Casting Machine #7 - Uncontrolled
- Casting Machine #8 - Uncontrolled
- Casting Machine #10 - Uncontrolled

The emissions are all below the NSPS allowable limits. Post pouring is normally not included in the grid casting facility; this unit was later re-permitted as an "other lead emitting" facility. Opacity readings were included for casting machines #7, #8, and #10, and were all at 0 percent.

The data for Plant Dd is from one uncontrolled grid casting machine (actually 3 single units, together called a "bank"). The emissions shown are above the NSPS, but the unit has recently been retested, and is now reported to be in compliance. No opacity readings were included with the test report.

The data received for Plant Ee is also for one uncontrolled grid casting unit. In this case, the emissions are below allowable limits. Once again, no opacity data were included.

Of the 51 emission tests received for grid casting facilities, 37 of these were in compliance with the NSPS. These units included: 25 that were uncontrolled, 4 controlled by baghouses, 3 by wet scrubbers, 2 by primary HEPA filters, 2 with prefilters and HEPA filters, and 1 by a cartridge collector. Of the 14 tests not in compliance, 13 units were uncontrolled, and 1 was controlled by a wet scrubber. Eleven of the facilities with emissions above the allowable were included in weighted average determinations of compliance. Of the remaining three, two have been brought into compliance, and one is being pursued by the local enforcement agency.

5.2.2 Paste Mixing

Emissions data for paste mixing facilities were received from 14 plants. This information is shown in Figure 5-2.

The facilities tested at Plant A include the following:

- Negative Oxide Unloading
- Positive Oxide Unloading
- Positive Paste Mixing
- Negative Paste Mixing
- Drying Oven-West
- Drying Oven-East

All of these facilities are controlled by baghouses, except for the drying ovens, which are uncontrolled. The mass emissions are all below the NSPS limits, and the opacities are 0 percent.

The three tests presented for Plant B are all for the same paste mixing/paste application exhaust stream, controlled by a wet scrubber. The second test was a result of a modification to the unit, and was above the NSPS limit. The third test reflects changes made (apparently in air flow rates) to bring the emissions below the allowable value. Opacity readings were included with the first test only, and were all 0 percent.

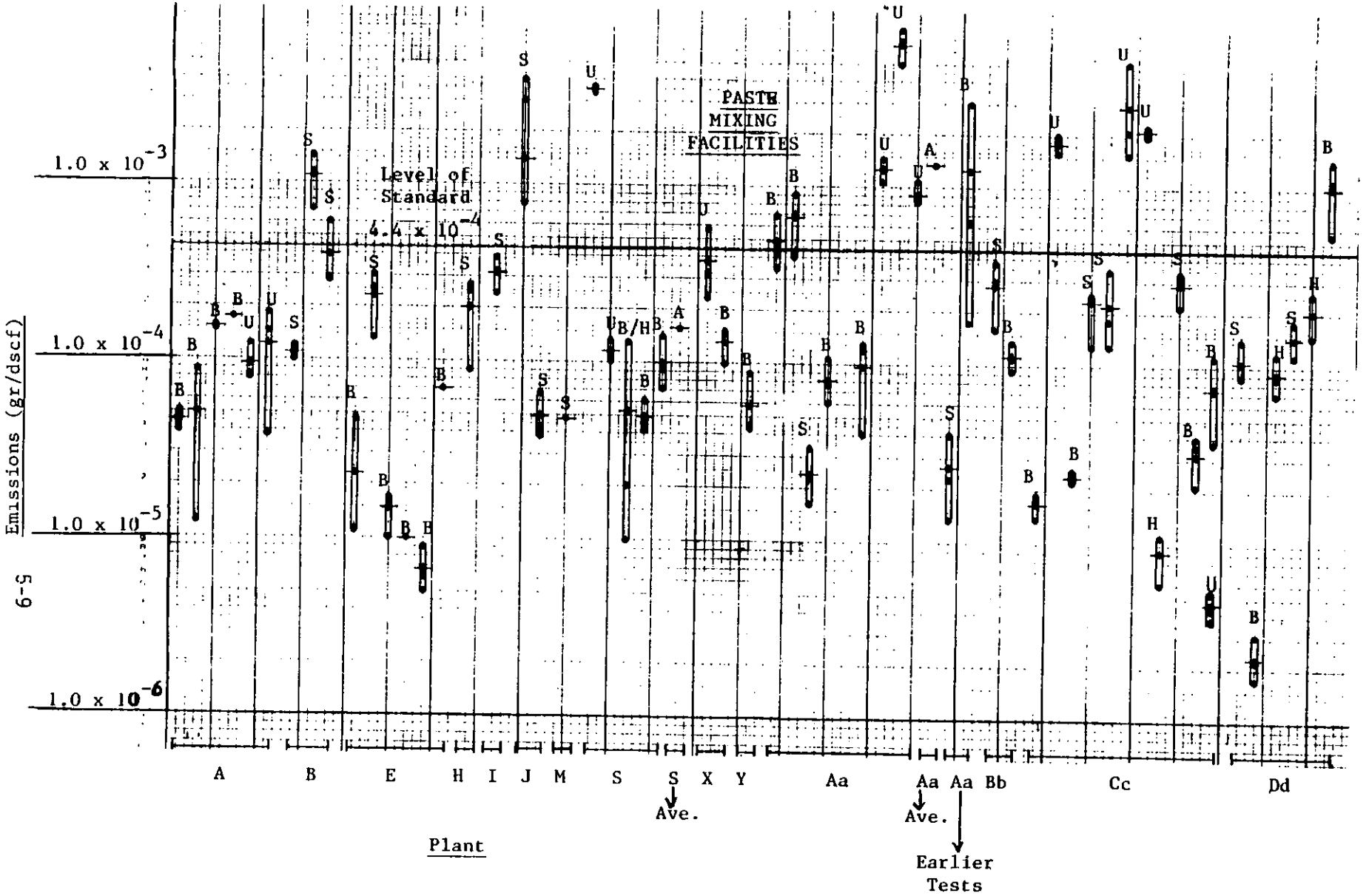


Figure 5-2. Emissions Data for Paste Mixing Facilities

NOTE: References shown in Section 5.3.

The six units tested at Plant E are as follows:

- Manual Pasting (5 stations) - Baghouses (2 units)
- Negative Paste Mixing - Wet Scrubbers
- Positive Paste Application (2 units) - Baghouse
- Positive Oxide Silo - Baghouse
- Negative Oxide Silo - Baghouse
- Modification to Positive Oxide Silo - Baghouse

Opacity readings of 0 percent were included with each test report. The mass emissions for all the units are below the allowable limits.

The data presented for Plant H are for a combined exhaust stream from two paste mixers and two paste application lines. The emissions are controlled by a wet scrubber. No opacity readings were included with the test report.

Plant I also has the emissions from paste mixing and paste application combined and controlled by a wet scrubber. Opacity data of 0 percent were included for all test runs.

Both tests presented for Plant J are for the same paste mixer, controlled by a wet scrubber. The second test reflects the installation of a new scrubber to bring the emissions below the NSPS allowable limits. Opacity readings of 0 percent were included with the second test.

The data from Plant M are for the combined emissions for the entire pasting area. This exhaust stream is controlled by a wet scrubber. No opacity data were included.

The tests presented for Plant S are for the following facilities:

- Automotive Plate Curing Ovens - Uncontrolled
- Industrial Plate Curing Ovens - Uncontrolled
- Paste Mixing & Paste Application - Baghouse w/HEPA
- Oxide Silos A&B - Baghouse
- Oxide Silo #2 - Baghouse

Although the automotive plate curing ovens have emissions above the NSPS allowable, the local enforcement agency for this plant interpreted the regulation such that compliance with the paste mixing standard is determined by taking a weighted average of the emissions from all operations at the plant that are included in the definition of paste mixing. This average (denoted on

Figure 5-2 by "Ave.") is below the allowable limit. No opacity measurements were included with the test reports.

The data from Plant X are for an uncontrolled paste drying oven, and for a Gortex™ baghouse controlling paste mixing/application. The baghouse data also included opacity measurements of 0 percent.

The one test from Plant Y is for a paste mixer. The unit is controlled by a baghouse. No opacity information was included in the test report.

The data presented for Plant Aa include the following facilities:

- North Oxide Storage Tank - Baghouse
- South Oxide Storage Tank - Baghouse
- Paste Mixers #1, #2, and #3 (wet cycle) - Wet Scrubber
- Paste Mixers #1, and #2 (dry cycle) - Baghouse
- Paste Mixer #3 (Dry Cycle) - Baghouse
- Curing Oven #1 - Uncontrolled
- Curing Oven #2 - Uncontrolled
- Curing Oven #3 - Uncontrolled

Several of these units have emissions above the allowable NSPS, including two controlled by baghouses; however, the local enforcement agency for this plant interpreted the regulation such that compliance with the paste mixing standard is determined by taking a weighted average of the emissions from all units defined as part of the paste mixing operation. This average (denoted on Figure 5-2 by "Ave.") is also above the NSPS limit. The plant is therefore currently operating under a consent order with their local enforcement agency. Test information was also received for two earlier tests; one on the wet scrubber controlling paste mixers #1, #2, and #3, and one on the baghouse controlling paste mixer #3 (these tests are marked "Earlier Tests" on Figure 5-2). These earlier tests had higher emissions than those later used to compute the weighted average discussed above. Opacity readings of 0 percent were included with all the test reports.

The two tests presented for Plant Bb are for the same paste mixer; one test is for a wet scrubber controlling the wet cycle of mixing, and the other is for a baghouse controlling the dry cycle. Both tests are below allowable limits. No opacity data were included with the test report.

The data presented for Plant Cc are for the following facilities:

- Paste Mixers #1, #2, #3, #4 (Dry Cycle) - Baghouse
- Drying Oven #3 - Uncontrolled
- Modification to Paste Mixers #1, #2, #3, #4 (Dry Cycle) - Baghouse
- Paste Mixers # 3, #4 (Wet Cycle) - Wet Scrubber
- Paste Mixers #1, #2 (Wet Cycle) - Wet Scrubber
- Drying Oven #1 - Uncontrolled
- Drying Oven #2 - Uncontrolled
- Pasting Lines (#1, #2, #3) - Primary HEPA
- Modification to Paste Mixers #3, #4 (Wet Cycle) - Wet Scrubber
- Oxide Storage Tank C - Baghouse
- Modification to Paste Mixers #1, #2, #3, #4 (Dry Cycle) - Baghouse
- Chem-Set Room (Plate Curing) - Uncontrolled

Opacity readings for the last four tests were all 0 percent. The test information for the three uncontrolled drying ovens is above the level of the standards. However, the local enforcement agency has interpreted the regulation such that the affected facility includes all equipment associated with paste mixing and application. Information on which actual test runs were used to compute a weighted average was not included; therefore, an actual average value is not presented.

The data presented for Plant Dd are for the following facilities:

- Paste Mixer #3 (Wet Cycle) - Wet Scrubber
- Paste Mixers #1, #2, #3 (Dry Cycle) - Baghouse
- Pasting Line #3 - Primary HEPA
- Paste Mixers #3, #4 (Wet Cycle) (addition of #4) - Wet Scrubber
- Pasting Line #4 - Primary HEPA
- Paste Mixer #4 (Dry Cycle) - Baghouse

Opacity readings were not included with any of the test reports. The test presented for paste mixer #4 (dry cycle) shows emissions in excess of

allowable. This unit was recently retested, and is now reported to be in compliance.

Of the 58 emission tests received for paste mixing facilities, 45 were in compliance with the NSPS. The control devices on these units included: 21 baghouses, 15 wet scrubbers, 3 primary HEPA filters, 1 baghouse and HEPA filter, and 5 uncontrolled units. There were 13 tests received with emissions above the allowable limit. Seven of these units had uncontrolled emissions, four used baghouses, and two used scrubbers. Ten of the units with emissions not in compliance with the NSPS are used in the computation of a weighted average to determine compliance. The other three remaining units have been brought into compliance.

5.2.3 Three-Process Operation

Emissions data for three-process operation facilities were received from 12 plants. This information is shown in Figure 5-3.

The data presented for Plant B includes the following:

- A & B Series Assembly Area - Baghouse
- C Series Assembly Area - Baghouse
- Modification to C Series Assembly Area - Baghouse
- D Series Assembly Area - Baghouse
- Modification to A and B Assembly - Baghouse
- E Series Assembly Area - Baghouse
- Three Wrapper/Stacker Units - Baghouse

Opacity readings of 0 percent were included with three of the test reports. The mass emissions for the wrapper/stacker units are above the allowable NSPS. However, the local enforcement agency has interpreted the regulation such that compliance is determined by a weighted average of emissions from all equipment associated with the three-process operation.

The three tests from Plant D are for the assembly processes for three different types of batteries. All of the units are controlled by fabric filters and are in compliance with the NSPS. No opacity data were included with the test reports.

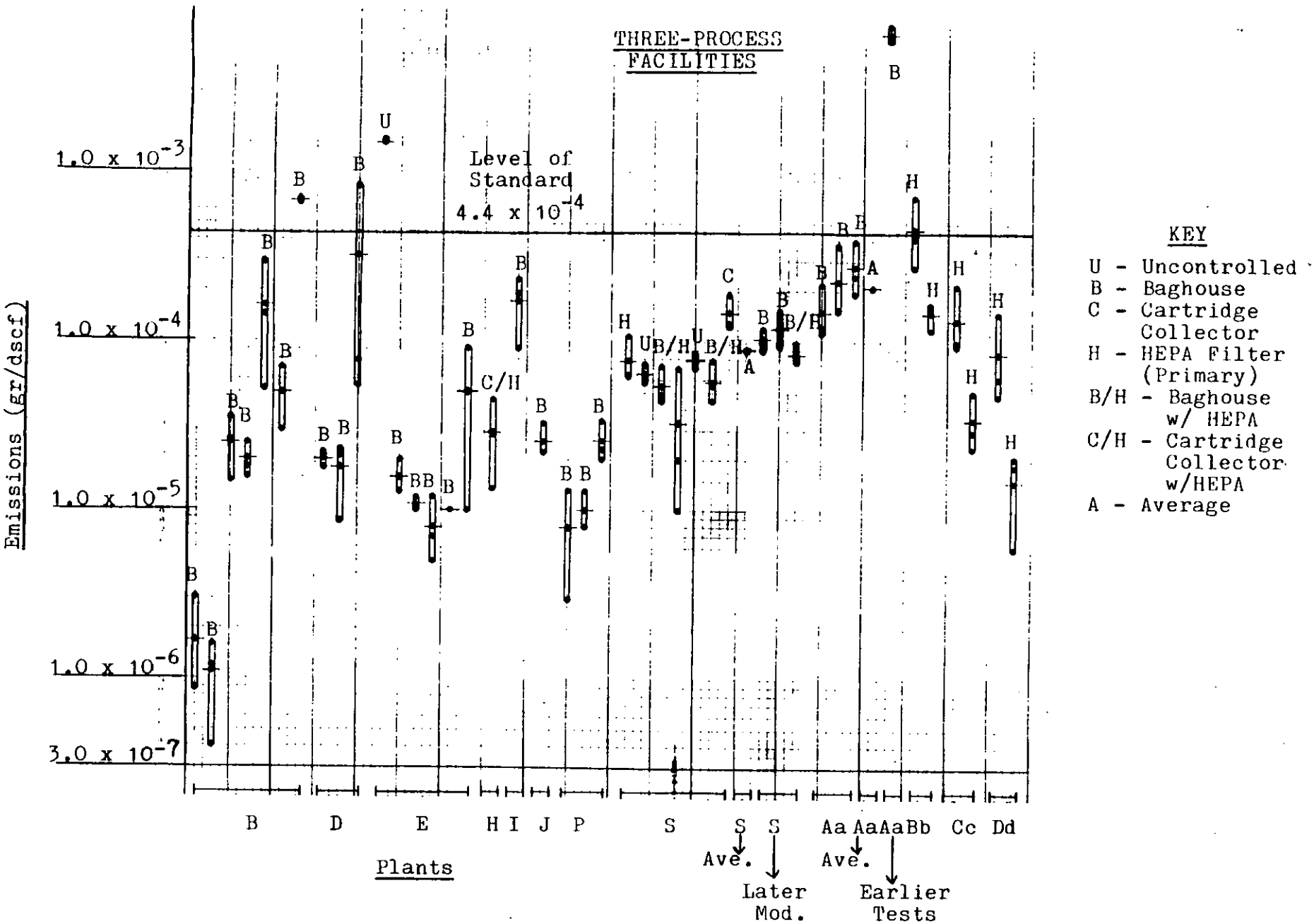


Figure 5-3. Emissions Data for Three-Process Facilities

NOTE: References shown in Section 5.3.

The data presented for Plant E includes the following:

- Laser Bonders (Plate burning) - Uncontrolled
- Stacking Area - Baghouse
- Post Brush - Baghouse
- Modified Laser Bonders (addition of a control device) - Baghouse
- Bond Repair - Baghouse
- Lasers and Stacking (now combined exhaust) - Baghouse

Opacity readings of 0 percent were included with all of the test reports. The laser bonders initially showed emissions in excess of the allowable NSPS; however, the later tests show this to be corrected via addition of a control device.

The one test from Plant H is for an automotive battery assembly system. Emissions are controlled by a cartridge collector with a secondary HEPA filter and are below the allowable NSPS. No opacity information was included with the test reports.

The test from Plant I is for the combined exhaust from two baghouses controlling various battery assembly processes (stack and burn, elements into cases, etc.). The mass emissions are within allowable limits, and the opacity was measured at 0 percent.

Plant J presents emissions data from one baghouse controlling plate wrapping, stacking, and cast-on-strap-operations, which shows the unit to be in compliance. The opacity was measured at 0 percent.

The three tests presented for Plant P are all for stack and burn operations. Each facility is controlled by a baghouse, with mass emissions below the allowable NSPS. No opacity data were included with the test reports.

The first seven tests presented for Plant S are for the following facilities:

- Automatic Repair Station - HEPA Filter
- Conventional Assembly #1 - Uncontrolled
- Automatic Assembly #1 - Baghouse w/HEPA

- Automatic Assembly #2, #3 - Baghouse w/HEPA
  (Later changed to cartridge house w/HEPA, but no new test received)
- Conventional Assembly #2 - Uncontrolled
- Industrial Assembly - Goretex™ Baghouse w/HEPA
- Conventional Stack & Burn - Cartridge Collector

All of these units have emissions below the NSPS allowable. The local enforcement agency for this plant interpreted the regulation such that compliance with the three-process standard is determined by taking a weighted average of the emissions from all three-process related operations at the plant. This average is denoted on Figure 5-3 by "Ave". Test information was also received for further modifications to some of the three-process facilities at Plant S (these tests are marked "Later Mod." on Figure 5-3). The first later test is for a new stacker/cast-on-strap operation (controlled by a baghouse), and the second test is for a modification to this unit. The final test is for a modification to the industrial assembly area. All of these later tests are also in compliance with NSPS limits. Only two tests from Plant S included opacity data, both of which were 0 percent.

The first three tests presented for Plant Aa are as follows:

- Cast-on strap/Assembly #1, #2 - Baghouse
- Cast-on-strap/Assembly #3 - Baghouse
- Cast-on-strap/Assembly #4 - Baghouse

Opacity readings of 0 percent were included with all of the reports, and the mass emissions are all below the NSPS allowable. The local enforcement agency for this plant interpreted the regulation such that compliance with the three-process standard is determined by taking a weighted average of the emissions from all of the three-process related units at the plant. This average is denoted on Figure 5-3 by "Ave." One earlier test was also received for the baghouse controlling two cast-on-strap/assembly lines (#1 and #2), and it was above the allowable limit. The later test (used to compute the weighted average) shows that this situation was corrected.

The data received for Plant Bb is from two cast-on-strap/assembly lines, both controlled by primary HEPA filters. The first unit has emissions slightly above the allowable NSPS; however, information on actions to lower

these emissions has been forwarded to the local enforcement agency. No opacity data were included with the reports.

The two test reports for Plant Cc are for the same stack, which serves several three-process stations controlled by several primary HEPA filters, and both show compliance with the NSPS. The second test reflects modifications to the facility. Opacity readings of 0 percent were included with the second report.

The data from Plant Dd are for two cast-on-strap/assembly lines. Both units are controlled by primary HEPA filters, with emissions below the allowable limit. Opacity data were not included with the test reports.

Of the 41 emission tests received for three-process facilities, 37 were in compliance with the NSPS. These units are controlled by: 24 baghouses, 5 primary HEPA filters, 4 baghouses with HEPA filters, 1 cartridge collector, 1 cartridge collector with HEPA filter, and 2 units are uncontrolled. Of the four tests not meeting the NSPS limits, two are for units controlled by baghouses, one by a primary HEPA filter, and one is uncontrolled. Two tests with emissions above allowable have been used in computing a weighted average to determine compliance, and one unit has been brought into compliance. Information concerning action to bring the remaining unit into compliance has been forwarded to the local enforcement agency.

5.2.4 Lead oxide production

Emissions data for lead oxide production facilities were received from seven plants. This information is shown in Figure 5-4. All of the data received are from systems using the Barton Process rather than a ball mill.

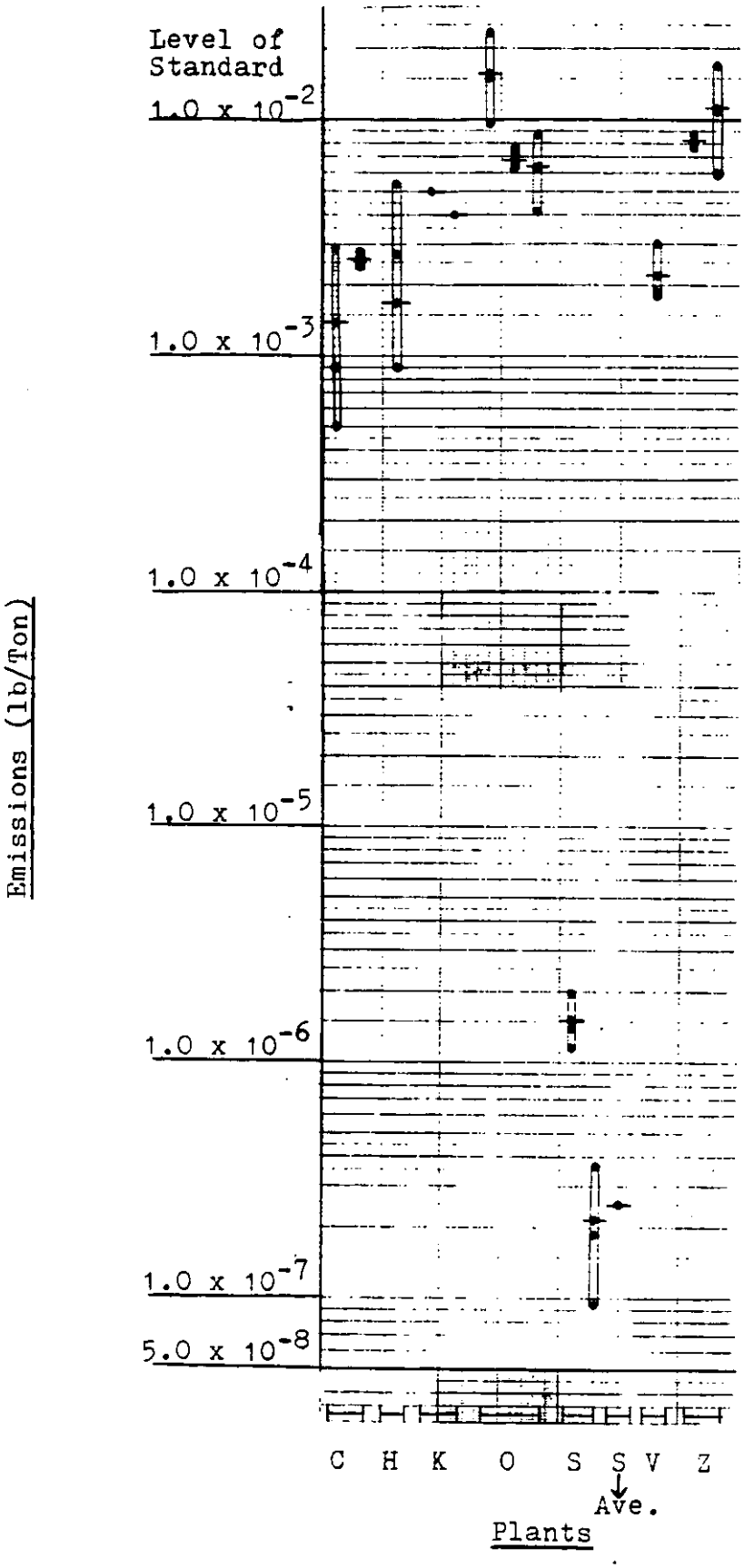
The two stacks tested for Plant C are from the same oxide mill; one serves the regular process baghouse, and the other is for an emergency back-up baghouse. Both are in compliance with the NSPS. Opacity readings were not included with the test report.

A baghouse with Goretex™ bags controls the oxide mill at Plant H. No opacity information was received. The mass emissions are within NSPS limits.

Plant K presented data for two oxide mills. Both units are controlled by baghouses with Goretex™ bags, and are in compliance. Opacity readings were not included with the test reports.

LEAD-OXIDE PRODUCTION FACILITIES

(Barton Process)



NOTE: All units are controlled by baghouses.

NOTE: References shown in Section 5.3.

Figure 5-4. Emissions Data for Lead-Oxide Production Facilities

The data from Plant O are for three separate oxide mills, each controlled by a baghouse with Goretex™ bags. Opacity data were not included with the test report. The test for the first mill shows emissions slightly above the NSPS limit. However, the local enforcement agency has interpreted the regulation such that compliance is determined using a weighted average of the emissions from all lead oxide production equipment.

The first test presented for Plant S is for a combined exhaust stream from two baghouses, each serving a single oxide mill. The second test is for a Goretex™ baghouse controlling a third oxide mill. All three mills have emissions well below the NSPS limit. No opacity data were included with the test reports. The local enforcement agency for this plant interpreted the regulation such that compliance with the lead oxide production standard is determined by taking a weighted average of the emissions from all lead oxide production facilities at the plant. This average is denoted on Figure 5-4 by "Ave."

The data from Plant V are for one oxide mill, controlled by a baghouse, and is in compliance with the NSPS. Opacity data were not included with the test information.

The two tests from Plant Z are for two oxide mills, each controlled by a baghouse. Opacity readings of 0 percent were included. The test for the second mill shows emissions slightly above the allowable limit; however, the unit was recently re-tested, and is now reported to be in compliance.

All 13 tests received for oxide production facilities were for units controlled by baghouses. Two of these tests showed emissions above the allowable NSPS. One of the tests not in compliance was used to compute a weighted average of emissions, and the other unit has been brought into compliance.

5.2.5 Lead Reclamation

No compliance data were received for lead reclamation facilities individually. There were, however, several cases where lead reclamation facility emissions were combined with those from another type of unit, and controlled by one device. This information is presented in Section 5.2.7.

5.2.6 Other Lead Emitting Operations

Emissions data for those facilities categorized as "other lead emitting operations" were received from four plants. This information is shown in Figure 5-5.

The facilities presented for Plant B are as follows:

- Central Vacuum System - Cyclone/Baghouse
- Plate Processing A - Baghouse
- Modification to Plate Processing A - Baghouse
- Plate Processing B - Wet Scrubber

All of the units had mass emissions below allowable limits. Opacity readings were included for two of the tests on plate processing, and were all at 0 percent.

The data presented for Plant W are for a plate unracking and brushing station. This unit is controlled by a baghouse, and is in compliance with the NSPS. No opacity information was included with the test report.

The facilities presented for Plant Aa are as follows:

- Central Vacuum System - Baghouse
- Plate & Paste Salvadge - Wet Scrubber
- Modification to Plate & Paste Salvage - Wet Scrubber

Opacity readings for the first and third tests were 0 percent. The central vacuum system is shown to have emissions slightly above the allowable limit; however, the unit has been re-tested, and is now reported to be in compliance.

The tests from Plant Cc are for two post pouring stations. Both of these units are uncontrolled, with emissions below the allowable NSPS. Opacity readings for all three facilities were 0 percent.

Of the 10 emission tests received for "other lead emitting" facilities, 9 were in compliance with the NSPS. These units were controlled by four baghouses, three wet scrubbers, and two units were uncontrolled. The one facility not meeting the NSPS was controlled by a baghouse; this unit has now been brought into compliance.

OTHER LEAD EMITTING

FACILITIES

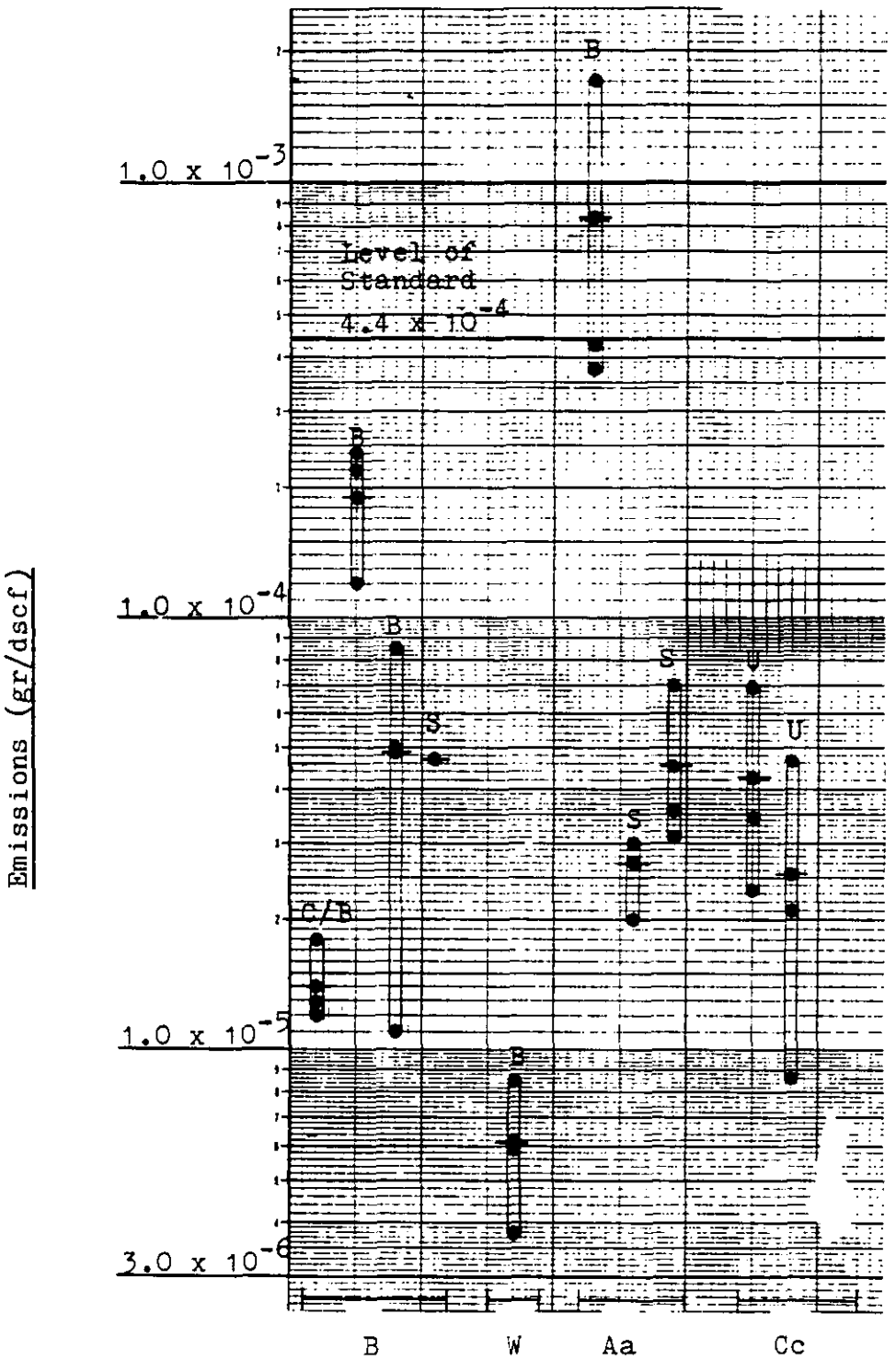


Figure 5-5. Emissions Data for Other Lead Emitting Facilities

5.2.7 Combined Facilities

In some cases, emissions from several different type facilities (often with different allowable emissions) are controlled by a common device. In this case, the allowable emission limit can be calculated by taking the weighted average of the standards for each unit. Emissions data for combined facilities were received from five plants, all of which were in compliance. This information is shown in Figure 5-6.

The first test presented for Plant G is from a baghouse controlling the combined emissions of the complete paste mixing (as well as application) and assembly (three-process) operations. The standard for both of these facilities is 4.4×10^{-4} gr/dscf. The second test is for the combined, uncontrolled emissions from the grid casting and lead reclamation operations. The weighted average allowable limit was stated in the test report to be 1.66×10^{-3} gr/dscf. No opacity data were included with the test reports.

The facility presented from Plant M is a baghouse controlling the combined exhaust from several lead melt pots (grid casting) and a lead reclamation operation. An allowable limit of 6.3×10^{-4} gr/dscf was presented in the test report. No opacity data were received.

The facility presented for Plant Y is a baghouse controlling the combined exhaust from the paste application and grid casting operations. An allowable limit of 4.3×10^{-4} gr/dscf was presented in the test report. No opacity data were included.

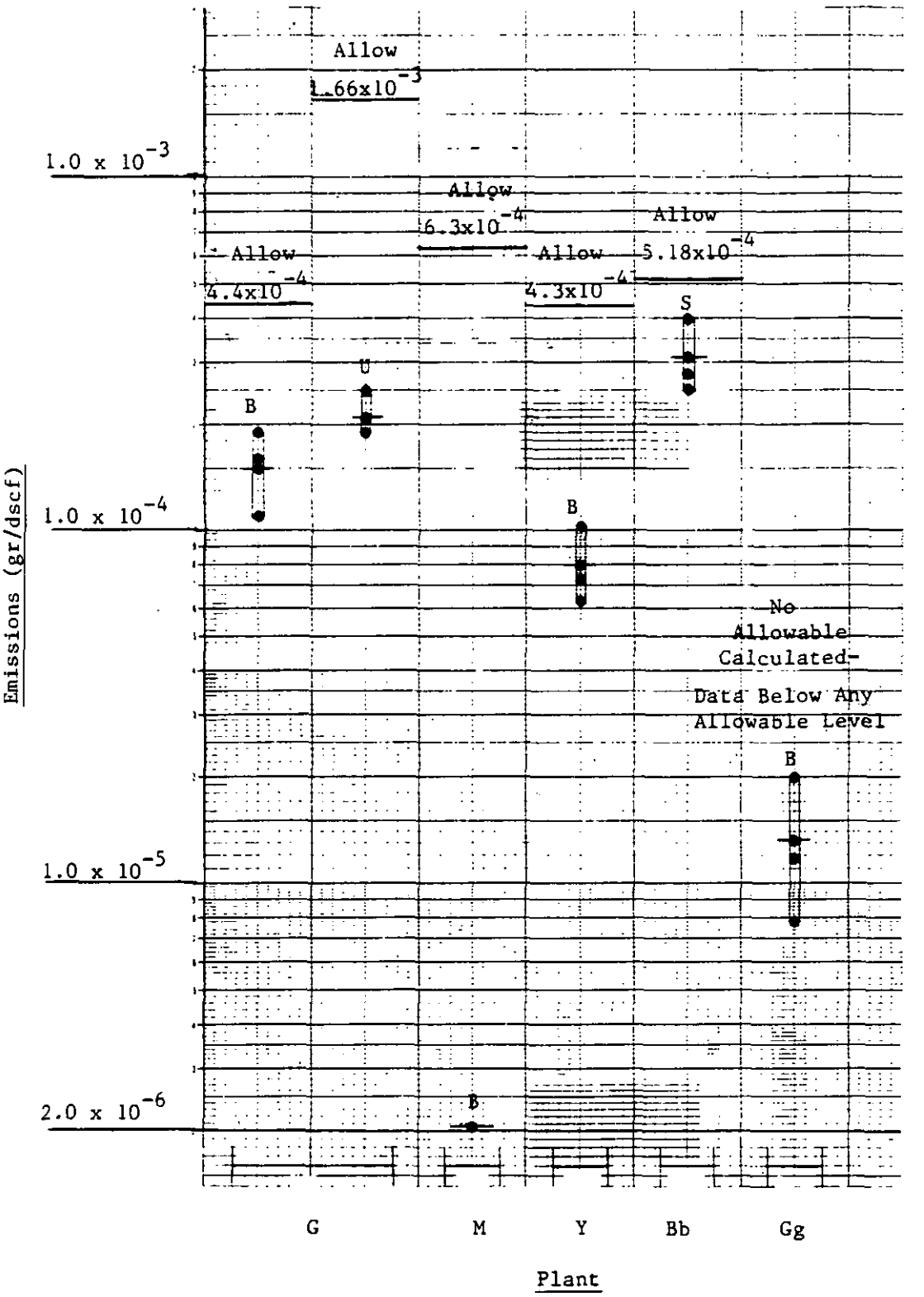
The data from Plant Bb is for the combined emissions from six grid casting units and a lead reclamation operation, all being controlled by a wet scrubber. The weighted average allowable limit was calculated to be 5.18×10^{-4} gr/dscf. Opacity information was not included.

At Plant Gg, all emissions from the plant are ultimately controlled by one central baghouse (some units have primary control devices prior to final control by this baghouse). The major emission points include:

- Oxide Silo Vent Filter
- Plate Breaking and Buffing Baghouse
- Paste Mixing
- Pasting and Three Process Control Devices (several)
- Grid Casting

COMBINED

FACILITIES



KEY

U - Uncontrolled
B - Baghouse
S - Wet Scrubber

NOTE: References shown in Section 5.3.

Figure 5-6. Emissions Data for Combined Facilities

It was not possible to calculate a weighted average emission limit with the available information; however, the emissions were well below any of the applicable limits. The opacity was stated to be 0 percent, although no actual data sheets were included.

5.3 REFERENCES

1. Letter and attachments from Hanslik, J., Battery Builders, Incorporated, to Farmer, J.R., EPA:ESD. August 16, 1988. Response to Section 114 Information Request.

2. Letter and attachments from Reich, P.J., C&D Charter Power Systems, Incorporated, to Farmer, J.R., EPA:ESD. June 21, 1988. Response to Section 114 Information Request.

3. Memo from Michelitsch, D.M., EPA:ISB, to Durkee, K.R.,EPA:ISB. January 9, 1989. Report on July 12, 1988, trip to C&D Charter Power Systems, Incorporated, Conyers, Georgia.

4. Letter and attachments from Eng, K., EPA:Region II, to Michelitsch, D.M., EPA:ISB. April 4, 1988. Response to request for information on battery manufacturing plants subject to the NSPS.

5. Letter and attachments from Turlinski, B.E., EPA:Region III, to Michelitsch, D.M., EPA:ISB. April 7, 1988. Response to request for information on battery manufacturing plants subject to the NSPS.

6. Memo from Michelitsch, D.M., EPA:ISB, to Durkee, K.R., EPA:ISB. October 18, 1988. Report on July 20, 1988, trip to Douglas Battery Manufacturing Company, Winston-Salem, North Carolina.

7. Memo from Michelitsch, D.M., EPA:ISB, to Durkee, K.R., EPA:ISB. December 6, 1988. Report on July 27, 1988, trip to East Penn Manufacturing Company, Lyon Station, Pennsylvania.

8. Materials from Baranski, J.P., Exide Corporation, to Michelitsch, D.M., EPA:ISB. July 26, 1988. Response to Section 114 Information Request.

9. Memo from Michelitsch, D.M., EPA:ISB, to Durkee, K.R., EPA:ISB. November 1, 1988. Report on July 26, 1988, trip to Exide Corporation, Reading, Pennsylvania.

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11. Memo from Whitmore, C., EPA:Region VII, to Michelitsch, D.M., EPA:ISB. March 31, 1988. Response to request for information on battery manufacturing plants subject to the NSPS.

12. Letter and attachments from Frank, S., Gates Energy Products, Incorporated, to Michelitsch, D.M., EPA:ISB. August 17, 1988. Response to Section 114 Information Request.

13. Letter and attachments from Miner, J.R., GNB Incorporated, to Farmer, J.R., EPA:ESD. August 5, 1988. Response to Section 114 Information

Request for Ft. Smith, Arkansas, plant.

14. Letter and attachments from Miner, J.R., GNB Incorporated, to Farmer, J.R., EPA:ESD. August 18, 1988. Response to Section 114 Information Request for Columbus, Georgia, plant.

15. Letter and attachments from Miner, J.R., GNB Incorporated, to Farmer, J.R., EPA:ESD. July 27, 1988. Response to Section 114 Information Request for Zanesville, Ohio, plant.

16. Memo from Nicewander, M.H., EPA:Region VI, to Michelitsch, D.M., EPA:ISB. April 20, 1988. Response to request for information on battery manufacturing plants subject to the NSPS.

17. Letter and attachments from Meverden, J.R., Johnson Controls, Incorporated, to Farmer, J.R., EPA:ESD. August 9, 1988. Response to Section 114 Information Request.

18. Memo from Michelitsch, D.M., EPA:ISB, to Durkee, K.R., EPA:ISB. December 6, 1988. Report on July 19, 1988, trip to Johnson Controls, Incorporated, Winston-Salem, North Carolina.

19. Letter and attachments from Ishihara, M.R., Johnson Controls, Incorporated, to Michelitsch, D.M., EPA:ISB. November 9, 1988. Additional Stack test information.

20. Memo from Michelitsch, D.M., EPA:ISB, to Durkee, K.R., EPA:ISB. November 7, 1988. Report on July 13, 1988, trip to Trojan Battery Manufacturing Company, Lithonia, Georgia.

21. Materials received from Goodwin, J.G., Trojan Battery Manufacturing Company, to Michelitsch, D.M., EPA:ISB. November 28, 1988. Test information on Santa Fe Springs, California, plant.

22. Materials from Flanders, G., U.S. Battery Manufacturing Company, to Farmer, J.R., EPA:ESD. May 12, 1988. Response to Section 114 Information Request.

23. Materials from VanMeter, L., West Kentucky Battery, to Michelitsch, D.M., EPA:ISB. November 18, 1988. Response to Section 114 Information Request.

6.0 COST ANALYSIS

6.1 INTRODUCTION

This chapter presents the capital investment, total annual costs, and cost effectiveness ratios in second quarter 1988 dollars for models of alternative control devices to meet New Source Performance Standards (NSPS). These control devices serve various emission points in model lead-acid battery manufacturing plants.

The control costs are estimated relative to a baseline reflecting a total absence of emission controls. The operations for which estimates are developed include grid casting, paste mixing, the "three-process" operation, formation, lead oxide manufacturing, lead reclamation, and the use of central vacuum systems.

The balance of this chapter is organized into five principal sections. Section 6.2 describes the major steps in the manufacture of lead-acid batteries, and identifies the emission points that would need to be controlled under the NSPS. Section 6.3 describes the alternative controls, while Section 6.4 presents the capital costs for the controls and the unit costs used in estimating the annual control costs. Total annual costs are developed in Section 6.5. Finally, Section 6.6 examines the cost effectiveness of each control alternative and Section 6.7 compares the estimates herein with industry experience reported in Section 114 letter responses.

6.2 PROCESS DESCRIPTION

6.2.1 Grid Casting

The manufacture of lead-acid batteries begins with the production of the lead-alloy grids which constitute the mechanical supporting structures for the battery electrodes or plates. For the most part, grids are produced through a casting process. They are also produced in the form of expanded metal obtained by punching and stretching a

wide strip of sheet lead alloy. In the context of this discussion, however, concern is only with the casting process.

Grids are generally cast in doublets (i.e., two grids per casting from molten lead alloy. The lead alloy is melted in gas-fired pots at a temperature of approximately 700°F (371°C). Casting is performed with single, rotary, or continuous casting machines. In some operations, the melting pots are attached directly to the casting machines. In other situations, the casting machines are fed from a central pot furnace.

Emissions from grid casting tend to be lower than those from other facilities at a lead-acid battery plant. However, a large plant can still emit up to 1,200 kg/yr of lead from this operation. In some instances, the emissions from the casting furnaces are vented directly to the atmosphere. This is done primarily to reduce worker exposures to lead. Generally, the areas around the casting machines are not vented.

6.2.2 Paste Mixing

Paste mixing is a batch operation performed using a muller, Day, or dough-type mixer. From 600 to 3,000 lb (272 to 1,361 kg) of lead oxide are added to the mixer. Water and sulfuric acid are then added, and the mixture blended to form a stiff paste. Different pastes are formulated for the positive and negative plates. About one weight percent of expander (commonly a mixture of carbon black, barium sulfate, and organic materials such as lignosulfonic acid) is added to batches of paste for negative electrodes. Depending on the type of mixer being used, the mixing cycle can last from 15 minutes to one hour.

The bulk of the emissions from the mixing operation occur during the charging of the dry ingredients to the mixer. In a one-hour cycle, the high-emissions phase would occur for roughly the first 10 minutes. The emissions consist of lead oxide, plus small amounts of other paste constituents such as Dynel®, organics, and carbon black.

Following the mixing operation, the paste is applied to the grids by hand or machine. The plates are then subjected to a drying and curing process to achieve the porosity and mechanical strength

required for adequate performance and service life. Curing ensures proper control of oxidation and sulfation of the plates.

6.2.3 The Three-Process Operation

Following the curing process, the plates are usually sent to the "three-process" operation, which consists of plate stacking, burning, and assembly of elements in the battery case. The plates are stacked in an alternating positive and negative block formation with insulating separators inserted between each pair of plates. The stacking is commonly performed by hand, although the operation can be automated.

The burning operation entails the welding of leads to the tabs of each positive and each negative plate, thereby fastening the element together. The completed elements are then assembled into battery cases either before formation (in "wet" formation) or after formation (in "dry" formation). An alternative to this operation is the "cast-on-strap" process in which molten lead is poured around and between the plate tabs to form the connection. A positive and a negative terminal are then welded to the element.

Most of the lead emissions in the three-process operation are generated during the plate stacking and burning/casting operations. The handling of plates between the process steps also produces considerable lead emissions. Workers typically straighten stacks of plates by striking them against a grated surface. The impact causes particles of paste to become airborne. These particles are generally collected in vents to protect the health of workers.

6.2.4 Formation

In the formation process, the inactive lead oxide-sulfate paste is chemically converted to an active electrode. The lead oxide in the positive plates is oxidized to lead peroxide. In the negative plates, the lead oxide is reduced to metallic lead. The process involves placing unformed plates in a dilute sulfuric acid solution, and connecting the positive plates to the positive pole of a direct current (dc) source, and the negative plates to the negative pole of the dc source.

During the process, hydrogen is released in the form of small bubbles. These bubbles carry sulfuric acid with them as they break through the surface of the solution and enter the atmosphere. The process is thus a source of sulfuric acid mist emissions. The emissions tend to increase with increases in temperature and charging rate. In addition, as the formation process nears its end, the release of hydrogen bubbles tends to increase.

Formation of the battery plates may be performed either within the battery case after assembly ("wet" formation) or in open tanks prior to battery assembly ("dry" formation). In wet formation, the cells are placed in the battery case, the lid is attached, sulfuric acid is added, and a charge is applied. After formation, the charging electrolyte is often removed from the battery for reuse, and new acid is added. Depending on the particular charging method used, wet formation may require from one to seven days for completion. In dry formation, the battery elements are formed by placing them in large tanks of sulfuric acid, then making an electrical connection. The process typically requires about 16 hours for completion.

Emissions from wet formation operations tend to be minor, and are usually not controlled or ducted to a stack. In dry formation, the emissions of acid mist may be controlled through the use of a surface foaming agent, mist eliminators, scrubbers, or some combination of these controls.

6.2.5 Lead Oxide Production

The lead oxide mixture used in battery paste production is typically 70 percent PbO, with the balance being free metallic lead. Lead oxide is produced by either the ball mill process or the Barton process. In the ball mill process, high purity lead pigs (ingots) are tumbled in a mill while being subjected to a regulated flow of air. Oxidation is initiated by the heat generated through the tumbling action. During the tumbling, the lead oxide that forms on the surface of a pig is broken off, along with fine particles of unoxidized lead. The resulting dust is removed from the mill by a circulating air stream. Larger particles are ground further in a hammermill. The

lead oxide mixture is conveyed to storage bins by means of totally enclosed screw conveyors. Enough lead oxide is entrained in the mill exhaust gases to justify gas cleaning for product recovery.

In the Barton process, molten lead is fed into a pot and stirred rapidly. Baffles in the pot break the lead into fine droplets. The droplets are then oxidized by an air stream directed over the surface of the molten lead. The resulting lead oxide is then conveyed by an airstream to a fabric filter for recovery. The particle-size distribution and apparent density of the oxide are controlled by the temperature maintained in the pot and the volume and velocity of the air stream that conveys the reacted products. Larger particles are captured in a cyclone prior to the fabric filter, and passed through a hammermill.

6.2.6 Lead Reclamation

Lead reclamation is a process in which relatively clean lead scrap is melted and cast into pigs for use in the battery manufacturing process. The melting is generally done in a pot-type furnace. Reclamation tends to be sporadic, being performed only when enough scrap lead is available for charging. The emissions from the pot-type furnaces tend to be minimal.

6.2.7 Central Vacuum Systems

Many lead-acid battery plants employ central vacuum systems for general housekeeping purposes. A central vacuum system is a utility which usually includes a fan and a small baghouse ducted to the various work stations. The vacuum connections at the work stations are used for clean up as required. In several cases, these units have been determined to be subject to the NSPS on the grounds that they fall within the category of "other lead emitting" sources.

6.3 POLLUTION CONTROL DEVICES

The alternative control devices are identified in Table 6-1. The alternatives for lead emissions are impingement scrubbers, fabric filters, and cartridge collectors. Recently some plants have

TABLE 6-1. LEAD-ACID BATTERY MANUFACTURE MODEL FACILITY PARAMETERS AND CONTROL SYSTEMS (a,s)

Facility	Plant(b) Size	Description of Control System: Control Device	Moisture (%)	Temperature (C)	Temperature (F)	Volume m3/min	Volume acfm	Uncontrolled Emissions kg/yr	Uncontrolled Emissions lbs/yr	Controlled(c) Emissions kg/yr	Controlled(c) Emissions lbs/yr	Pollutants Collected kg/yr	Pollutants Collected lbs/yr
Grid Casting(j)	Small	Wet Scrubber(d)	2-3	76.5	170	98.0	3,460	156.9	345.8	4.7	10.3	152.2	335.5
		F/F-6/1 A/C(e)	2-3	76.5	170	98.0	3,460	156.9	345.8	0.6	1.3	156.3	344.5
		Cart.Col.(n)	2-3	76.5	170	98.0	3,460	156.9	345.8	0.6	1.3	156.3	344.5
		Sec. HEPA(p)	2-3	76.5	170	98.0	3,460	q	q	1.8E-04	3.9E-04	0.5998	1.3
	Medium	Wet Scrubber(d)	2-3	76.5	170	489.9	17,300	784.5	1,729.6	46.7	103	737.8	1,626.6
		F/F-6/1 A/C(e)	2-3	76.5	170	489.9	17,300	784.5	1,729.6	6.0	13.3	778.5	1,716.3
		Cart.Col.(n)	2-3	76.5	170	489.9	17,300	784.5	1,729.6	6.0	13.3	778.5	1,716.3
		Sec. HEPA(p)	2-3	76.5	170	489.9	17,300	q	q	1.81E-03	3.99E-03	5.998	13.296
	Large	Wet Scrubber(d)	2-3	76.5	170	734.8	25,950	1,176.9	2,594.6	106.3	234.2	1,070.6	2,360.4
		F/F-6/1 A/C(e)	2-3	76.5	170	734.8	25,950	1,176.9	2,594.6	13.3	29.3	1,163.6	2,565.3
		Cart.Col.(n)	2-3	76.5	170	734.8	25,950	1,176.9	2,594.6	13.3	29.3	1,163.6	2,565.3
		Sec. HEPA(p)	2-3	76.5	170	734.8	25,950	q	q	3.99E-03	8.80E-03	13.296	29.291
Paste Mixing	Small	F/F-6/1 A/C(e)	2-4	38.0	100	317.1	11,200	4,517.5	9,959.4	37.9	83.5	4,479.6	9,875.9
		Cart. Col.(n)	2-4	38.0	100	317.1	11,200	4,517.5	9,959.4	37.9	83.5	4,479.6	9,875.9
		Sec. HEPA(p)	2-4	38.0	100	317.1	11,200	q	q	0.0114	0.0251	37.888	83.475
	Medium	F/F-6/1 A/C(e)	2-4	38.0	100	1,585.7	56,000	22,586.0	49,793.9	381	840	22,205	48,953.9
		Cart. Col.(n)	2-4	38.0	100	1,585.7	56,000	22,586.0	49,793.9	381	840	22,205	48,953.9
		Sec. HEPA(p)	2-4	38.0	100	1,585.7	56,000	q	q	0.1141	0.2517	380.886	839.748
	Large	F/F-6/1 A/C(e)	2-4	38.0	100	2,378.6	84,000	33,879.2	74,691.1	852.1	1878.5	33,027.1	72,812.6
		Cart. Col.(n)	2-4	38.0	100	2,378.6	84,000	33,879.2	74,691.1	852.1	1878.5	33,027.1	72,812.6
		Sec. HEPA(p)	2-4	38.0	100	2,378.6	84,000	q	q	0.2554	0.5631	851.845	1,877.937

TABLE 6-1. LEAD-ACID BATTERY MANUFACTURE MODEL FACILITY PARAMETERS AND CONTROL SYSTEMS (a,s) (cont.)

Facility	Plant(b) Size	Description of Control System: Control Device	Moisture (%)	Temperature (C)	Temperature (F)	Volume m3/min	Volume acfm	Uncontrolled Emissions kg/yr	Uncontrolled Emissions lbs/yr	Controlled(c) Emissions kg/yr	Controlled(c) Emissions lbs/yr	Pollutants Collected kg/yr	Pollutants Collected lbs/yr
Lead Oxide Manufacturing (h)	Small	f	f	f	f	f	f	f	f	f	f	f	f
	Medium	F/F-2/1 A/C(g)	2-3	115	240	696.6	24,600	101.9	224.6	51.1	112.7	50.8	111.9
		Cart.Col.(n)	2-3	115	240	696.6	24,600	101.9	224.6	51.1	112.7	50.8	111.9
		Sec. HEPA(p)	2-3	115	240	696.6	24,600	q	q	0.0153	0.0338	51.085	112.666
Seven Linklater Systems	Large	F/F-2/1 A/C(g)	2-3	115	240	1,044.9	36,900	152.8	336.9	76.5	168.6	76.3	168.3
		Cart.Col.(n)	2-3	115	240	1,044.9	36,900	152.8	336.9	76.5	168.6	76.3	168.3
		Sec. HEPA(p)	2-3	115	240	1,044.9	36,900	q	q	0.0229	0.0506	76.477	168.549
Two Barton Systems		F/F-2/1 A/C(g)	2-3	115	240	373.8	13,200	152.8	336.9	76.5	168.6	76.3	168.3
		Cart.Col.(n)	2-3	115	240	373.8	13,200	152.8	336.9	76.5	168.6	76.3	168.3
		Sec. HEPA(p)	2-3	115	240	373.8	13,200	q	q	0.0229	0.0506	76.477	168.549
Three Process Operation	Small	F/F-6/1 A/C(e)	1-2	27	80	534.6	18,880	2,564.0	5,652.6	64.1	141.3	2,499.9	5,511.3
		Cart.Col.(n)	1-2	27	80	534.6	18,880	2,564.0	5,652.6	64.1	141.3	2,499.9	5,511.3
		Sec.HEPA(p)	1-2	27	80	534.6	18,880	q	q	0.0190	0.0419	64.081	141.258
	Medium	F/F-6/1 A/C(e)	1-2	27	80	2,673.1	94,400	12,819.0	28,261.2	641.1	1413.4	12,177.9	26,847.8
		Cart.Col.(n)	1-2	27	80	2,673.1	94,400	12,819.0	28,261.2	641.1	1413.4	12,177.9	26,847.8
		Sec.HEPA(p)	1-2	27	80	2,673.1	94,400	q	q	0.1918	0.4228	640.908	1412.96
	Large	F/F-6/1 A/C(e)	1-2	27	80	4,009.7	141,600	19,228.5	42,391.8	1442.6	3180.5	17,785.9	39,211.3
		Cart. Col.(n)	1-2	27	80	4,009.7	141,600	19,228.5	42,391.8	1442.6	3180.5	17,785.9	39,211.3
		Sec. HEPA(p)	1-2	27	80	4,009.7	141,600	q	q	0.4326	0.9537	1,442.170	3,179.550

TABLE 6-1. LEAD-ACID BATTERY MANUFACTURE MODEL FACILITY PARAMETERS AND CONTROL SYSTEMS (a,s) (cont.)

Facility	Plant(b) Size	Description of Control System: Control Device	Moisture (%)	Temperature (C)	Temperature (F)	Volume m3/min	Volume acfm	Uncontrolled Emissions kg/yr	Uncontrolled Emissions lbs/yr	Controlled(c) Emissions kg/yr	Controlled(c) Emissions lbs/yr	Pollutants Collected kg/yr	Pollutants Collected lbs/yr
Lead Reclamation (j,k) :	Small	Wet Scrubber(d)	2-3	115	240	198	7,000	134.1	295.7	6.4	14.2	127.7	281.5
		F/F-6/1 A/C(e)	2-3	115	240	198	7,000	134.1	295.7	3.1	6.7	131.0	289.0
		Cart. Col.(n)	2-3	115	240	198	7,000	134.1	295.7	3.1	6.7	131.0	289.0
		Sec. HEPA(p)	2-3	115	240	198	7,000	q	q	0.00092	0.00203	3.099	6.698
	Medium	Wet Scrubber(d)	2-3	115	240	198	7,000	671.1	1,479.6	33.1	73.1	638.0	1,406.5
		F/F-6/1 A/C(e)	2-3	115	240	198	7,000	671.1	1,479.6	14.7	32.3	656.4	1,447.3
		Cart. Col.(n)	2-3	115	240	198	7,000	671.1	1,479.6	14.7	32.3	656.4	1,447.3
		Sec. HEPA(p)	2-3	115	240	198	7,000	q	q	0.00440	0.00969	14.696	32.290
	Large	Wet Scrubber(d)	2-3	115	240	198	7,000	1,006.6	2,219.3	49.5	109.2	957.1	2,110.1
		F/F-6/1 A/C(e)	2-3	115	240	198	7,000	1,006.6	2,219.3	22.0	48.5	984.6	2,170.8
		Cart. Col.(n)	2-3	115	240	198	7,000	1,006.6	2,219.3	22.0	48.5	984.6	2,170.8
		Sec. HEPA(p)	2-3	115	240	198	7,000	q	q	0.00659	0.01454	21.993	48.485
Formation(l)	Small	Mist Eliminator	N.A.	27	80	1,330.9	47,000	2.00E+06	4.41E+06	2.00E+04	4.41E+04	1.98E+06	4.37E+06
	Medium	Mist Eliminator	N.A.	27	80	6,654.4	235,000	9.83E+06	2.17E+07	9.83E+04	2.17E+05	9.73E+06	2.15E+07
	Large	Mist Eliminator	N.A.	27	80	9,981.7	352,500	1.34E+07	2.95E+07	1.34E+05	2.95E+05	1.33E+07	2.92E+07
Central Vacuum Systems	Small	F/F-3.9/1 A/C(r)		21	70	16.4	580						
	Medium	F/F-3.9/1 A/C(r)		21	70	82.1	2,900						
	Large	F/F-3.9/1 A/C(r)		21	70	123.2	4,350						

Table 6-1 (Continued)

(a) Developed using information from original Background Information for Proposed Standards (EPA-450/3-79/028a, November 1979), original Background Information for Promulgated Standards (EPA-450/3/79/-028b, November 1980), and information gathered from industry through survey letters and plant visits; revised according to comments received from Battery Council International (BCI).

(b) A small plant is one with the capacity to produce in any one day batteries which would contain, in total, an amount of lead equal to 18.1 Mg (20 tons); a medium plant could product lead equal to 90.7 Mg (100 tons); a large plant could product lead equal to 136.1 Mg (150 tons). This is based upon an average weight of lead per battery of 20 lbs.

(c) Emissions controlled to the level of the standard, in comparison to the uncontrolled case, except where otherwise noted.

(d) Impingement-type scrubber operating at a pressure drop of about 1.25 kPa (5 in W.G.).

(e) Pulse-jet fabric filter with a 6/1 air-to-cloth ratio.

(f) It is assumed that small plants have no lead-oxide manufacturing facilities.

(g) Pulse-jet fabric filter with a 2/1 air-to-cloth ratio.

(h) Lead-oxide manufacturing facilities include a fabric filter (3/1 A/C ratio) for product recovery as part of the process; this is presented as uncontrolled. The controlled case represents a well controlled system, which uses a cartridge collector or a fabric filter with a 2/1 A/C (air-to-cloth) ratio, in lieu of a 3/1 A/C ratio fabric filter that is used only for economical recovery of lead oxide. For Barton process oxide production, two systems are available; Linklater and Barton. The Barton units are large, and only used in large plants; they also have a much smaller air flow rate per unit of production than Linklater systems. Therefore, for large plants, two model plants are presented; one using Linklater equipment, and one using Barton equipment.

(j) The emissions from the fabric filter and cartridge collector controlled cases are calculated to the level achievable by these systems, which is lower than the current standard.

(k) All plant sizes are assumed to have the same size reclaim facility, however, they process different amounts of lead per year.

Table 6-1 (Continued)

(l) Emissions from the formation process consist of H_2SO_4 mist. The emission values are based upon the dry formation process, using a mist eliminator with 99 percent control efficiency as a control device.

(n) Pulse-jet cartridge collector with a 1.5/1 air-to-filter-surface ratio.

(p) Secondary high efficiency particulate air filter (HEPA) to achieve additional pollutant collection following fabric filters or cartridge collectors. The pollutants collected are those in addition to those collected by the primary device, assuming a HEPA collection efficiency of 99.97 percent.

(q) The "uncontrolled" values for the secondary collectors are the controlled values for the primary collectors, which will vary depending upon the primary collector used (i.e., fabric filter or cartridge collector).

(r) Pulse-jet fabric filter with a 3.9/1 air-to-cloth ratio.

(s) Plant sizes and exhaust volumes were changed due to BCI comments and emission values adjusted accordingly. The uncontrolled emissions from the pasting line portion of the "paste mixing" process were assumed to be equal to the uncontrolled emissions from the three-process operation (on a per-battery basis).

installed high efficiency particulate air (HEPA) filters downstream of the primary emission control filter (a "secondary HEPA") to further clean the exhaust air to allow it to be recirculated through the work area. HEPA filters have a collection efficiency of 99.97 percent and are described in detail in Reference 1. This reduces costs by allowing the heated exhaust air to be recirculated in the winter time. HEPA filters can be applied to any of the facilities where the primary emission control device is either a fabric filter or cartridge collector. Specifically, they can be used in grid casting, paste mixing, lead oxide manufacturing, the three-process operation, or lead reclamation.

The fabric filters estimated for this study were pulse-jet designs with polyester felt bags using venturis and cages. It was estimated from data in References 2 through 7 that 30 percent of the bags would require replacement annually. Cartridge collectors are similar to a pulse-jet baghouse, but utilize a non-woven filter media of chemically treated cellulose and synthetic fibers. The filter media are pleated to increase the filtering area and to reduce the pressure drop across the filter without sacrificing the unit collection efficiency. Also, the media are formed into cartridges to allow easy replacement. The cartridges are cleaned automatically during the operation of the unit. About 50 percent of the cartridges are replaced annually (Reference 7). Cartridge collectors are finding increasing application in lead-acid battery plants. The average air-to-filter-surface ratio of a cartridge collector is 1.5/1.

For grid-casting operations, the alternatives include impingement scrubbers, pulse-jet fabric filters, pulse-jet cartridge collectors, and secondary HEPA filters. In Table 6-1, these are denoted as "Wet scrubber," "F/F--6/1 A/C," "Cart. col.," and "Sec. HEPA," respectively.

Impingement scrubbers are commonly used to control emissions from grid casting machines and furnaces. The units are relatively small, and have moderate power requirements (1.25 kPa or 5 in W.G.) and low water requirements.

For paste mixing, the alternatives include pulse-jet fabric filters, pulse-jet cartridge collectors, and secondary HEPA filters. The specifications are the same as those given above. Currently, both baghouses and scrubbers are used to control emissions from paste mixing operations. Some plants vent emissions to a baghouse during the material charging phase, and to a wet collector during the final wet mixing stage. However, there would appear to be no technological reasons why fabric filters or cartridge collectors could not be used to control emissions during the entire mixing cycle.

Lead oxide production facilities employ settling chambers or cyclones followed by a shaker fabric filter operating at a 3/1 air-to-cloth (A/C) ratio to collect the product. The arrangement provides economical product recovery but does not achieve the required NSPS emission rates. To meet NSPS emission rates either a second fabric filter must be installed downstream of the product collection filter or the product collection filter must be replaced with one with a 2/1 A/C ratio (F/F-2/1 A/C in Table 6-1) or another control device of similar efficiency. Whichever arrangement is used to meet NSPS emission rates, a secondary HEPA can be installed downstream if it is desired to recirculate the exhaust.

For the three-process operation, the alternative controls include pulse-jet fabric filters, pulse-jet cartridge collectors, and secondary HEPA filters. The specifications of the alternatives are as previously described. Currently, fabric filters or scrubbers are used to control emissions from the three-process operation. Most plants vent the stacking, burning, and assembly operations to a common duct before cleaning the gases. Other plants use a common system to control emissions from the three-process operation and paste mixing.

The alternative control devices for lead reclamation include impingement scrubbers, pulse-jet fabric filters, pulse-jet cartridge collectors, and secondary HEPA filters. The specifications for these devices are as previously discussed. The exhaust stream from lead reclamation operations is similar to that emanating from

grid casting. It is therefore a common practice to vent these operations to a single control device.

As noted earlier, the formation process is a source of sulfuric acid mist. Higher emissions are generally associated with dry formation. The formation model plant emissions in Table 6-1 are based on the dry formation process. The control device is usually an irrigated mist eliminator ("Mist Eliminator," in Table 6-1) consisting of a fan/separator followed by an integral short packed section. These units typically have a 99 percent removal efficiency (Reference 9). The scrubbing liquid is sprayed into the fan inlet. Gas-liquid contacting is promoted by the turbulence in the fan which also acts as a centrifugal separator, removing the larger droplets. The remaining droplets are separated by inertial impingement in the short packed section. As shown in Table 6-1 there is a large quantity of acid mist which dissolves in the scrubbing liquor. The liquor must be treated before it is discarded.

For central vacuum systems, the proposed control device is a pulse-jet fabric filter with a 3.9/1 air-to-cloth ratio (F/F-3.9/1 A/C in Table 6-1).

6.4 COST DATA, METHODOLOGY AND ASSUMPTIONS

The exhaust stream volumes on which the control cost estimates are based are given in Table 6-1. The volumes are based on data supplied by the Battery Council International. The data and the calculations used to develop the flows in Table 6-1 are given in Reference 10. Since the size of these exhaust streams is partially attributable to OSHA standards, the costs developed also partially result from the OSHA standards.

All costs, both capital and annual, are based on inclusion of controls in new plant construction.

6.4.1 Capital Costs

Capital costs include the purchased equipment costs and the direct and indirect costs of installation. The purchased equipment costs include the cost of major equipment items and auxiliaries such as instrumentation and the cost of taxes and freight. Direct

installation costs include foundations, erection, electrical, piping, and similar charges. Indirect charges are those resulting from engineering, supervision, contractors' fees, and start-up assistance and tests.

All capital costs include ductwork, control device, fan, and instrumentation and controls. All equipment was estimated in carbon steel except that used in formation, where plastic and stainless steel were used to resist the acid mist. Hooding was not included. The estimates were developed assuming that OSHA workplace air quality standards, would require hoods and therefore these should not be charged against EPA emissions standards. If there were no emission requirements the hoods would be ducted directly to a fan mounted on the building roof, probably directly above the operation, which discharged directly to the atmosphere. Since there are emission standards, the individual hoods are ducted to large collecting ducts which lead the exhaust of all the hoods for a particular facility to an emission control device and fan. Only the costs of the collecting ducts were included in this study.

Ductwork was sized at 4,500 ft/min (Reference 11). Ductwork sizes, lengths, and fittings estimated for each model facility are listed in Appendix A. Ductwork costs were obtained from References 12 and 13 for the carbon steel ductwork and Reference 14 for the fiberglass reinforced plastic (FRP) specified for the formation area.

Fan costs were estimated using a vendor's budget quote (Reference 15) for sizes up to 16,200 acfm and References 16 and 17 for the larger sizes.

Wet scrubber costs were estimated from a manufacturer's budget quote (Reference 18 and 19). With the exception of lead oxide manufacture and the central vacuum systems, fabric filters were estimated as pulse jets using a 6/1 air-to-cloth ratio. Sizes between 4,000 and 16,000 ft^2 of filtering area were estimated using the data and procedures in Reference 20. Manufacturer's quotes, References 21 and 22, were used for the sizes which are not covered by the charts in Reference 20.

Cartridge collector costs were estimated from a manufacturer's budget quotes (References 23 and 25). Reference 24 is a manufacturer's quote for HEPA filters.

Sulfuric acid mist is removed from air exhausted from formation by an irrigated mist eliminator; budget costs were obtained from the manufacturer (References 26 and 27). The mist eliminator discharge must be treated before it leaves the plant so these systems include a carbon steel storage tank and a plastic or stainless steel feed pump for 50 percent NaOH. Storage tank costs were estimated from data in References 28 and 29. A manufacturer's quote list (Reference 30) was used to estimate the caustic feed pump cost for the small and medium model facilities. Pumps for the medium and large facilities were estimated from data in Reference 31.

Basic equipment costs obtained as described above were factored to obtain first the total purchased equipment cost and then the direct and indirect installation costs using procedures and factors in Reference 32. The total purchased equipment costs and the direct and indirect installation costs were then summed to obtain the total capital investment. A detailed example of capital cost estimation using this procedure is given in Appendix B. An exception to this procedure was made for wet scrubbers and pulse-jet fabric filters handling less than approximately 10,000 acfm. These controls can be obtained with the fan, motor, and instruments mounted on the unit and prewired. This substantially reduces installation costs. For these units an installation cost of 25 percent (Reference 20) of the purchased equipment cost was used.

Pulse-jet fabric filters larger than about 10,000 acfm and cartridge filters do not appear to be available as package units, hence, the factors in Reference 32 were used for all installations of these controls.

The only basic equipment items included in the secondary HEPA filter installations were the filters and the filter frames. The cost estimates are for standard 24 in by 24 in by 11½ in filters, which are sized at 1200 acfm per filter. It was assumed that any increase in fan and motor capital cost resulting from the low pressure drop ($\leq$2

in H_2O) would be negligible. The cost of ductwork was not included as a separate item. It was assumed that since the HEPA filters would be installed close to the primary control device the small amount of ductwork required would be covered by the installation cost factors. Factors from Reference 32 were used to establish the installation cost and the total capital investment for HEPA filters.

All capital costs are on a second quarter 1988 basis. Where necessary, costs were adjusted to second quarter 1988 using the cost indices published in Chemical Engineering. The specific indices used were:

	Index
Fans	Process Machinery
Motors	Electrical Equipment
Fabric Filters	Process Equipment
Storage Tanks	Process Equipment

Costs calculated as described above should have study estimate accuracy of about ± 30 percent.

The factors used to establish total capital investment include an allowance for instruments, but individual instruments are not broken out. The NSPS requires that for any subject facility controlled by a scrubbing system, a monitoring device be installed that measures and records the pressure drop across the scrubbing system at least once every 15 minutes. A differential pressure transmitter and a remote (if desired) 24-hour circular chart recorder to accomplish this task have a total purchased cost of $2,000 (Reference 33 for the recorder, Reference 34 for the transmitter). Installation costs would be highly dependent on the particular situation but might range from $400 to $2,000. Annual operating costs would be minimal.

Capital costs for all controls are given in Tables 6-2 through 6-10.

6.4.2 Annual Costs

Annual costs are the sum of direct operating and maintenance charges, which are the direct costs of operating the equipment and indirect costs most of which are fixed and accrue whether the equipment is operating or not. Direct operating costs include operating and maintenance labor, maintenance materials, replacement

TABLE 6-2. CAPITAL COST: FOR CONTROL OF GRID CASTING FURNACE AND MACHINE

New Construction - Second quarter 1988 dollars

Control device and basic equipment	Cost (thousand $) Plant size Small	Medium	Large
Wet scrubber			
Scrubber, fan, motor	12.2	27.7	56.0
Ductwork	4.9	10.8	12.8
Freight, taxes, instruments	3.1	6.9	12.4
Purchased equipment cost	20.2	45.4	81.2
Total capital investment[a]	25.2[b]	86.7	155.0
Fabric filter			
Fabric filter, fan, motor	16.1	41.0	64.3
Ductwork	4.9	10.8	12.8
Freight, taxes, instruments	3.8	9.3	13.9
Purchased equipment cost	24.8	61.1	91.0
Total capital investment[a]	31.0[b]	132.6	197.4
Cartridge collector			
Cartridge collector	12.8	36.6	46.4
Fan and motor	3.5	9.0	20.7
Ductwork	4.9	10.8	12.8
Freight, taxes, instruments	3.8	10.2	14.4
Purchased equipment cost	25.0	66.6	94.3
Total capital investment[a]	54.1	144.5	204.6
Secondary HEPA filter			
HEPA filter	1.8	5.7	9.5
Freight, taxes, instruments	0.3	1.0	1.7
Purchased equipment cost	2.1	6.7	11.2
Total capital investment[a]	4.8	14.5	24.4

[a]The installation cost, which is the difference between the purchased equipment cost and the total capital investment, was calculated as the sum of factors of the purchased equipment cost, as described in Reference 32 and shown in Appendix B.

[b]Installation costs are low for the wet scrubber and fabric filter for the small plant for this facility because they can be obtained as packaged units.

TABLE 6-3. CAPITAL COST: FOR CONTROL OF PASTE MIXING

New Construction - Second quarter 1988 dollars

Control device and basic equipment	Cost (thousand $) Plant size Small	Medium	Large
Fabric filter			
Fabric filter, fan, motor	36.5	102.7	143.6
Ductwork	8.9	9.8	21.5
Freight, taxes, instruments	8.2	20.3	29.7
Purchased equipment cost	53.6	132.8	194.8
Total capital investment[a]	116.3	288.3	422.8
Cartridge collector			
Cartridge collector	28.0	83.1	102.0
Fan and motor	7.0	21.0	26.8
Ductwork	8.9	9.8	21.5
Freight, taxes, instruments	7.9	20.5	27.1
Purchased equipment cost	51.8	134.4	177.4
Total capital investment[a]	112.5	291.8	384.9
Secondary HEPA filter			
HEPA filter	4.1	17.7	25.8
Freight, taxes, instruments	0.7	3.2	4.6
Purchased equipment cost	4.8	20.9	30.4
Total capital investment[a]	10.6	45.2	66.1

[a]The installation cost, which is the difference between the purchased equipment cost and the total capital investment, was calculated as the sum of factors of the purchased equipment cost, as described in Reference 32 and shown in Appendix B.

TABLE 6-4. CAPITAL COST: FOR CONTROL OF LEAD OXIDE MANUFACTURING

New Construction - Second quarter 1988 dollars

Control device and basic equipment	Cost (thousand $)[a] Plant size		
	Medium	Large, Seven Linklater Systems	Large, Two Barton Systems
Fabric filter 2/1 A/C[b]			
Incremental cost fabric filter	31.0	70.1	16.8
Incremental freight, taxes, instruments	5.6	12.6	3.0
Incremental purchased equipment cost	36.6	82.7	19.8
Incremental capital investment[e]	79.5	179.5	42.9
Cartridge collector 1.5/1 A/C[b]			
Incremental cost cartridge collector	(27.4)	(45.9)	(12.7)
Incremental freight, taxes, instruments	(4.9)	(8.3)	(2.3)
Incremental purchased equipment cost	(32.3)	(54.2)	(15.0)
Incremental capital investment[e]	(70.2)	(117.5)	(32.5)
Fabric filter 3/1 A/C[c]			
Fabric filter	72.8	103.9	44.2
Fan and Motor	20.7	43.0	7.6
Ductwork	12.2	15.3	9.4
Freight, taxes, instruments	19.0	29.2	11.0
Purchase equipment cost	124.7	191.4	72.2
Total capital investment[e]	270.8	415.3	156.8
Secondary HEPA filter[d]			
HEPA filter	10.7	14.8	6.2
Freight, taxes, instruments	1.9	2.7	1.1
Purchased equipment cost	12.6	17.5	7.3
Total capital investment[e]	27.4	37.9	15.9

See footnotes on following page

TABLE 6-4. CAPITAL COST: FOR CONTROL OF LEAD OXIDE MANUFACTURING (cont.)

[a]Numbers in parenthesis are credits.
[b]The uncontrolled case in lead oxide manufacture is a pulse-jet fabric filter with a 3/1 A/C ratio which will provide economical product collection but will not meet NSPS emission requirements. Substituting either a pulse-jet fabric filter with a 2/1 A/C ratio or a cartridge collector for the 3/1 A/C ratio pulse-jet filter will provide both product collection and emissions that meet NSPS standards at these incremental capital costs.
[c]This is the uncontrolled case which will provide economical product collection but will not meet NSPS emission requirements, see footnote b.
[d]Costs shown are those for installing a HEPA filter downstream of either a 2/1 A/C pulse-jet fabric filter or a cartridge collector.
[e]The installation cost, which is the difference between the purchased equipment cost and the total capital investment, was calculated as the sum of factors of the purchased equipment cost, as described in Reference 32 and shown in Appendix B.

TABLE 6-5. CAPITAL COST: FOR CONTROL OF THREE PROCESS OPERATION

New Construction - Second quarter 1988 dollars

Control device and basic equipment	Cost (thousand $) Plant size Small	Medium	Large
Fabric filter			
Fabric filter	32.0	130.0	206.1
Fan, motor	9.4	32.5	55.2
Ductwork	11.4	23.3	29.3
Freight, taxes, instruments	9.5	33.4	52.3
Purchased equipment cost	62.3	219.2	342.9
Total capital investment[a]	135.3	475.6	774.1
Cartridge collector			
Cartridge collector	41.7	126.0	177.9
Fan and motor	9.4	32.5	55.2
Ductwork	11.4	23.3	29.3
Freight, taxes, instruments	11.3	32.7	47.2
Purchased equipment cost	73.8	214.5	309.6
Total capital investment[a]	160.1	465.5	671.9
Secondary HEPA filter			
HEPA filter	5.9	30.9	43.5
Freight, taxes, instruments	1.1	5.6	7.8
Purchased equipment cost	7.0	36.5	51.3
Total capital investment[a]	15.1	79.2	111.3

[a]The installation cost, which is the difference between the purchased equipment cost and the total capital investment, was calculated as the sum of factors of the purchased equipment cost, as described in Reference 32 and shown in Appendix B.

TABLE 6-6. CAPITAL COST: FOR CONTROL OF LEAD RECLAMATION[a]

New Construction - Second quarter 1988 dollars

Control device and basic equipment	Cost (thousand $)
Wet scrubber	
Scrubber, fan, motor	17.4
Ductwork	7.3
Freight, taxes, instruments	4.5
Purchased equipment cost	29.2
Total capital investment[b]	36.5
Fabric filter	
Fabric filter, fan, motor	23.1
Ductwork	7.3
Freight, taxes, instruments	5.5
Purchased equipment cost	35.9
Total capital investment[b]	44.9
Cartridge collector	
Cartridge collector	24.8
Fan, motor	5.2
Ductwork	7.3
Freight, taxes, instruments	6.8
Purchased equipment cost	44.1
Total capital investment[c]	95.7
Secondary HEPA filter	
HEPA filter	3.6
Freight, taxes, instruments	0.7
Purchased equipment cost	4.3
Total capital investment[c]	9.3

[a]All plant sizes are assumed to have the same size reclamation facility.
[b]Installation costs are low for these devices because they can be obtained as packaged units.
[c]The installation cost, which is the difference between the purchased equipment cost and the total capital investment, was calculated as the sum of factors of the purchased equipment cost, as described in Reference 32 and shown in Appendix B.

TABLE 6-7. CAPITAL COST: FOR CONTROL OF PASTE MIXING PLUS THREE PROCESS OPERATION BY SAME DEVICE

New Construction - Second quarter 1988 dollars

Control device and basic equipment	Cost (thousand $) Plant size Small	Medium	Large
Fabric filter			
Fabric filter	48.6	240.1	370.0
Fan, motor	33.0	53.5	82.0
Duct	22.4	40.1	63.5
Freight, taxes, instruments	18.7	60.0	92.8
Purchased equipment cost	122.7	393.7	608.3
Total capital investment[a]	266.5	854.1	1,319.9
Cartridge collector			
Cartridge collector	51.7	184.0	276.0
Fan and motor	33.0	53.5	82.0
Freight, taxes, instruments	22.4	40.1	63.5
Purchased equipment cost	19.3	50.0	75.9
	126.4	327.6	497.4
Total capital investment	274.3	710.6	1,079.2
Secondary HEPA filter			
HEPA filter	9.8	45.2	69.3
Freight, taxes, instruments	1.8	8.1	12.5
Purchased equipment cost	11.6	53.3	81.8
Total capital investment	25.1	115.6	177.4

[a]The installation cost, which is the difference between the purchased equipment cost and the total capital investment, was calculated as the sum of factors of the purchased equipment cost, as described in Reference 32 and shown in Appendix B.

TABLE 6-8. CAPITAL COST: FOR CONTROL OF GRID CASTING PLUS LEAD RECLAMATION BY SAME DEVICE

New Construction - Second quarter 1988 dollars

Control device and basic equipment	Cost (thousand $) Plant size Small	Medium	Large
Wet scrubber			
Scrubber, fan, motor	21.4	56.0	66.0
Ductwork	13.3	20.3	22.2
Freight, taxes, instruments	6.2	13.7	15.9
Purchased equipment cost	40.9	90.0	104.1
Total capital investment[a]	78.2	172.0	198.8
Fabric filter			
Fabric filter	28.4	37.6	47.6
Fan, motor	b	22.0	40.0
Ductwork	13.3	20.3	22.2
Freight, taxes, instruments	7.5	14.4	19.8
Purchased equipment cost	49.2	94.3	129.6
Total capital investment[a]	106.7	204.7	281.0
Cartridge collector			
Cartridge collector	26.2	45.4	57.0
Fan and motor	6.6	22.0	40.0
Ductwork	13.3	20.3	22.2
Freight, taxes, instruments	8.3	15.8	21.5
Purchased equipment cost	54.4	103.5	140.7
Total capital investment[a]	118.2	224.7	305.2
Secondary HEPA filter			
HEPA filter	4.9	10.7	14.8
Freight, taxes, instruments	0.9	1.9	2.7
Purchased equipment cost	5.8	12.6	17.5
Total capital investment[a]	12.7	27.4	37.9

[a]The installation cost, which is the difference between the purchased equipment cost and the total capital investment, was calculated as the sum of factors of the purchased equipment cost, as described in Reference 32 and shown in Appendix B.
[b]Filter price includes the fan and motor.

TABLE 6-9. CAPITAL COST: FOR CONTROL OF FORMATION

New Construction - Second quarter 1988 dollars

Control device and basic equipment	Cost (thousand $) Plant size Small	Medium	Large
Mist eliminator			
Mist eliminator, fan, motor	59.1	224.0	363.6
Ductwork	19.3	60.2	107.4
Stack	1.0	3.1	7.7
Caustic storage tank	50.0	66.5	77.5
Caustic pump	5.1	0.7	0.7
Freight, taxes, instruments	24.2	63.8	100.2
Purchased equipment cost	158.7	418.3	657.1
Total capital investment[a]	302.9	798.8	1,255.2

[a]The installation cost, which is the difference between the purchased equipment cost and the total capital investment, was calculated as the sum of factors of the purchased equipment cost, as described in Reference 32 and shown in Appendix B.

TABLE 6-10. CAPITAL COST: FOR CONTROL OF CENTRAL VACUUM SYSTEM

New Construction - Second quarter 1988 dollars

Control device and basic equipment	Cost (thousand $) Plant Size		
	Small	Medium	Large
Fabric filter			
Fabric filter, fan, motor	7.2	18.3	22.6
Ductwork	0.7	2.0	3.0
Stack	1.0	1.2	1.2
Freight, taxes, instruments	1.6	3.9	4.8
Purchased equipment cost	10.5	25.4	31.6
Total capital investment[a]	13.2	31.7	39.4

[a]Installation costs are low because the filter can be obtained as a packaged unit.

TABLE 6-11. UNIT COSTS USED FOR ESTIMATING CONTROL SYSTEM ANNUAL COSTS

Second quarter 1988 dollars

Annual cost item	Unit cost (credit)
Direct Annual Costs[a]	
Operating labor[b]	$11.33/hour
Supervision	15 percent of operating labor
Maintenance labor[c]	$12.46/hour
Maintenance materials[d]	Equal to maintenance labor
Electricity[e]	$0.07/kwh
Compressed air[f]	$0.16/1,000 scf
Scrubber water[g]	$0.25/1,000 gal
Caustic soda, 50% liquid[h]	$225.00/ton
Indirect Annual Costs	
Overhead[f]	60 percent of the sum of operating, supervisory, and maintenance labor plus maintenance materials
Property taxes[f]	1 percent of total capital investment
Insurance[f]	1 percent of total capital investment
Administration[f]	2 percent of total capital investment
Capital recovery[i]	CRF x (total capital investment)
Recovery Credits	
Lead[j]	($0.37/lb)[l]
Fuel gas[k]	($3.80/$10^6$ Btu)[l]

[a]Annual control costs are based on 6000 annual operating hours for all facilities with the exception of lead reclamation where 2000, 4000, and 6000 annual operating hours were used for the small, medium and large facilities respectively.
[b]Reference 35.
[c]Computed as 10 percent over Operating Labor - Reference 20.
[d]Computed as 100 percent of Maintenance Labor - Reference 20.
[e]Reference 36.
[f]Reference 20.
[g]Reference 37.

TABLE 6-11. UNIT COSTS USED FOR ESTIMATING CONTROL SYSTEM ANNUAL COSTS (cont.)

[h]Reference 49; cost is on a 100% caustic soda basis; 73% Na_2O.

[i]$$CRF = \frac{i(1+i)^n}{(1+i)^{n-1}}$$

where i = interest rate. Ten percent was used in this study in accordance with Office of Management and Budget guidelines.
n = the economic life of the installation in years.

[j]Reference 38.
[k]References 39, 40.
[l]Numbers in parenthesis are credits.

parts, utilities, and supervision. Indirect charges are overhead, taxes, insurance, administrative charges, and capital recovery. Unit annual costs and their sources are listed in Table 6-11. Examples of the calculation of annual costs are given in Appendix C. All annual cost charges are current.

Information on the number of operating and maintenance man-hours required to operate fabric filters and wet scrubbers was obtained from Section 114 letters (References 2 through 7). The ranges given in the response letters and the values chosen for use in this study are given below:

	Man-hours/week			
	Operating		Maintenance	
	Range	Used in this Study	Range	Used in this Study
Wet scrubber	0-2	1	2-6	4
Fabric filter	0-3	2	0.5-5	5
Cartridge collector	-	2.5	-	4
HEPA filter	-	2	-	2

Reference 7 provided the values for operating and maintenance man-hours for cartridge collectors; the estimates for the HEPA filters were from data in References 2, 4, and 5. It was estimated that 100 percent of the HEPA filter media would have to be replaced annually (Reference 41) and that 50 percent of the cartridge collector cartridges would be replaced annually. Data in References 2 through 7 also provided the estimate that 30 percent of the fabric filter bags would be replaced annually. HEPA filter disposal costs were not included in the annual cost calculation. For disposal in a hazardous waste landfill the cost could be 1 to 3¢/(cfm)(yr) (References 50 and 51). For a typical filter for a medium-sized plant handling 20,000 acfm the annual disposal cost would be $200 to $600, small in comparison with the other HEPA filter costs (and credits).

Capital recovery is the series of equal annual payments spread over the economic life of the control system which return the capital

investment plus interest. It is calculated as the product of the Capital Recovery Factor (CRF) and the total capital investment, i.e.,

$$CRF = \frac{i(1+i)^n}{(1+i)^n-1}$$

where

i = the interest rate

n = the economic life

For this study all control systems were estimated to have an economic life of 10 years. An interest rate of 10 percent was used in accordance with Office of Management and Budget (OMB) guidelines.

Lead recovered by the control devices is recycled to a smelter; the unit annual cost for lead shown on Table 6-11 was used to calculate the credit for the recovered lead when calculating the annual costs. Similarly, the unit cost for fuel gas was used to determine the credit for the energy recovered when heated exhaust air was recycled via a HEPA filter (see below).

The annual costs calculated using the unit costs described above are approximately as accurate as the capital costs, that is $\pm$ 30 percent.

6.5 ANNUAL CONTROL COSTS

Annual control costs are detailed by emitting facility and control device in Tables 6-12 through 6-20. All costs were based on 24 hours/day, 5 days/week, 50 weeks/year operation, which is equivalent to 6,000 hours per year.

Comparing fabric filters' annual costs with those for cartridge collectors shows that in the smaller sizes (Grid casting, Table 6-12) the costs are comparable within study estimate accuracy. The lower electric power cost resulting from the lower pressure drop offered by the cartridge collector versus a fabric filter partially offsets the higher capital recovery charges resulting from the cartridge collector's higher installation cost. In the larger sizes cartridge collectors have a somewhat lower capital cost than fabric filters (see Table 6-5). The lower capital recovery cost combined with the lower energy consumption provides a significantly lower annual cost (e.g., see Three-Process Operation, Table 6-16).

TABLE 6-12. ANNUAL COST: FOR CONTROL OF GRID CASTING FURNACE AND MACHINE

New Construction - Second quarter 1988 dollars

	Cost (thousand dollars)											
	Wet scrubber			Fabric filter			Cartridge collector			Secondary HEPA		
	Plant size											
	small	medium	large	small	medium	large	small	medium	large	small	medium	large
Direct Annual Costs												
Operating labor	0.6	0.6	0.6	1.1	1.1	1.1	1.4	1.4	1.4	1.1	1.1	1.1
Supervision	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maintenance labor	2.5	2.5	2.5	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Maintenance materials	2.5	2.5	2.5	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Filter media				0.1	0.6	0.9	0.5	2.0	2.9	0.5	2.4	3.8
Utilities												
Electricity[a]	3.3	11.3	16.0	3.9	14.6	20.9	2.8	8.7	12.1	0.5	2.6	3.9
Scrubber water[b]	0.1	0.5	0.8									
Compressed air[c]				0.4	2.0	3.0	0.4	2.0	3.0			
Indirect Annual Costs												
Overhead	3.4	3.4	3.4	4.5	4.5	4.5	4.0	4.0	4.0	2.3	2.3	2.3
Property tax	0.3	0.9	1.6	0.3	1.3	2.0	0.5	1.4	2.0	d	0.1	2.4
Insurance	0.3	0.9	1.6	0.3	1.3	2.0	0.5	1.4	2.0	d	0.1	2.4
Administration	0.5	1.7	3.1	0.6	2.7	3.9	1.1	2.9	4.1	0.1	0.3	4.9
Capital recovery	4.1	14.1	25.2	5.0	21.6	32.1	8.8	23.5	33.3	0.7	2.4	4.0
Recovery Credit												
Lead	(0.1)	(0.6)	(0.9)	(0.1)	(0.6)	(0.9)	(0.1)	(0.6)	(0.9)	d	d	d
Fuel[e]										(8.2)	(41.1)	(61.7)
Total Annual Cost[f]	17.4	37.8	56.5	22.7	55.5	76.0	25.1	51.9	69.0	(0.2)	(27.1)	(34.1)

[a]Pressure drops used to calculate electric power consumption were, in inches of water: ductwork 7.5, 3.6, and 3.1 for small, medium, and large plants respectively, wet scrubber 5.0, fabric filter 7.5, and cartridge collector 3.0. Secondary HEPA electric power consumption costs were based on the pressure drop (2 in H_2O) through the filter only.
[b]Scrubber water consumption estimated at 1.5, 5.7, and 9.3 gpm for small, medium, and large facilities respectively from manufacturers' literature -- see Reference 42.
[c]Compressed air usage estimated at 2 scfm/1,000 acfm fed to the filter -- Reference 20.
[d]Amount is less than $50.00.
[e]Fuel credits resulting from recirculating heated air via HEPA filter from October through April.
[f]Columns may not add exactly to totals due to rounding.

TABLE 6-13. ANNUAL COST: FOR CONTROL OF PASTE MIXING

New Construction - Second quarter 1988 dollars

	Cost (thousand dollars)								
	Fabric filter			Cartridge collector			Secondary HEPA		
	Plant size								
	small	medium	large	small	medium	large	small	medium	large
Direct Annual Costs									
Operating labor	1.1	1.1	1.1	1.4	1.4	1.4	1.1	1.1	1.1
Supervision	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maintenance labor	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Maintenance materials	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Filter media	0.4	1.8	2.4	1.2	6.2	9.6	1.6	7.7	11.5
Utilities									
Electricity[a]	10.0	46.9	65.8	6.2	26.0	37.0	1.7	8.5	12.8
Compressed air[b]	1.3	6.5	9.7	1.3	6.5	9.7			
Indirect Annual Costs									
Overhead	4.5	4.5	4.5	4.0	4.0	4.0	2.3	2.3	2.3
Property tax	1.2	2.9	4.2	1.1	2.9	3.8	0.1	0.5	0.6
Insurance	1.2	2.9	4.2	1.1	2.9	3.8	0.1	0.5	0.6
Administration	2.3	5.8	8.5	2.3	5.8	7.7	0.2	0.9	1.3
Capital recovery	18.9	48.2	68.8	18.3	47.5	62.6	1.7	7.4	10.8
Recovery Credit									
Lead	(3.7)	(18.1)	(26.9)	(3.7)	(18.1)	(26.9)	c	(0.3)	(0.7)
Fuel[d]							(13.4)	(66.9)	(100.3)
Total Annual Cost[e]	43.7	108.9	149.0	38.4	90.3	118.0	(1.9)	(35.8)	(57.2)

[a]Pressure drops used to calculate power consumption were, in inches of water: ductwork 4.3, 3.1, and 2.8 for small, medium, and large plants respectively, fabric filter 7.5, and cartridge collector 3.0. Secondary HEPA electric power consumption costs were based on the pressure drop (2 in H_2O) through the filter only.
[b]Compressed air usage estimated at 2 scfm/1,000 acfm fed to the filter -- Reference 20.
[c]Amount is less than $50.00.
[d]Fuel credits resulting from recirculating heated air via HEPA filter from October through April.
[e]Columns may not add exactly to totals due to rounding.

TABLE 6-14. ANNUAL COST ANALYSIS: FOR CONTROL OF LEAD OXIDE MANUFACTURING
New Construction - Second quarter 1988 dollars

	Incremental Cost (thousand $)[a,b]						Cost (thousand $)[c,d]		
	Fabric filter			Cartridge collector			Secondary HEPA		
	Plant size								
	medium	large		medium	large		medium	large	
		Seven Linklater Systems	Two Barton Systems		Seven Linklater Systems	Two Barton Systems		Seven Linklater Systems	Two Barton Systems
Direct Annual Costs									
Operating labor	0	0	0	0.3	0.3	0.3	1.1	1.1	1.1
Supervision	0	0	0	f	f	f	0.2	0.2	0.2
Maintenance labor	0	0	0	(0.6)	(0.6)	(0.6)	1.2	1.2	1.2
Maintenance materials	0	0	0	(0.6)	(0.6)	(0.6)	1.2	1.2	1.2
Filter media	0.8	1.2	0.4	(1.3)	(2.0)	0.8	5.6	8.4	3.4
Utilities									
Electricity[e]	(7.1)	(10.7)	(3.8)	(15.5)	(23.3)	(8.3)	3.7	5.6	2.0
Compressed air				0.4	0.9				
Indirect Annual Costs									
Overhead	0	0	0	(0.6)	(0.6)	(0.6)	2.3	2.3	2.3
Property tax	0.8	1.8	0.4	(0.7)	(1.2)	(0.3)	0.3	0.4	0.2
Insurance	0.8	1.8	0.4	(0.7)	(1.2)	(0.3)	0.3	0.4	0.2
Administration	1.6	3.6	0.9	(1.4)	(2.4)	(0.7)	0.5	0.8	0.3
Capital recovery	2.9	29.2	7.0	(11.4)	(19.1)	(5.3)	4.5	6.2	2.6
Recovery Credit									
Lead oxide	f	(0.1)	(0.1)	f	f	(0.1)	f	(0.1)	(0.1)
Fuel gas[g]	-						(87.6)	(131.4)	(47.0)
Total Annual Cost[h]	9.8	26.9	5.3	(32.1)	(49.8)	(15.6)	(66.7)	(103.6)	(32.4)

[a]Costs shown are the incremental annual costs incurred when replacing a 3/1 A/C pulse-jet filter selected for economical product collection with either a 2/1 A/C shaker pulse-jet or a cartridge collector, either of which will both collect product and control emissions to NSPS requirements.
[b]Costs in parenthesis indicate a negative incremental cost.
[c]Costs shown are the total annual costs for operating a HEPA filter.
[d]Costs in parenthesis are credits
[e]Pressure drops used to calculate power consumption were, in inches of water: ductwork 3.0, 2.7, and 3.2 for the medium, large seven Linklaters and large two Bartons cases respectively, cartridge collector 3.0, 3/1 A/C pulse-jet filter 11.3, 2/1 A/C pulse-jet filter 7.5. Secondary HEPA electric power consumption costs were based on the pressure drop (2 in H_2O) through the filter only.
[f]Amount is less than $50.00.
[g]Fuel credits resulting from recirculating heated air via HEPA filter from October through April.
[h]Columns may not add exactly to totals due to rounding.

TABLE 6-15. ANNUAL COST: FOR CONTROL OF THREE-PROCESS OPERATION

New Construction - Second quarter 1988 dollars

	Cost (thousand dollars)								
	Fabric filter			Cartridge collector			Secondary HEPA		
	Plant size								
	small	medium	large	small	medium	large	small	medium	large
Direct Annual Costs									
Operating labor	1.1	1.1	1.1	1.4	1.4	1.4	1.1	1.1	1.1
Supervision	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maintenance labor	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Maintenance materials	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Filter mediam	0.6	3.3	4.9	2.4	11.0	8.6	2.6	12.8	19.2
Utilities									
Electricity[a]	16.6	73.9	111.0	10.2	41.6	62.5	2.9	14.4	21.5
Compressed air[b]	2.2	10.9	16.3	2.2	10.9	16.3			
Indirect Annual Costs									
Overhead	4.5	4.5	4.5	4.0	4.0	4.0	2.3	2.3	2.3
Property tax	1.4	4.8	7.7	0.2	4.7	6.7	0.2	0.8	1.1
Insurance	1.4	4.8	7.7	0.2	4.7	6.7	0.2	0.8	1.1
Administration	2.7	9.5	15.5	0.3	9.3	13.4	0.3	1.6	2.2
Capital recovery	22.0	77.4	125.9	26.1	75.7	109.3	2.5	12.9	18.1
Recovery Credit									
Lead	(2.0)	(9.9)	(14.5)	(2.0)	(9.9)	(14.5)	(0.1)	(0.5)	(1.2)
Fuel[c]							(16.2)	(80.8)	(121.2)
Total Annual Cost[d]	56.8	186.6	286.7	50.0	158.5	219.7	(1.7)	(32.0)	(53.0)

[a]Pressure drops used to calculate power consumption were, in inches of water: ductwork 4.1, 2.8, and 2.8 for the small, medium, and large plants respectively, fabric filter 7.5, and cartridge collector 3.0. Secondary HEPA electric power consumption costs were based on the pressure drop (2 in H_2O) through the filter only.
[b]Compressed air usage estimated at 2 scfm/1,000 acfm fed to the filter -- Reference 20.
[c]Fuel credits resulting from recirculating heated air via HEPA filter from October through April.
[d]Columns may not add exactly to totals due to rounding.

TABLE 6-16. ANNUAL COST: FOR CONTROL OF LEAD RECLAMATION

New Construction - Second quarter 1988 dollars

	Cost (thousand dollars)											
	Wet scrubber			Fabric filter			Cartridge collector			Secondary HEPA		
	Plant size											
	small	medium	large	small	medium	large	small	medium	large	small	medium	large
Direct Annual Costs												
Operating labor	0.2	0.4	0.6	0.4	0.8	1.1	0.4	0.9	1.4	0.4	0.8	1.1
Supervision	d	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2
Maintenance labor	0.8	1.7	2.5	1.0	2.1	3.1	0.8	1.7	2.5	0.4	0.8	1.2
Maintenance materials	0.8	1.7	2.5	1.0	2.1	3.1	0.8	1.7	2.5	0.4	0.8	1.2
Filter media				0.2	0.3	0.5	0.4	0.8	1.2	0.6	1.1	1.7
Utilities												
Electricity[a]	1.2	2.3	3.5	1 5	2.9	4.4	1.2	2.3	3.5	0.4	0.7	1.1
Scrubber water[b]	0.1	0.2	0.3									
Compressed air[c]				0.3	0.5	0.8	0.3	0.5	0.8			
Indirect Annual Costs												
Overhead	1.1	2.3	3.4	1.5	3.0	4.5	1.3	2.6	4.0	0.8	1.5	2.3
Property tax	0.4	0.4	0.4	0.4	0.4	0.4	1.0	1.0	1.0	0.1	0.1	0.1
Insurance	0.4	0.4	0.4	0.4	0.4	0.4	1.0	1.0	1.0	0.1	0.1	0.1
Administration	0.7	0.7	0.7	0.9	0.9	0.9	1.9	1.9	1.9	0.2	0.2	0.2
Capital recovery	5.9	5.9	5.9	7.3	7.3	7.3	15.6	15.6	15.6	1.5	1.5	1.5
Recovery Credit												
Lead	(0.1)	(0.5)	(0.8)	(0.1)	(0.5)	(0.8)	(0.1)	(0.5)	(0.8)	d	d	d
Fuel[e]										(8.3)	(16.6)	(24.9)
Total Annual Cost[f]	11.6	15.4	19.5	14.9	20.4	25.9	24.7	29.6	34.8	(3.5)	(8.9)	(14.2)

[a]Pressure drops used to calculate power consumption were in inches of water: ductwork 3.6, wet scrubber 5.0, fabric filter 7.0, and cartridge collector 3.0. Secondary HEPA electric power consumption costs were based on the pressure drop (2 in H_2O) through the filter only.
[b]Scrubber water consumption estimated at 3.2 gpm from manufacturer's literature -- see Reference 42.
[c]Compressed air usage estimated at 2 scfm/1,000 acfm fed to the filter -- Reference 20.
[d]Amount is less than $50.00.
[e]Fuel credits resulting from recirculating heated air via HEPA filter from October through April.
[f]Columns may not add exactly to totals due to rounding.

TABLE 6-17. ANNUAL COST: FOR CONTROL OF PASTE MIXING PLUS THREE-PROCESS OPERATION CONTROLLED BY SAME FILTER

New Construction - Second quarter 1988 dollars

	Cost (thousand dollars)								
	Fabric filter			Cartridge collector			Secondary HEPA		
	Plant size								
	small	medium	large	small	medium	large	small	medium	large
Direct Annual Costs									
Operating labor	1.1	1.1	1.1	1.4	1.4	1.4	1.1	1.1	1.1
Supervision	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maintenance labor	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Maintenance materials	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Filter media	0.9	4.9	7.3	3.4	8.8	25.2	4.0	20.2	30.7
Utilities									
Electricity[a]	31.6	120.6	179.4	21.5	69.2	102.3	4.6	22.8	34.3
Compressed air[b]	3.4	17.3	26.0	3.4	17.3	26.0			
Indirect Annual Costs									
Overhead	4.5	4.5	4.5	4.0	4.0	4.0	2.3	2.3	2.3
Property tax	2.7	8.5	13.2	2.7	7.1	10.8	0.3	1.2	1.8
Insurance	2.7	8.5	13.2	2.7	7.1	10.8	0.3	1.2	1.8
Administration	5.3	17.1	26.4	5.5	14.2	21.6	0.5	2.3	3.5
Capital recovery	43.4	139.0	214.8	44.6	115.6	175.6	4.1	18.8	28.9
Recovery Credit									
Lead	(5.7)	(28.0)	(41.4)	(5.7)	(28.0)	(41.4)	(0.1)	(0.8)	(1.9)
Fuel[c]							(29.6)	(147.7)	(221.5)
Total Annual Cost[d]	96.4	300.0	450.9	88.8	221.9	341.4	(9.9)	(76.0)	(116.3)

[a]Pressure drops used to calculate power consumption were, in inches of water: ductwork 6.4, 3.0, and 3.0 for small, medium, and large plants respectively, fabric filter 7.5, cartridge collector 3.0. Secondary HEPA electric power consumption costs were based on the pressure drop (2 in H_2O) through the filter only.
[b]Compressed air usage estimated at 2 scfm/1,000 acfm fed to the filter -- Reference 20.
[c]Fuel credits resulting from recirculating heated air via HEPA filter from October through April.
[d]Columns may not add exactly to totals due to rounding.

TABLE 6-18. ANNUAL COST: FOR CONTROL OF GRID CASTING PLUS LEAD RECLAMATION CONTROLLED BY SAME DEVICE

New Construction -- Second quarter 1988 dollars

	Cost (thousand dollars)											
	Wet scrubber			Fabric filter			Cartridge collector			Secondary HEPA		
	Plant size											
	small	medium	large	small	medium	large	small	medium	large	small	medium	large
Direct Annual Costs												
Operating labor	0.6	0.6	0.6	1.1	1.1	1.1	1.4	1.4	1.4	1.1	1.1	1.1
Supervision	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maintenance labor	2.5	2.5	2.5	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Maintenance materials	2.5	2.5	2.5	3.1	3.1	3.1	2.5	2.5	2.5	1.2	1.2	1.2
Filter media				0.4	0.8	1.1	1.2	2.9	4.1	2.5	5.6	8.4
Utilities												
Electricity[a]	5.7	18.5	28.6	6.8	22.7	34.8	4.8	15.7	23.6	1.6	3.7	5.0
Scrubber water[b]	0.2	0.5	0.6									
Compressed air[c]				0.7	2.5	3.8	0.7	2.5	3.8			
Indirect Annual Costs												
Overhead	3.4	3.4	3.4	4.5	4.5	4.5	4.0	4.0	4.0	2.3	2.3	2.3
Property tax	0.8	1.7	2.0	1.1	2.0	2.8	1.2	2.2	3.1	0.1	0.3	0.4
Insurance	0.8	1.7	2.0	1.1	2.0	2.8	1.2	2.2	3.1	0.1	0.3	0.4
Administration	1.6	3.4	4.0	2.1	4.1	5.6	2.4	4.5	6.1	0.3	0.5	0.8
Capital recovery	12.7	28.0	32.3	17.4	33.3	45.7	19.2	36.6	49.7	2.1	4.5	6.2
Recovery Credit												
Lead	(0.2)	(1.1)	(1.7)	(0.2)	(1.2)	(1.8)	(0.2)	(1.1)	(1.8)	d	d	d
Fuel[e]										(16.5)	(57.7)	(86.6)
Total Annual Cost[f]	30.6	61.8	76.9	41.3	78.4	106.9	41.0	76.1	102.1	(3.8)	(36.8)	(59.5)

[a]Pressure drops used to calculate power consumption were, in inches of water: ductwork 8.0, 6.1, and 6.4 for the small, medium, and large plants respectively, wet scrubber 5.0, fabric filter 7.0, and cartridge collector 3.0. Secondary HEPA electric power consumption costs were based on the pressure drop (2.0 in H_2O) through the filter only.

[b]Scrubber water consumption estimated at 4.7, 5.6, and 7.1 gpm for the small, medium, and large units respectively from manufacturer's literature -- see Reference 42.

[c]Compressed air usage estimated at 2 scfm/1,000 acfm fed to the filter -- Reference 20.

[d]Amount is less than $50.00.

[e]Fuel credits resulting from recirculating heated air via HEPA filter from October through April.

[f]Columns may not add exactly to totals due to rounding.

TABLE 6-19. ANNUAL COST: FOR CONTROL OF FORMATION

New Construction - Second quarter 1988 dollars

	Cost (thousand dollars) Mist eliminator Plant size		
	small	medium	large
Direct Annual Cost			
Operating labor	1.7	2.3[e]	3.4[e]
Supervision	0.3	0.3[e]	0.5[e]
Maintenance labor	3.1	5.6[e]	9.3[e]
Maintenance materials	3.1	5.6[e]	9.3[e]
Sodium hydroxide[a]	414.0	1,980.0	2,680.0
Utilities			
Electricity[b]	20.0	84.0	131.3
Scrubber water[c]	1.4	10.8	18.0
Indirect Annual Costs			
Overhead	4.9	8.3	13.6
Property tax	3.0	8.0	12.6
Insurance	3.0	8.0	12.6
Administration	6.1	16.0	25.1
Capital recovery	49.3	130.0	204.2
Total Annual Cost[d]	509.8	2,258.8	3,119.9

[a]As 50 percent solution (Reference 49).
[b]Pressure drops used to calculate power consumption were, in inches of water: ductwork 3.6, 2.7, and 2.9 for the small, medium, and large plants respectively, scrubber 2.0.
[c]Scrubber water consumption per manufacturer's recommendation -- see Reference 26.
[d]Columns may not add exactly to total due to rounding.
[e]Large model facility required two scrubbers in parallel; operating and maintenance labor were thus increased.

TABLE 6-20. ANNUAL COST: FOR THE CONTROL OF CENTRAL VACUUM SYSTEM

New Construction - Second quarter 1988 dollars

Plant Size	Cost (thousand dollars) Fabric filter Small	Medium	Large
Direct Annual Cost			
Operating labor	1.1	1.1	1.1
Supervision	0.2	0.2	0.2
Maintenance labor	3.1	3.1	3.1
Maintenance materials	3.1	3.1	3.1
Filter media	c	0.1	0.2
Utilities			
Electricity[a]	1.3	3.8	5.7
Compressed air[b]	0.1	0.3	0.5
Indirect Annual Costs			
Overhead	4.5	4.5	4.5
Property tax	0.1	0.3	0.4
Insurance	0.1	0.3	0.4
Administration	0.3	0.6	0.8
Capital recovery	2.1	5.2	6.4
Total Annual Cost[d]	16.1	22.7	26.4

[a]Pressure drops used to calculate power consumption were, in inches of water: ductwork 21.2, 9.7, and 9.7 for the small, medium, and large plants respectively, filter 7.5.
[b]Compressed air usage estimated at 2 scfm/1,000 acfm fed to the filter -- see Reference 20.
[c]Amount is less than $50.
[d]Columns may not add exactly to total due to rounding.

Lead oxide manufacturing facilities include a pulse-jet fabric filter operating at 3/1 A/C ratio for product recovery. In this study this represents the uncontrolled case. Emission control can be achieved by switching to a 2/1 A/C ratio pulse-jet filter (or to another control device of similar efficiency) for use as the product recovery filter. Table 6-14 shows the annual incremental cost for operating either a 2/1 A/C pulse-jet filter or a cartridge collector rather than 3/1 A/C pulse-jet filter as the product recovery filter. Note that nearly all of the individual annual costs for the cartridge collector are less than those of the 3/1 A/C ratio pulse-jet fabric filter. This results in net annual incremental credits for the cartridge collector. However, because they are more expensive to purchase and operate, the 2/1 A/C ratio fabric filters show net incremental costs in Table 6-14. Table 6-14 also shows the total annual cost (a credit in this case) of adding a HEPA filter downstream of the primary control device in lead oxide manufacturing.

It can be seen from Table 6-1 that lead-acid battery plants exhaust a great deal of air to maintain the workplace atmosphere within OSHA contaminant guidelines. This air must be replaced with fresh outside air which must be heated during the winter months. By removing virtually all the contaminants from the air (see Table 6-1), HEPA filters placed downstream of the primary filter allow the exhausted air to be recirculated during the winter months. This minimizes the need to heat replacement outside air and recovers process heat to warm the building. For this study, it was assumed that the HEPA filters would be operated all year although this is not necessarily industry practice. During the summer the HEPA filter exhaust would be vented to the atmosphere. When a HEPA filter is used the total capital and annual costs for air pollution control is the sum of the costs for the primary control device and the HEPA filter. For instance, the total incremental annual credit for controlling the medium lead oxide manufacturing facility with a 2/1 A/C baghouse and a secondary HEPA would be $9,800 + ($66,700) = ($56,900). An example of the calculations used to establish the credit for recirculation is given in Appendix C.

Using HEPA filters to recover heat by recycling exhausted air is clearly a cost saving innovation. For all model facilities the fuel credits exceed the sum of all other costs, resulting in a net savings. The savings increase with the size of the air stream and with its temperature.

The cost of controlling sulfuric acid mist during formation is given in Table 6-19. The major cost item by a factor of approximately 10 for each model facility is the cost of 50 percent sodium hydroxide solution to treat the mist eliminator discharge.

Lead-acid battery plants have one or more central vacuum systems used for general cleaning. Typically, these discharge to a small fabric filter. Estimated annual costs for such a system are shown in Table 6-20.

6.6 COST EFFECTIVENESS

Cost effectiveness, as calculated for this study, is the annual cost per unit mass of pollutant removed. Annual cost is defined as the annual cost of operating the control device and includes direct operating charges such as operating and maintenance labor, maintenance materials and utilities, and indirect charges such as overhead, taxes, insurance, administrative charges, and capital recovery.

Recovered material and fuel credits are included and reduce the annual cost. Total annual costs are given in Tables 6-12 through 6-20. The mass of pollutant removed by each control system is listed in Table 6-1.

Cost effectiveness was obtained by dividing the total annual cost for a control device by the mass of pollutant removed, e.g., for a fabric filter controlling a grid casting furnace and machine in a large model facility:

$$\text{Cost Effectiveness} = \frac{\$76{,}000/\text{yr (Table 6-12)}}{2565.3 \text{ lbs/yr (Table 6-1)}} = \$30/\text{lb}$$

This definition allows alternative control devices for each model facility to be compared. Cost effectiveness ratios are tabulated in Tables 6-21 and 6-22.

Study of Tables 6-21 and 6-22 shows that wet scrubbers are somewhat more cost-effective than either fabric filters or cartridge collectors. Consistent with the annual costs, cartridge collectors are slightly less cost-effective than fabric filters in the smaller sizes (<10,000 acfm) and slightly more cost-effective in the larger sizes. The negative cost-effectiveness ratios for the HEPA filters reflect the cost savings resulting from installing a HEPA filter and recirculating the heated air during the winter months. To obtain the overall control cost effectiveness for a model facility employing a HEPA filter the total annual costs for the fabric filter or cartridge collector must be added to the credit (usually) for the HEPA filter and this sum divided by the total lead emissions captured by the two devices.

6.7 COMPARISON WITH SECTION 114 LETTER DATA

Total installed capital investment costs for fabric filters obtained from industry in response to the EPA's request (References 2 through 8, 43, 44, 45) for cost information are compared in Figure 6-1 with the capital costs developed for this study. The industry costs were for both shaker and pulse-jet filters, although most of the filters were pulse-jets. The costs from this study are for the fabric filters described in Table 6-1. A log-log plot was used to allow all size fabric filters to be compared on the graph. Where required, the industry data was escalated to second quarter 1988 costs using the Chemical Engineering plant cost index. In the few cases where the date of installation was not specified, the data were plotted as received. The solid line on Figure 6-1 is a regression line calculated using all of the plotted points. The two dashed lines enclose the $\pm$ 30 percent region above and below the regression line. The data shows considerable scatter. This is not surprising since each installation is different and not necessarily in accordance with the assumptions made for this study. Nevertheless, the data show that the capital cost data developed for this study are consistent with industry experience and are not strongly biased one way or the other.

TABLE 6-21. COST EFFECTIVENESS: CONTROL OF GRID CASTING, LEAD OXIDE MANUFACTURE, LEAD RECLAMATION, AND GRID CASTING PLUS LEAD RECLAMATION

Second quarter 1988 dollars

Facility and Plant Size	Pollution control cost effectiveness[a,d]							
	Wet scrubber		Fabric filter		Cartridge collector		Secondary HEPA[b]	
	$/kg	$/lb	$/kg	$/lb	$/kg	$/lb	$/kg	$/lb
Grid Casting								
Small	114	52	145	66	161	73	(339)	(154)
Medium	51	23	71	32	67	30	(4,490)	(2,040)
Large	53	24	65	30	59	27	(2,570)	(1,160)
Lead Oxide Manufacture								
Medium			193[c]	88[c]	(632)[c]	(287)[c]	(1,300)	(592)
Large, Seven Linklater Systems			352[c]	160[c]	(652)[c]	(296)[c]	(1,355)	(615)
Large, Two Barton Systems			69[c]	31[c]	(204)[c]	(93)[c]	(424)	(192)
Lead Reclamation								
Small	91	41	114	52	188	85	(1,150)	(523)
Medium	24	11	31	14	45	20	(608)	(276)
Large	20	9	26	12	35	16	(646)	(293)
Grid Casting Plus Lead Reclamation								
Small	109	50	144	65	143	65	(1,050)	(475)
Medium	45	20	55	25	53	24	(1,780)	(807)
Large	38	17	50	23	48	22	(1,690)	(765)

[a]All values except those for the HEPA filter are calculated from a no control baseline.
[b]Values calculated for HEPA filter positioned downstream of fabric filter or cartridge collector and with HEPA filter discharge recirculated during winter months (October through April).
[c]For lead oxide manufacture the no control base was a pulse-jet filter with a 3/1 A/C ratio. Values shown are incremental costs for a 2/1 A/C pulse-jet filter and a cartridge collector, respectively.
[d]Figures in parenthesis indicate a credit.

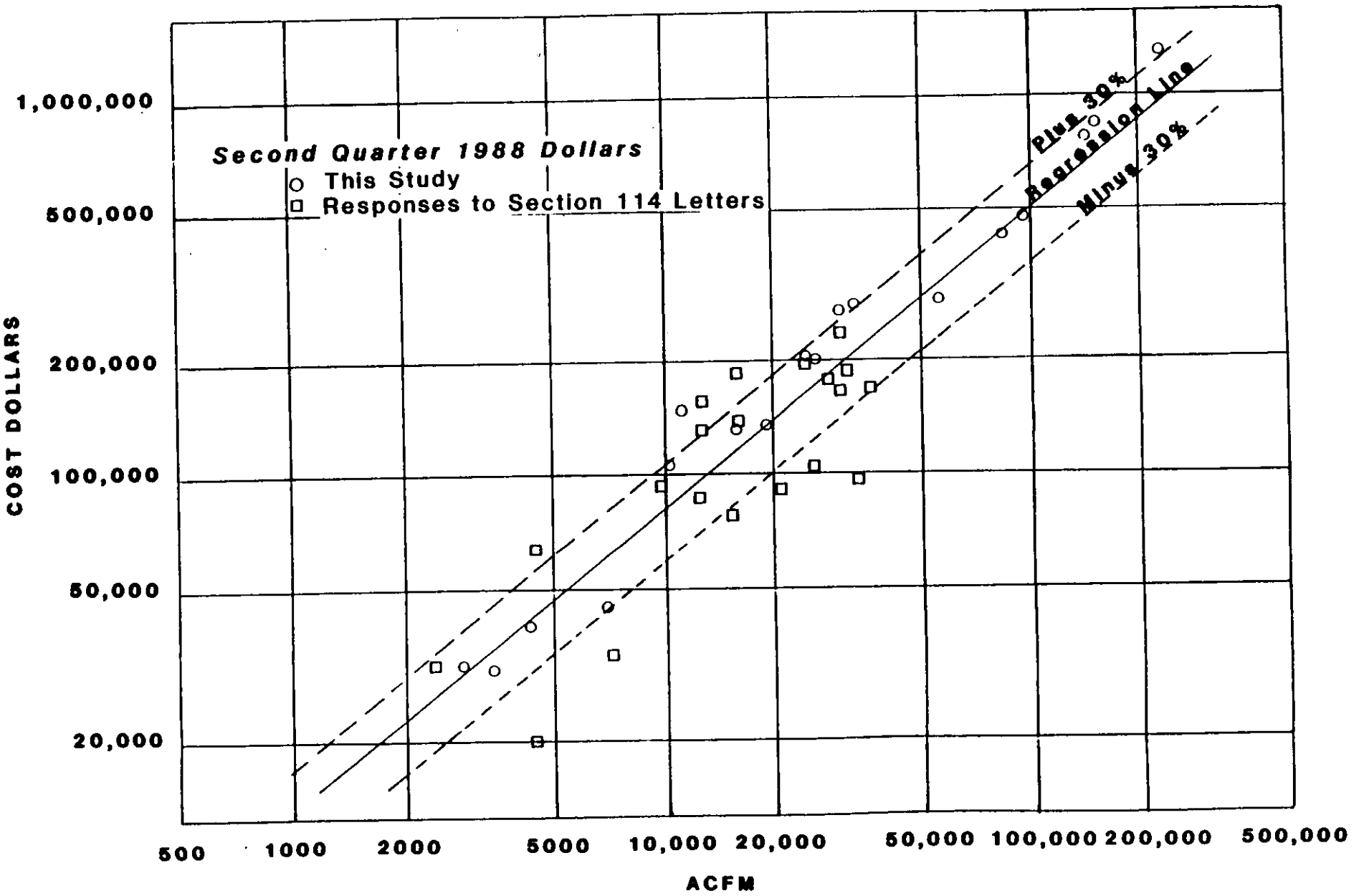
TABLE 6-22. COST EFFECTIVENESS: CONTROL OF PASTE MIXING, THREE-PROCESS OPERATION, FORMATION, AND PASTE MIXING PLUS THREE-PROCESS OPERATION

Second quarter 1988 dollars

Facility and Plant Size	Pollution control cost effectiveness[a,c]							
	Mist eliminator		Fabric filter		Cartridge collector		Secondary HEPA[b]	
	$/kg	$/lb	$/kg	$/lb	$/kg	$/lb	$/kg	$/lb
Paste Mixing								
Small			10	4	9	4	(50)	(23)
Medium			5	2	4	2	(94)	(43)
Large			5	2	4	2	(67)	(30)
Three-Process Operation								
Small			23	10	20	9	(27)	(12)
Medium			15	7	13	6	(50)	(23)
Large			16	7	13	6	(37)	(17)
Formation								
Small	0.26	0.12						
Medium	0.23	0.11						
Large	0.24	0.11						
Paste Mixing Plus Three-Process Operation								
Small			14	6	12	6	(97)	(44)
Medium			9	4	6	3	(74)	(34)
Large			9	4	7	3	(51)	(23)

[a]All values except those for the HEPA filter are calculated from a no control baseline.
[b]Values calculated for HEPA filter positioned downstream of fabric filter or cartridge collector and with HEPA filter discharge recirculated during winter months (October through April).
[c]Figures in parenthesis indicate a credit.

Figure 6-1
Fabric Filter Total Installed
Capital Investment Costs, Second Quarter, 1988



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APPENDIX A

DUCTWORK DESCRIPTION

Facility	Plant	Duct Diameter inches	Duct Description
Grid Casting Furnace and Machine	Small	11	200 feet straight run
	Medium	26	10 elbows
	Large	32	1 blast gate
Paste Mixing	Small	21	200 feet straight run
	Medium	47	10 elbows
	Large	58	1 blast gate
Lead Oxide Manufacturing	Medium	31	200 feet straight run
	Large	38	10 elbows
Three-Process Operation	Small	27	200 feet straight run
	Medium	62	10 elbows
	Large	75	2 blast gates
Lead Reclamation	Small		200 feet straight run
	Medium	18	10 elbows
	Large		1 blast gate
Paste Mixing plus Three-Process Operation	Small	21	100 feet straight run
			10 elbows
			1 blast gate
		27	100 feet straight run
			10 elbows
			1 blast gate
		34	100 feet straight run
			10 elbows
			1 blast gate

Facility	Plant	Duct Diameter inches	Duct Description	
Paste Mixing plus Three-Process Operation (continued)	Medium Paste-Mixing	47	250 feet straight run 10 elbows	Each facility would be ducted individually to control device.
	Three-Process	62	250 feet straight run 10 elbows	
	Large Paste-Mixing	58	250 feet straight run 10 elbows	Each facility would be ducted individually to control device.
	Three-Process	75	250 feet straight run 10 elbows	
Grid Casting Plus Lead Reclamation	Small	11	100 feet straight run 10 elbows 1 blast gate	
		18	100 feet straight run 10 elbows 1 blast gate	
		20	100 feet straight run 10 elbows 1 blast gate	
	Medium	26	100 feet straight run 10 elbows 1 blast gate	
		18	100 feet straight run 10 elbows 1 blast gate	
		31	100 feet straight run 10 elbows 1 blast gate	

Facility	Plant	Duct Diameter inches	Duct Description
Grid Casting Plus Lead Reclamation (continued)	Large	18	100 feet straight run 10 elbows 1 blast gate
		32	100 feet straight run 10 elbows 1 blast gate
		36	100 feet straight run 10 elbows 1 blast gate
Formation	Small	43	250 feet straight run
	Medium	97	250 feet straight run
	Large	60, 4 parallel runs	250 feet straight run
Vacuum System	Small	3	2 branches each 150 feet long containing: 10 elbows 2 blast gates
	Medium	5	4 branches each 100 feet long containing: 10 elbows 4 blast gates
	Large	5	6 branches each 100 feet long containing: 10 elbows 4 blast gates

Duct Pressure Drop

Example Calculation

Grid Casting and Machine - Small Facility

As mentioned in Section 6.4.1, the ductwork is sized to achieve a velocity of 4,500 ft/min to keep the entrained lead particles in suspension. For the small grid-casting and machine facility, the size of the duct would be:

$$\text{Duct area, in sq ft} = \frac{3,460}{4,500} = 0.769 \text{ ft}^2$$

where 3,460 is the actual cubic feet per minute carried by the duct

$$\text{Duct diameter in inches} = \frac{0.769 \times 4}{\pi}^{\frac{1}{2}} \times 12 = 11.87 \text{ inches}$$

To avoid custom fabrication, round this to 11 inches. The actual velocity in 11 inch duct is:

$$11 \text{ inches} = 0.9167 \text{ feet}$$

$$\text{Duct area} = \frac{(0.9167)^2\pi}{4} = 0.660 \text{ ft}^2$$

$$\text{Velocity} = u = \frac{3,460}{0.660} = 5,242 \text{ ft/min} = 87.4 \text{ ft/sec}$$

The gas density is calculated from the gas law:

$$PV = nRT$$

where

P = Pressure in atmospheres = 1

V = Gas volume = 1 ft^3

n = Number of moles = $\frac{\text{density}}{28.9}$

R = Gas constant = 0.7302 $\frac{(\text{atm})(\text{ft}^3)}{(\text{lb mole})(^\circ\text{R})}$

T = Temperature in degrees Rankine
= 459.7 + temperature in degrees Fahrenheit

$$\text{Density} = \frac{28.9 \times 1 \times 1}{0.7302\ (459.7 + 170)} = 0.0629 \text{ lbs/ft}^3$$

where 28.9 is the molecular weight of air

The friction factor is obtained from a Moody, Reynolds number versus friction factor chart in Reference 46, page A-24. The Reynolds number is calculated as

$$Re = \frac{Du\rho}{\mu}$$

where

Re = Reynolds number

D = Duct diameter in feet = 0.9167

u = Gas velocity in ft/sec

ρ = Gas density in lbs/ft^3

μ = Gas viscosity - 1.426×10^{-5} lbs/(ft)(sec) from Reference 46

$$Re = \frac{(0.9167)(87.4)(0.0629)}{1.426 \times 10^{-5}} = 353,403$$

From page A-23 in Reference 46 the wall roughness to pipe diameter ratio (E/D) is 0.00017 for 11 in duct. Using the Moody friction factor chart on page A-24 of Reference 46

$$f = 0.0158$$

The pressure loss due to friction for straight pipe is then calculated from the Darcy formula:

$$h_L = f\frac{(L)}{(D)}\frac{u^2}{2g} \text{ for straight pipe}$$

and from p 2-8 of Reference 46

$$h_L = K\frac{u^2}{2g} \text{ for a long radius elbow}$$

where

h_L = Frictional head loss in the duct in feet of gas

D = Duct diameter in feet = 0.9167

L = Duct length in feet = 200

u = Gas velocity in duct = 87.4 feet/sec

g = Mass/force conversion factor = 32.17

K = Resistance coefficient for long radius elbow = 0.18 from Reference 46

The total frictional loss then is

$$h_L = f \frac{(L)}{(D)} \frac{(u^2)}{2g} + K \frac{(u^2)}{2g} = \frac{u^2}{2g} \left(f \frac{L}{D} + K\right)$$

$$= \frac{(87.4)^2}{2 \times 32.17} \left(0.0158 \frac{200}{0.9167} + 10\ (0.18)\right) = 623.0 \text{ feet}$$

where 10 is the number of elbows.

Converting feet of gas to inches of water

in H_2O = 623.0 x 0.0629 x 0.1923 = 7.54 ~ 7.5

where 0.1923 converts lbs/ft^2 to in H_2O

Appendix B
Capital Cost Estimation Example
Cartridge Collector
Three Process Operation - Small Facility

	$
Purchased equipment costs	
Cartridge collector (Reference 23)	40,700
Gate and drum kit (Reference 23)	1,000
Fan, motor, drive (Reference 15)	9,400
Ductwork (Reference 2 and description in Appendix A)[a]	11,434
Total basic equipment (BE)	62,534
Instruments and controls, 0.1 (BE) =	6,253
Taxes, 0.03 (BE)	1,876
Freight 0.05 (BE)	3,127
Total purchased equipment (PE)	73,790
Direct installation costs	
Foundation and supports, 0.04 (PE)	2,952
Erection and handling, 0.50 (PE)	36,895
Electrical, 0.08 (PE)	5,903
Piping, 0.01 (PE)	738
Insulation for ductwork 0.07 (PE)	5,165
Painting 0.02 (PE)	1,476
Total direct installation costs	53,129
Total direct costs	126,919
Indirect costs	
Engineering and supervision, 0.1 (PE)	7,379
Construction and field expense, 0.2 (PE)	14,758
Construction fee, 0.1 (PE)	7,379
Startup fee, 0.01 (PE)	738
Performance test, 0.01 (PE)[b]	738
Contingencies, 0.03 (PE)	2,214
Total indirect costs	33,205
Total capital investment	160,124
say	160,000

[a]Ductwork costs were estimated as follows:

Description from Appendix A	Cost from Reference 12 $
200 feet, 27 in, straight run, 16 ga	$25.45/ft x 200 = 5,090
10, 27 in elbows, 16 ga	$355.00/ea x 10 = 3,550
2 blast gates	$172/gate x 2 = 344
70 connectors	$35/ea x 70 = 2,450
Total ductwork	11,434

[b]This performance test is to demonstrate that the equipment operates properly, not that the emission limits will be met.

Appendix C
Line Item Annual Cost Examples
Example 1
Three-Process Operation - Small Facility - Fabric Filter

Direct Costs	
Operating Labor at 2 hr/week 2 x 50 x 11.33	1,133
Supervision at 15% of Operating Labor 0.15 x 1,133	170
Maintenance Labor at 5 hr/week 5 x 50 x 11.33 x 1.1	3,116
Maintenance Material at 100% of Maintenance Labor	3,116
Filter Media, replace 30% per year 0.3 x 2,050[a]	615
Utilities	
Electricity 39.6[b] x 6,000 x 0.07	16,632
Compressed Air[c]	2,175
Total Direct Cost	26,957
Indirect Costs	
Overhead at 60% of the sum of Operating Labor, Supervision, Maintenance Labor and Maintenance Material 0.6 (1,133 + 170 + 2 x 3,116)	4,521
Property Tax at 1% of Total Capital Investment 0.01 x 135,300[d]	1,353
Insurance at 1% of Total Capital Investment 0.01 x 135,300[d]	1,353
Administration at 2% of Total Capital Investment 0.02 x 135,300[d]	2,706
Capital Recovery, 10 year life and 10% Interest $\frac{0.1(1.1)^{10}}{(1.1)^{10}-1}$ x 135,300	22,013
Total Indirect Cost	31,946
Recovery Credit	
Lead 5,511.3[e] x 0.37[f]	(2,039)
Total Annual Cost	56,864

Notes - Example 1

[a]Data in References 18 through 24 was used to estimate that 30% of the bags would be replaced annually. Bag costs were estimated from data and procedures in Reference 20:

$$\text{At 6/1 A/C ratio, net cloth area} = \frac{18,880}{6} = 3,147 \text{ ft}^2$$

Cost of 5-1/8 in dia. pulse jet bags made of polyester felt is $\$0.59/\text{ft}^2$ in 3Q86.

$$\text{Bag cost} = 3,147 \times 0.59 \times \frac{371.6}{336.6} = \$2,050;\ \$2,050 \times 0.3 = \$615$$

Where 371.6 and 336.6 are the Chemical Engineering equipment cost indices for June '88 and September '86 respectively.

[b]Pressure drop in the ductwork was calculated to be 4.1 in water. Pressure drop in the filter was estimated to be 7.5 in water for a total of 11.6 in water. Power requirement is then from equation 5-15 in Reference 20:

$$kw = 0.000181(18,880)\ (11.6) = 39.6 \text{ kw}$$

where 18,880 is the acfm gas handled by the fan - see Table 6-1.

[c]Reference 20 recommends estimating compressed air usage at 2 scfm per 1,000 acfm gas handled by the filter.

$$\text{Compressed air cost} = 2 \times \frac{18,880}{1,000} \times 60 \times 6,000 \times \frac{0.16}{1,000} = \$2,175$$

Where $0.16 is the cost of 1,000 scfm of compressed air from Table 6-11.

[d]Total capital investment of $135,300 is given in Table 6-5 for a small three-process operation model facility.

[e]Lead recovered by the filter is 5,511.3 lbs/yr, see Table 6-1.

[f]The cost of lead is $.37/lb - See Table 6-11.

Example 2
HEPA Filter
Three-Process Operation - Small Facility

Direct Costs	
Operating Labor at 2 hr/week 2 x 50 x 11.33	1,133
Supervision at 15% of Operating Labor 0.15 x 1,133	170
Maintenance Labor at 2 hr/week 2 x 50 x 11.33 x 1.1	1,246
Maintenance Material at 100% of Maintenance Labor	1,246
Filter Media, replace 100% per year[a]	2,560
Utilities	
Electricity 6.8[b] x 6,000[c] x 0.07	2,856
Total Direct Cost	9,211
Indirect Costs	
Overhead at 60% of the sum of Operating, Labor, Supervision, Maintenance Labor, and Maintenance Material 0.6 (1,133 + 170 + 2 x 1,246)	2,277
Property Tax at 1% of Total Capital Investment 0.01 x (15,100)[d]	151
Insurance at 1% of Total Capital Investment 0.01 x (15,100)[d]	151
Administration at 2% of Total Capital Investment 0.02 x (15,100)[d]	302
Capital Recovery, 10 year life and 10% Interest $\frac{0.1(1.1)^{10}}{(1.1)^{10}-1}$ X 15,100	2,457
Total Indirect Cost	5,338
Recovery Credits	
Lead 141.258[e] x 0.37[f]	(52)
Fuel[g]	(16,162)
Total Annual Cost	(1,665)

Notes - Example 2

[a]The capacity of a standard 24 x 24 x 11½ in HEPA was estimated to be 1,200 acfm. The number of standard filters required then is:

$$\frac{18{,}880 \text{ acfm (Table 6-1)}}{1{,}200} = 16$$

From Reference 25, the cost of a standard filter is $160; based on 100 percent replacement the cost of filter media is 16 x $160 = $2,560.

[b]HEPA filter pressure drop is estimated in vendors' literature to be 1.5 to 2.0 in water. This study used 2.0 in.

$$Kw = 0.000181\ (18{,}880)\ (2.0) = 6.8 \text{ kw}$$

Where 18,880 acfm is the gas handled by the filter.

[c]The HEPA filter is operated the entire year or 6,000 hours. Heated air is recirculated through the HEPA filter only during the heating season of October through April or for 3,500 hours of operation. During the remainder of the year HEPA exhaust is vented to the atmosphere.

[d]The total capital investment can be found in Table 6-5 for a small three-process operation facility.

[e]Lead recovered by the filter is 141.258 lbs/yr, see Table 6-1.

[f]The cost of lead is $.37/lb - See Table 6-11.

[g]Fuel credit is calculated in two parts. First, the cost of heating outside air to 65°F is calculated using the degree days. Degree days vary by region. For this study degree days typical of the Mid-Atlantic were used, first because it is a heavily populated area where a number of battery manufacturing plants are located and second because it is midway between north and south and thus represents a median.

I Cost Savings = $$\frac{18{,}880 \times 60 \times 24 \times 0.018 \times 5{,}200 \times 3.80 \times 10^{-6}}{0.85}$$

= $11,376

Where

18,880 = the acfm recirculated
60 = minutes/hour
24 = hours/day
0.018 = heat capacity of air in Btu/(°F)(acfm)
5,200 = degree days from Reference 47
3.80×10^{-6} = cost of fuel in $/Btu - Table 6-11.
0.85 = air heater efficiency (Reference 48)

The second part of the calculation develops the value of the heat returned above 65°F:

$$\text{II Cost Savings} = \frac{60 \times 3{,}500 \times 0.018 \times 18{,}880 \times (80-65) \times 3.8 \times 10^{-6}}{0.85}$$

$$= \$4{,}786$$

Where

60 = minutes/hour
3,500 = number of operating hours in heating season October through April.
18,880 = the acfm recirculated.
80 = the temperature of the recirculated air in °F.
65 = the base temperature for the degree day calculation in °F.
3.8×10^{-6} = the cost of fuel in $/Btu - Table 6-11.
0.85 = the air heater efficiency (Reference 48).

Total fuel credit = $11,376 + $4,786 = $16,162.

7.0 ENFORCEMENT ASPECTS

Based on data gathered during this NSPS Review, there have been no major, widespread problems within the industry in meeting the NSPS requirements. There are, however, some concerns over the interpretation of the definition of affected facility, and the required emission testing.

7.1 DEFINITION OF AFFECTED FACILITY

There have been uncertainties in interpretation of affected facilities, and, therefore, inconsistencies in enforcement of the NSPS among the regulatory agencies. Some agencies have determined that the affected facility is all equipment performing a particular operation (i.e., all grid casting machines, or all three-process equipment, whether new or old), whereas others have determined that individual units are the affected facility. When the entire operation is determined as subject, some agencies require that each emission point from the operation meet the applicable standard, while others require that the weighted average of emissions meet the standard.

The choice of affected facility interpretation can have a significant effect upon a plant's compliance status. For example, assume a plant installs two new Barton oxide mills. Taken as individual facilities, one unit's emissions may meet the NSPS limits, while the other may not. However, taken as one affected facility, the weighted average emissions may meet the allowable NSPS limit.

It appears that the original intent of the regulation was for all equipment performing an operation to be the affected facility, as evidenced by the following paragraph from the preamble to the proposed rule:

"Selection of Affected Facilities

Lead emitting process operations selected as affected facilities are lead oxide production, grid casting, paste mixing, three-process operation, lead reclamation, and other lead emitting operations. These process operations often consist of several machines or production lines which perform the same function and which are located in the same area and ducted to the same control device. Therefore, for each of the process operations mentioned above, the affected facility is the entire operation. For example, at a plant with more than one three-process line, all of the lines together would be the affected facility."[1]

However, during this review, it has been determined that these units are often not located in the same area, and often are ducted to several, separate control devices (especially in cases of modification/ reconstruction).

The Stationary Source Compliance Division has issued a compliance determination to at least one EPA Regional Office as follows:

Several new grid casting machines were constructed at an existing plant, and therefore increased the facility's overall emission rate. It was determined that the addition of the new casters would constitute a modification of the entire casting facility (both new and old casting equipment), and the emission standard would be applied to the weighted average sum of emissions from all discharge points within the entire facility.[2]

This particular Regional Office has subsequently made several compliance determinations of the same nature, applying to any type of affected facility.[3]

Several members of the industry have expressed some concerns with the "entire department affected facility" approach. One concern is that it is often difficult or extremely costly to duct the emissions from the various

individual sources in an affected facility to a common stack or control device (especially in modification/reconstruction cases). This then results in the also costly need to test many separate stacks. Another industry opinion is that including existing equipment in an affected facility is requiring retrofit control, which they feel is not the intent of an NSPS, and is creating a form of "bubble" policy. Another common occurrence in the industry is that often, when an entire "department" is determined as the subject facility, the plant will control only selected sources within the facility to bring the weighted sum of emissions to just below the allowable limit. The individual units that are controlled are not necessarily the new units, and the control technique is often not the best technology.

7.2 EMISSION TESTING

Several industry representatives have expressed concerns dealing with emissions testing at lead-acid battery plants. The first area deals with the difficulty of performing Method 12, and the variability of results. Comments were received that Method 12 is very time consuming and difficult to perform. This often makes it hard to complete three runs in one day (thus increasing cost), and the runs are for the minimum length of one hour. This, in turn, results in very small quantities of lead being collected, and increases the effect of small process variations on the test results.[4] There was also some concern expressed over variability of the test results between testing firms.

Two tests on the same facility, but from different testing firms, were submitted for review. The Emission Measurement Branch evaluated both reports, and found that each one had been correctly performed according to the parameters of Method 12. Since the tests were not performed simultaneously, it was not possible to assess the precision of Method 12. It is believed that the variability between emission test results was due to process fluctuations within normal operating conditions. Method 12, Section 2.3 states that, "The within-laboratory precision, as measured by the coefficient of variation ranges from 0.2 to 9.5 percent relative to a

run-mean concentration." However, longer sampling times are more representative of process conditions and should be used, if possible.[5,6,7]

One solution suggested by industry representatives was to use Method 17 in lieu of Method 12. However, Method 17 is an in-stack filter method (does not include impinger catch), and would not catch lead fume. Also, the collection efficiency of Method 17 is very dependent upon the stack temperature. Furthermore, the standard is based upon Method 12 data; in order to use Method 17, a correlation between the results of the two Methods would have to be developed.[8] Therefore, Method 17 is not a viable option.

Several of the industry representatives felt that opacity readings were meaningless at the grain loadings required by the mass standards. Approximately 50 percent of the test data received during this review included opacity readings, all of which were 0 percent.

There are some sources at lead-acid battery plants with very small stacks (3 inches in diameter), low flow rate (200 scfm), low velocities(400 fpm), or intermittent operation and emissions that are being determined as subject to the standard (i.e., lead oxide storage; emissions occur only during filling of the silo). The industry stated that testing of these sources at proper flowrates and velocities, and for the proper length of time is difficult.[8] However, EPA Reference Methods 1A, 2C, and 2D, describing procedures for testing small stacks, were promulgated on March 28, 1989, and address such situations as noted by the industry.[9]

7.3 REFERENCES

1. U.S. Environmental Protection Agency. Standards of Performance for New Stationary Sources; Lead-Acid Battery Manufacture: Proposed Rules. Federal Register. 45(9):2790-2802. January 14, 1980.

2. Materials from Farrell, S., EPA:SSCD, to Michelitsch, D.M., EPA:ISB. December 6, 1988. Compliance determinations on Subpart KK.

3. Materials from Reinermann, P., EPA:Region IV, to Michelitsch, D.M., EPA:ISB. February 2, 1989. Compliance determinations on Subpart KK.

4. Memo from Michelitsch, D.M., EPA:ISB, to Durkee, K.R., EPA:ISB. November 2, 1988. Report on June 22, 1988, meeting with Battery Council International.

5. U.S. Environmental Protection Agency. Method 12 - Determination of Inorganic Lead Emission from Stationary Sources. 40 CFR 60, Appendix A, Method 12. Washington, D.C. Office of the Federal Register. July 1, 1984.

6. Letter and attachments from Meverden, J.R., Johnson Controls Incorporated, to Farmer, J.R., EPA:ESD. August 9, 1988. Response to Section 114 Information Request.

7. Memo from Toney, M.L., EPA:EMB, to Michelitsch, D.M., EPA:ISB. June 1, 1989. Response to questions about variability of EPA Method 12.

8. Reference 4.

9. U.S. Environmental Protection Agency. Standards of Performance for New Stationary Sources; Methods 1A, 2C, 2D: Final Rule. Federal Register. 54(58):12621-12626. March 28, 1989.

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