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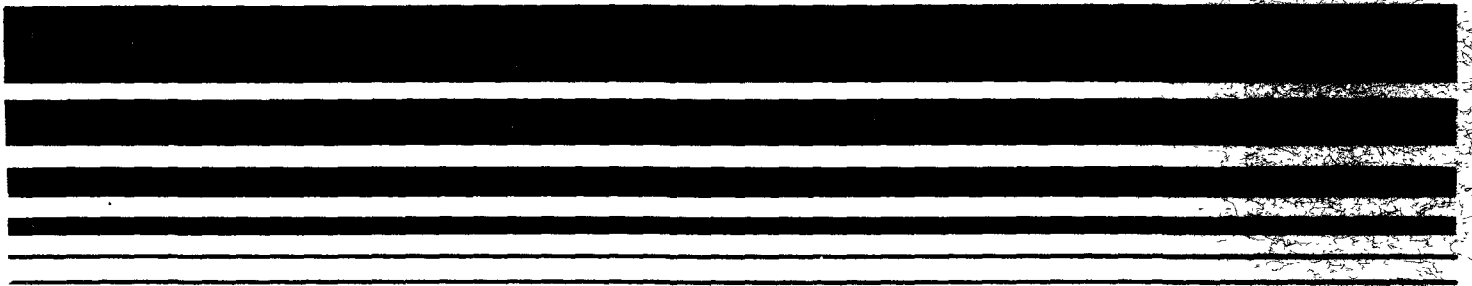
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Air



Hazardous Air Pollutant Emissions from Mercury Cell Chlor-Alkali Plants

Background Information Document for Proposed Standards





**NATIONAL EMISSION STANDARDS FOR
HAZARDOUS AIR POLLUTANTS
FROM MERCURY CELL CHLOR-ALKALI PLANTS**

Background Information Document
for Proposed Standards

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1.0 INTRODUCTION

1.1 INTRODUCTION

This background information document (BID) provides information relevant to the proposal of national emission standards for hazardous air pollutants (NESHAP) for limiting mercury emissions from mercury cell chlor-alkali plants. The standards are being developed according to section 112(d) of Title III of the Clean Air Act (CAA) as amended in 1990.

Chapter 2 presents a description of the mercury cell chlor-alkali industry and process. Chapter 3 discusses the techniques used to control mercury emissions from the mercury emission sources at mercury cell chlor-alkali plants. Chapter 4 describes the regulatory alternatives considered by the Environmental Protection Agency (EPA) for proposal. Chapters 5 and 6 discuss the estimation of environmental and energy impacts and cost impacts, respectively, of the regulatory alternatives on the industry. Chapter 7 presents the detailed rationale behind the selection of the proposed NESHAP.

1.2 STATUTORY BASIS

Section 112 of the CAA contains EPA's authorities for reducing emissions of hazardous air pollutants (HAP). Section 112(c)(6) requires the EPA to list source categories and

subcategories assuring that sources accounting for not less than 90 percent of the aggregate emissions of each of seven specific bioaccumulative pollutants (including mercury) are subject to standards under subsection 112(d)(2) or (d)(4) of the CAA.

Section 112(d) requires the Administrator to promulgate regulations establishing emission standards for each category or subcategory of major sources and area sources of HAP listed in section 112(c). Section 112(d)(2) specifies that emission standards promulgated under the section shall require the maximum degree of reductions in emissions of the HAP subject to section 112 that are deemed achievable. This level of control is referred to as maximum achievable control technology (MACT). These regulations are often termed "technology-based" standards because they are based on the degree of emissions control achievable through the application of technologies that the best performing sources in the particular source category are using. These technologies may include equipment or process design, chemical substitution, collection and treatment of emissions, work practices, and other measures.

For area sources determined to present a threat of adverse effects to human health or the environment, standards or requirements that represent generally available control technologies (GACT) or management practices to reduce HAP may be promulgated, in lieu of establishing standards based on MACT.

The minimum level allowed for NESHAP established under section 112(d)(2) is referred to as the MACT floor (section 112(d)(3)). For new sources, the MACT floor cannot be less stringent than the emission control that is achieved in practice by the best-controlled similar source. The MACT floor for existing sources must be at least as stringent as the average emission limitation achieved by the best-performing 12 percent of existing sources in the category or subcategory (or the best-performing 5 sources for categories or subcategories with fewer than 30 sources).

In developing MACT, control options that are more stringent than the floor may also be considered. Standards more stringent than the floor may be established based on the consideration of cost of achieving the emissions reductions, any non-air quality health and environmental impacts, and energy impacts.

Section 112(d)(4) provides for consideration of health thresholds with an ample margin of safety. Certain other sections of section 112 require the EPA, in addition to technology-based standards, to evaluate risk to public health and the environment in determining whether other control measures are appropriate.

1.3 BACKGROUND ON SOURCE CATEGORY

As previously noted, section 112(c)(6) of the CAA requires the EPA to list source categories and subcategories assuring that sources accounting for not less than 90 percent of the aggregate

emissions of each of seven specific bioaccumulative pollutants (including mercury) are subject to standards under subsection 112(d)(2) or (d)(4) of the CAA. It was estimated that chlor-alkali production sources contribute around 5½ percent of the total nationwide anthropogenic stationary source category mercury emissions (63 FR 17838), and over 25 percent of the total nationwide anthropogenic stationary source category mercury emissions from non-combustion sources.

2.0 INDUSTRY CHARACTERIZATION

2.1 INTRODUCTION

Chlorine is an essential chemical building block, ranking among the top ten by volume of all chemicals produced in the United States.¹ According to the Chlorine Institute, a trade association that represents North American chlorine producers, chemicals production is the largest use sector (35 percent) for the chlorine produced in North America. This is followed by plastics production (28 percent); solvents production (18 percent) for metalworking, dry cleaning, and electronics; pulp and paper bleaching (14 percent); and water/wastewater purification (5 percent).²

Chlorine producers are identified by Standard Industrial Classification (SIC) code 2812 - Alkalies and Chlorine³ and North American Industry Classification System (NAICS) code 325181 - Alkalies and Chlorine Manufacturing.⁴

The majority of chlorine is produced by electrolysis involving three technologies, namely diaphragm cells, mercury cells, and membrane cells. With these methods, an electric current is passed through a salt solution (brine), causing the dissociation of the salt and resulting in the generation of chlorine gas and an alkaline solution (caustic soda, or sodium

hydroxide, and caustic potash, or potassium hydroxide). These saleable chemicals are viewed as co-products, hence the designation of the production methods as "chlor-alkali" processes. Like chlorine, caustic soda is used in a diverse range of processes. This includes pulp and paper, detergent, textiles (particularly, rayon), pigments, petroleum, pharmaceuticals, and sodium hypochlorite (bleach) production.⁵ Hydrogen gas is also produced as a by-product of chlor-alkali processes. The hydrogen is primarily used on-site, either as fuel for boilers or as high-purity raw material for other chemical production. By-product hydrogen is also released to the atmosphere when supply exceeds demand.

Aside from the three chlor-alkali processes, chlorine is also produced as a co-product or by-product in four other types of processes. The first is an electrolytic process involving molten salts rather than a salt solution (Downs sodium process). The second is an electrolytic process that uses hydrogen chloride (HCl) as a raw material instead of salt (Uhde HCl decomposition process). The third process is non-electrolytic and involves chlorine as a co-product of potassium nitrate production (nitric acid/salt process). The fourth is the electrolytic primary magnesium production process.

In 1997, there were 43 chlorine production plants operating in the United States.⁶ The majority of the plants, 38 in all, used diaphragm, mercury, and/or membrane cells. Seven plants

used a combination of two types of chlor-alkali cells and one plant used all three types of cells. Of the remaining chlorine production plants, three plants used magnesium production process, and one plant each used the Downs sodium, Uhde HCl decomposition, and nitric acid/salt process.

While chlorine is produced in various types of processes, the focus of this document and the corresponding EPA regulatory action is mercury emissions, which only occur from chlor-alkali production using mercury cell technology. Therefore, this chapter characterizes mercury cell chlor-alkali plants as an industry (Section 2.2), the mercury cell chlor-alkali production facilities (Section 2.3) at these plants, and mercury recovery facilities (Section 2.4) that are co-located with mercury cell chlor-alkali production facilities. Unless specified otherwise in this chapter and in subsequent chapters of this background information document, the information presented originated from Section 114 questionnaires and supplementary clarifications (including performance test reports),^{7,8} site visits,^{9,10,11,12,13} and meetings with industry representatives.^{14,15,16,17,18}

2.2 MERCURY CELL CHLOR-ALKALI INDUSTRY PROFILE

There are twelve mercury cell chlor-alkali plants currently operating in the United States.^a Table 2-1 presents basic information about each plant, specifically the owner and location, the year mercury cell chlor-alkali production started,¹⁹ the number and types of mercury cells, and the annual amount of chlorine produced.²⁰ The twelve plants are owned and operated by eight different companies. Occidental Chemical Corporation, Olin Corporation, and PPG Industries, Incorporated own and operate multiple plants (three, two, and two plants, respectively). ASHTA Chemicals, Incorporated, HoltraChem Manufacturing Company, Pioneer Chlor-Alkali Company, Incorporated, Vulcan Materials Company, and Westlake CA&O Corporation each own and operate one plant. The plants are located in ten states: Louisiana and Texas (two plants each), and Delaware, Georgia, Kentucky, Maine, Ohio, Tennessee, West Virginia, and Wisconsin (one plant each).

The ages of the plants vary, as mercury cell chlor-alkali production started in 1938 at the oldest plant and in 1970 at the newest plant. As such, new mercury cell chlor-alkali production facilities have not been constructed in over thirty years. This

^a At the time of printing of this document, one plant (HoltraChem Manufacturing Company's Orrington, Maine plant) had closed (in September 2000), and one plant (Westlake CA&O Corporation's Calvert City, Kentucky) had indicated it would convert to membrane cell technology by the end of 2001. However, both plants were considered in developing the proposed NESHAFF.

TABLE 2-1. PROFILE OF MERCURY CELL CHLOR-ALKALI PLANTS

| Plant Owner | Plant Location | Year Chlorine Production via Mercury Cell Chlor-Alkali Process Started ^a | Make/Model and Number of Mercury Cells | Chlorine Produced by Mercury Cell Chlor-Alkali Process (Megagrams per year) ^b |
|------------------|----------------------|---|--|--|
| ASHTA | Ashtabula, OH | 1963 | Olin E-11, 24 | 43,110 |
| HoltraChem | Orrington, ME | 1967 | De Nora 24H5, 24 | 65,860 |
| Occidental | Muscle Shoals, AL | 1952 | De Nora 12x3, 116 | 127,322 |
| Occidental | Delaware City, DE | 1965 | De Nora 18x4, 88 | 132,450 |
| Occidental | Deer Park, TX | 1938 | De Nora 18x6, 52 | 88,146 |
| Olin | Augusta, GA | 1965 | Olin 510, 60 | 108,210 |
| Olin | Charleston, TN | 1962 | Olin 510, 58; Olin 812, 48 | 238,592 |
| Pioneer | St. Gabriel, LA | 1970 | Uhde 300-100, 52 | 173,274 |
| PPG | Lake Charles, LA | 1969 | De Nora 48H5, 70 | 234,056 |
| PPG | New Martinsville, WV | 1958 | Uhde 20 sq. m, 54 | 66,225 |
| Vulcan | Port Edwards, WI | 1967 | De Nora 24H5, 24 | 71,092 |
| Westlake | Calvert City, KY | 1966 | De Nora 24H5, 36 | 111,041 |
| Nationwide Total | | | | 1,459,379 |

^aExcept for the two PPG plants, the year specified is when the plant was built. The two PPG plants did not initially use mercury cells when chlorine production commenced (1947 for PPG's Lake Charles, LA plant and 1943 for PPG's New Martinsville, WV plant).

^bThe values specified for Occidental's Deer Park, TX plant, PPG's Lake Charles, LA plant, and PPG's New Martinsville, WV plant do not include all chlorine produced at the site, as diaphragm cells are co-located with the mercury cells at the site. The total chlorine production capacities of these plants are 348,672, 1,156,792, and 359,568 Megagrams per year, respectively (Source: 1997 Directory of Chemical Producers: United States of America, SRI International).

is largely due to the development of membrane cell technology. Historically, one of the reasons for selecting mercury cell technology over diaphragm cell technology was the quality of caustic produced, both in terms of purity and strength. In fact, the production of rayon fiber evolved to depend on the availability of the high-purity mercury cell grade caustic soda, which came to be known as rayon grade caustic soda. When membrane cell technology was developed, it became the preferred method, as high purity caustic soda could be produced with a lower energy consumption per unit of caustic product.²¹

The nationwide chlorine production resulting from the use of mercury cell technology is 1,460,674 Megagrams (1,608,672 tons) per year. These plants also produce over 450 million standard cubic meters (16 billion standard cubic feet) of hydrogen annually.

2.3 MERCURY CELL CHLOR-ALKALI PROCESS DESCRIPTION

The central unit in the mercury-cell chlor-alkali chlorine production process is the mercury cell, which consists of an electrolyzer, a decomposer, one or more end boxes, a mercury pump, and other components linking the electrolyzer and decomposer. While each mercury cell is an independent production unit, numerous cells are connected electrically in series to form a cell circuit. Mercury cells are situated in a cell room and typically arranged in two rows separated by a center aisle. The cell room generally designates a two-story structure in which

mercury cells are housed on the upper floor. The lower floor is the site of various process and housekeeping functions. The cell room is more fully discussed as a source of fugitive mercury emissions in Chapter 3, Section 3.5.

Section 2.3.1 describes the general operation in and around the mercury cell. Sections 2.3.2 through 2.3.6 provide general descriptions of ancillary operations. Figure 2-1 presents a simplified flow diagram of the mercury cell chlor-alkali process.

2.3.1 Mercury Cell Operation

A typical mercury cell measures about 15 meters (about 50 feet) in length and 1.5 meters (about 5 feet) in width^b and holds about 3,600 kilograms (around 8,000 pounds) of mercury. The number of cells at a given plant ranges from 24 to 116 and averages 56. The most prevalent cell make is DeNora (seven plants), followed by Olin (three plants), and Uhde (two plants). Every plant uses cells made by only one manufacturer, and only Olin's Charleston, Tennessee plant utilizes more than one cell model. Also, Occidental's Delaware City, Delaware plant uses the same cell model throughout its cell room but loads half of the cells with more mercury. DeNora cells (all cell models) are generally run with the highest amount of mercury, followed by Uhde and Olin cells. The amount of mercury held by a cell is largely a function of the cross-sectional area of the

^b The dimensions cited are dimensions of the electrolyzer, the largest component of the mercury cell.

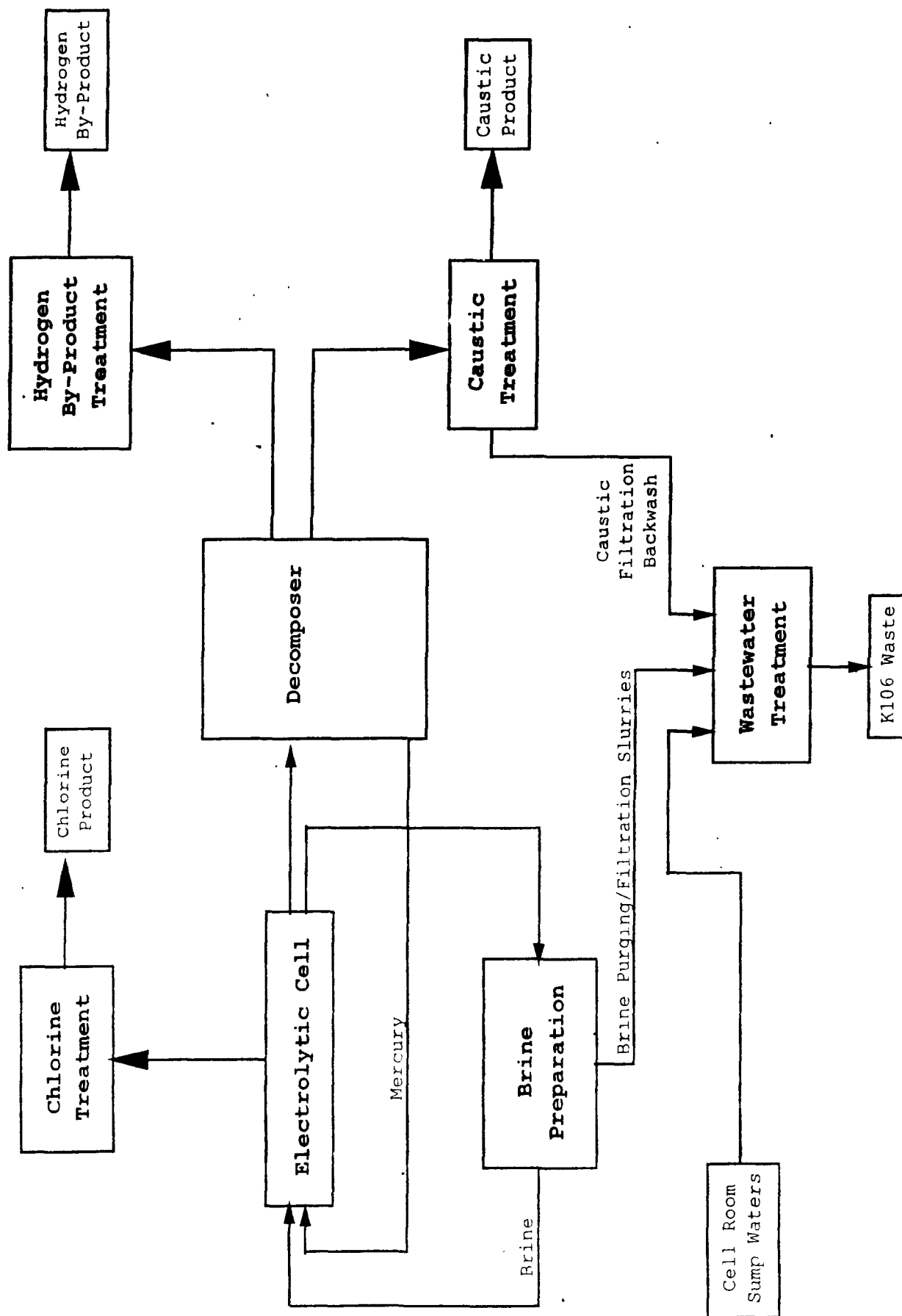


Figure 2-1. Mercury Cell Chlor-Alkali Process Flow Diagram

electrolyzer, in which the depth of the mercury layer (on the order of one centimeter) is much smaller than the length and width. Thus, because DeNora cell electrolyzers have the greatest length on average (widths vary to a much lesser extent), DeNora cells can be considered the largest, followed by Uhde and Olin cells.

A mercury cell involves two distinct reactions, which occur in separate vessels. The electrolyzer produces chlorine gas, and the decomposer produces hydrogen gas and caustic solution. The electrolyzer can be described as an elongated, shallow steel trough enclosed by side panels and a top cover. The decomposer is a four to five-foot high cylindrical vessel located at the end of the cell and is usually oriented vertically (PPG's New Martinsville, West Virginia plant has horizontal decomposers). The electrolyzer and the decomposer are typically linked at the ends by an inlet end box and an outlet end box.

A shallow stream of liquid mercury flows continuously between the electrolyzer and the decomposer. The mercury enters the cell at the inlet end box and flows down a slight grade to the outlet end box, where it flows out of the electrolyzer into the decomposer. After being processed in the decomposer, the mercury is pumped back up to the inlet end box.

Saturated brine (sodium chloride solution or potassium chloride solution) is fed to the electrolyzer via the inlet end box and flows toward the outlet end box on top of the mercury

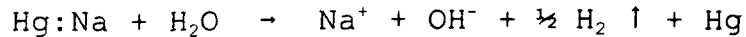
layer. The brine and mercury flow under dimensionally stable metal anodes, typically made of a titanium substrate with a metal catalyst, that are suspended in the electrolyzer top. The mercury serves as the cathode in the cell.

Electric current applied between the anode and the mercury (Hg) cathode causes a reaction producing chlorine (Cl_2) at the anode and a sodium:mercury (Na:Hg) amalgam at the cathode. If sodium chloride (NaCl) brine is used, the overall electrolytic reaction is as follows:



The reaction is essentially the same for potassium chloride (KCl) brine except that potassium is substituted for sodium in the chemical equation. The chlorine gas is collected at the top of the electrolyzer and transported to a gas purification and usually to liquefaction units, as described in Section 2.3.2. The sodium:mercury amalgam ultimately exits via the outlet end box and enters the decomposer. The brine, whose salt content has been partially depleted in the reaction, also exits the cell at the outlet end box and is transferred to a brine preparation system, as described in Section 2.3.3.

The decomposer functions as a packed bed reactor where the mercury amalgam is contacted with deionized water in the presence of a catalyst. The amalgam reacts with the water (H_2O), regenerating elemental mercury and producing caustic and hydrogen (H_2). The overall decomposer reaction is as follows:



Again, potassium is substituted for sodium if the plant is producing potassium hydroxide (KOH) rather than sodium hydroxide (NaOH). The caustic and mercury are separated in a trap at the end of the decomposer. Prior to transfer to ancillary treatment operation (as described in Section 2.3.4), the caustic stream exiting each decomposer is may be passed through a caustic basket, a fixture containing a serrated funnel that breaks the stream into droplets so that electric current is not conveyed. The hydrogen is also transferred to an ancillary treatment process (as described in Section 2.3.5), and the mercury is pumped back to the inlet end of cell.

2.3.2 Product Chlorine Purification

Individual chlorine streams are collected under vacuum from each mercury cell electrolyzer and fed into a header system leading out of the cell room. The chlorine then undergoes condensation, mist elimination, and absorption (drying).

Initially, the chlorine is routed to one or more indirect contact heat exchangers. Next, it is passed through a wet demister. The condensates from cooling and mist elimination may be fed to the brine preparation system. The average concentration of mercury (in its elemental form) in chlorine at this point and for the remainder of the treatment process ranges from 0.002 to 0.1 ppm, with a mean value of about 0.03 ppm. Subsequently, the chlorine encounters a series of countercurrent

sulfuric acid towers to remove water vapor, followed by a dry demister to remove entrained acid. Finally, the chlorine gas is purified, and further cooling, compression, and liquefaction operations may be conducted to obtain liquid chlorine.

2.3.3 Brine Preparation System

Brine flows in a continuous loop between the mercury cells and brine preparation system, which provides clean, saturated brine to the mercury cell chlor-alkali process. Eight mercury cell chlor-alkali plants use sodium chloride brine, two use potassium chloride brine, and two plants use both types of brines in different mercury cell circuits. Due to contact of brine and mercury, mercury is present in the brine system in its molecular form as dissolved mercuric chloride. The average mercury concentration ranges from 3 parts per million (ppm) to 25 ppm, with a mean value of about 14 ppm.

In the brine loop, an individual brine stream to a mercury cell passes through the cell and leaves the cell room (via a brine header) with a reduced salt content. This stripped brine is acidified with hydrochloric acid and, then, purified of chlorine. The chlorine vapor stream generated is fed to the chlorine product header for treatment. After dechlorination, the brine is resaturated with raw sodium chloride or potassium chloride. An important function of the brine preparation system is the removal of impurities, such as calcium, magnesium, iron, aluminum, strontium, nickel, molybdenum, manganese, copper,

chromium, lead, and vanadium, that may be introduced in the raw salt. The presence of these elements can adversely affect mercury cell efficiency, as they amalgamate with mercury to form mercury "butters." Accordingly, caustic solutions and sodium carbonate are added to raise pH, depress metal solubility, and form metal precipitates. The resulting slurries are filtered to produce brine muds. Although such muds are designated hazardous wastes ("K071") in accordance with EPA's solid waste classifications (40 CFR part 261, subpart D), the muds are "delisted" at some mercury cell chlor-alkali plants (due to their low mercury content) so that they may be disposed of in an industrial landfill, rather than at a hazardous waste facility. Subsequently, the brine is acidified to remove excess caustic, subjected to heat exchange for temperature adjustment, and returned to the mercury cells as clean saturated brine.

2.3.4 Product Caustic Purification

Eight mercury cell chlor-alkali plants produce sodium hydroxide, two produce potassium hydroxide, and two plants produce both caustic solutions. Because the mercury cell chlor-alkali process produces a caustic solution that is 50 percent by weight sodium hydroxide or potassium hydroxide in the decomposer reaction, the treatment process mainly involves mercury removal.

The average concentration of mercury (found in its elemental form) in the caustic stream leaving the decomposer ranges from about 3 ppm to 15 ppm, with a mean value of 10 ppm. The streams

from the decomposers are combined into a caustic header. Then the caustic may undergo cooling to condense entrained mercury prior to filtration. Five plants use candle filters with carbon pre-coat only, while two plants use another material in addition to carbon for the candle filters. Four plants use candle filters with a cellulose-based material. Two plants use plate filters with carbon pre-coat (one of these two plants uses both plate and candle filters with carbon pre-coat). The average mercury content of caustic product ranges from 0.02 ppm to 0.2 ppm, with a mean value of 0.08 ppm.

2.3.5 By-Product Hydrogen Cleaning

Hydrogen exiting a decomposer contains vaporized mercury. Accordingly, each decomposer is equipped with an adjacent cooler through which the hydrogen stream is routed to immediately condense mercury and return it to the mercury cell (this is true for all but one mercury cell chlor-alkali plant, which does not have initial coolers associated with each decomposer). Most of these coolers are indirect contact devices, including shell and tube, plate-and-frame, radiator-type, U-tube, and double-pipe, cooling jacket exchangers. Two plants use direct contact packed bed, counter-current coolers. The temperature at the decomposer outlet ranges from 160 degrees Fahrenheit (°F) to 260°F, with a mean of 209°F and a median of 220°F. Most plants have an individual cooler associated with each decomposer. The temperature of the hydrogen stream after passage through

individual coolers ranges from 70°F to 200°F, with a mean of 135°F and a median was 130°F.

After initial cooling, the streams are collected into a common header. The hydrogen is then purified of mercury via various combinations of condensation, mist elimination, absorption, and adsorption. This is further discussed in Section 3.2, as the by-product hydrogen stream is a point source of mercury emissions.

2.3.6 Wastewater Treatment

In the mercury cell chlor-alkali process, various aqueous liquids containing mercury are generated and must be treated to remove mercury. These wastewaters can originate from a variety of sources.

Water from washdowns, cleanup activities, and liquid mercury collection, as well as end-box wash waters, are channeled to wastewater treatment via open-air drains and the cell room sump. Brine is occasionally purged to wastewater treatment to remedy the buildup of metallic impurities. Alternatively, slurries from the purification of saturated brine (if they are not filtered as part of brine system) may be fed to wastewater treatment. From caustic treatment, the waters involved in periodic regeneration of the mercury filters (i.e., caustic filtration "backwash") are generally fed to wastewater treatment. Waters from absorbers (absorption is discussed in Section 3.6.2, as a mercury emission control technology) may also be routed to wastewater treatment.

The wastewater treatment method most commonly used by mercury cell chlor-alkali plants was developed in the 1970's and is highly dependent on pH. The method entails three broad steps. First, sodium hydrosulfide is added to wastewaters, which contains both elemental mercury and mercury compounded as mercuric chloride, to form mercuric sulfide. Next, the mercuric sulfide is removed via precipitation and filtration, resulting in wastewaters separated from a mercuric sulfide filter cake. Lastly, the dissolved mercury in the wastewaters is removed via carbon adsorption. The treated wastewaters may be then be released in accordance with plant discharge permits. The mercuric sulfide filter cake is a designated hazardous waste ("K106") in accordance with EPA's solid waste classifications (40 CFR part 261, subpart D). "K106" wastes may be treated on-site to recover elemental mercury, as described in Section 2.4, prior to disposal.

2.4 DESCRIPTION OF MERCURY RECOVERY PROCESSES

Most mercury cell chlor-alkali plants recover elemental mercury from mercury-containing wastes. The types of waste processed include "K106" wastes and "D009" wastes. As previously discussed, "K106" wastes are sludges from wastewater treatment filtration. "D009" wastes are general mercury-containing waste solids that exceed the toxicity characteristic for mercury, according to EPA's solid waste classifications (40 CFR part 261, subpart C). "D009" wastes are categorized as either debris or

non-debris. "D009" debris are those greater than about 2½ inches in any one dimension, such as hardware, tools, and protective gear. "D009" non-debris include graphite from decomposers, cell room sump sludges, and other small solids. Additionally, spent carbon media from carbon adsorbers (adsorption is discussed in Section 3.6.3, as a mercury emission control technology) are also processed.

Of the twelve mercury cell chlor-alkali plants, nine plants have mercury recovery processes on-site. Six plants have mercury thermal recovery units, two plants have REMERC™ units, and one plant has a batch purification still.

Collectively, the nine plants process about 1,044 Megagrams (1,550 tons) of wastes per year, with the annual waste throughput ranging from over 3.2 Megagrams (3.5 tons) to 454 Megagrams (500 tons) and averaging about 157 Megagrams (173 tons). The percentages of total waste processed by type of mercury recovery unit are 85.6 percent for mercury thermal recovery units, 14.2 percent for REMERC™ units, and 0.2 percent for the batch purification still.

The amount of mercury recovered annually for the nine plants totals about 56 Megagrams (61 tons). The percentages of mercury recovered by type of mercury recovery unit are 89.7 percent for mercury thermal recovery units, 4.6 percent for REMERC™ units, and 5.7 percent for the batch purification still. The remainder

of this section discusses mercury thermal recovery units, REMERC™ units, and the batch purification still.

2.4.1 Mercury Thermal Recovery Units

A mercury thermal recovery unit designates the retort(s) where mercury-containing wastes are heated to volatilize mercury and the mercury recovery/control system (control devices and other equipment) where the retort off-gas is cooled, causing mercury to condense and liquid mercury to be recovered.

Six plants conduct thermal recovery (retorting) in a mercury thermal recovery unit. These units can be classified into oven type units and non-oven type units, based on the type of retort (furnace) used. Discussed below are descriptions and operating characteristics of the thermal recovery units, focusing on the retorts used, which include three basic designs: batch oven (three plants), rotary kiln (two plants), and single hearth (one plant). The recovery/control systems of all the units are less differentiated and are further discussed in Section 3.6, since the mercury thermal recovery unit vent, where treated off-gas is discharged to the atmosphere, is a point source of mercury emissions.

There are three plants, all owned and operated by Occidental, that each have a mercury thermal recovery unit with batch oven retorts. The Delaware City, Delaware plant operates five ovens, the Muscle Shoals, Alabama plant operates three ovens, and the Deer Park, Texas plant operates two ovens. The

batch ovens are D-tube retorts, which are so named because each resembles an uppercase letter "D" on its side. Pans are filled with waste, typically around 10 cubic feet, and then placed into an oven. After inserting three or four pans, the oven door is closed and the retort is heated to about 1,000°F. The residence time varies from about 24 to 48 hours, depending on the type of waste being processed. While retorting, the oven is kept under a vacuum and the mercury vapors are pulled into the mercury recovery/control system. After the cycle is completed, the unit is allowed to cool and the pans are then removed. Retorting at all three plants is conducted between 6,000 to 7,000 hours per year. The amounts of waste processed and the amounts of mercury recovered range from 90 to almost 300 tons per year and from 3 to 20 tons per year, respectively.

PPG's Lake Charles, Louisiana plant and Olin's Charleston, Tennessee plant each have a mercury thermal recovery unit with a rotary kiln retort. The rotary kilns are long, refractory-lined rotating steel cylinders in which the waste charge to be treated flows counter-current to hot combustion gases used for heating. Wastes to be treated are conveyed into a ram feeder, which inserts a waste charge into the kiln at regular intervals, typically about every 5 minutes. Each is fired with natural gas and is heated to 1,300°F and above. The rotation of the kiln provides for mixing and transfer of the waste to the discharge end. The residence time is about 3 hours. The gas stream

leaving the kiln passes through an afterburner, where the temperature is increased to 2,000°F to complete combustion reactions involving sulfur and carbon, and then to a mercury recovery/control system. Over 300 tons per year and around 500 tons per year are processed in each unit, and over 12 tons per year and about 10 tons per year of mercury are recovered

Vulcan's Port Edwards, Wisconsin plant has a mercury thermal recovery unit with a single hearth retort. This retort is comprised of a vertically-mounted refractory lined vessel with a single hearth and a rotating rabble. Waste is charged onto the hearth through a charge door by way of a conveyor. Once charged, the conveyor is withdrawn, the charge door is closed, and the heating or treatment cycle begins. The waste is stirred by the rabble rake, which turns continuously, and is heated to around 1,350°F. The residence time, which ranges according to waste type, is typically much longer than for rotary kilns. Like the kilns, the retort off-gas passes through an afterburner, where the temperature is increased to 2,000°F to complete combustion reactions involving sulfur and carbon, and then to a mercury recovery/control system. The amount of waste processed in, and the amount of mercury recovered by, the unit are considered confidential business information by this plant.

Thus, three plants have batch oven retorts, and three plants have non-oven (rotary kiln and single hearth) retorts. Both "K106" and "D009" wastes are processed in all six retorts. As

indicated above, there are differences between the two types related to operating temperature and residence time. Oven retorts have lower operating temperatures and substantially longer residence times. This is related primarily to the more efficient waste mixing and heating achieved in kilns.

Additionally, oven retorts typically have volumetric flow rates around 100 scfm, which is an order of magnitude lower than non-oven retorts, which have flow rates around 1,000 scfm.

2.4.2 REMERC™ Units

REMERC™ units involve liquid-phase operations and produce no discharges to the air. Moreover, the process is used to recover mercury from "K106" wastes only. REMERC™ units are operated at Pioneer's St. Gabriel, Louisiana plant and Westlake's Calvert City, Kentucky plant, which are both based on a proprietary design developed by Universal Dynamics.

REMERC™ units are operated in batch mode, with following steps: (1) leaching mercuric sulfide and metallic mercury from the "K106" sludges* with sodium hypochlorite, sulfuric acid, and brine to form dissolved mercuric chloride; (2) thickening the leach product to separate low mercury content solids from mercury rich liquids; (3) subjecting the solids to filtration and washing to obtain final treated "K106" muds*; and (4) subjecting the liquid solution containing mercuric chloride to cementation, or reaction with metallic iron, to precipitate elemental mercury. At Westlake's Calvert City, Kentucky plant, this last step is

forgone, and the mercuric chloride solution is sent to the brine preparation system for eventual recycling of mercury back to the mercury cells.

One plant processes 18.2 Megagrams (20 tons) per year of "K106" wastes, while the other plant processes about 182 Megagrams (200 tons) annually. The annual amount of mercury recovered is 0.27 Megagrams (0.3 ton) and 2.3 Megagrams (2.5 tons), respectively.

2.4.3 Batch Purification Still

At PPG's New Martinsville, West Virginia plant, a batch purification still is physically located within a cell room and involves indirectly heating a small volume of material with a high mercury concentration. This contrasts with mercury thermal recovery units, which heat large volumes of low mercury-content wastes.

This plant operates the batch purification still an average of seven times each year. Only end-box residues, which are heavy metal impurities amalgamated with mercury, are processed for mercury recovery. During a batch run, a vacuum pump is activated to achieve a vacuum before heating commences. During this startup period, evacuation vapors are routed through two identical carbon adsorption beds, one located before the vacuum pump and one located after the pump. Then, the residues are heated to a temperature of about 320 degrees Celsius (600 degrees Fahrenheit) and held at that temperature for 24 to 36 hours in

order to volatilize mercury. The mercury is then recovered in a receiving tank via a total condenser. The plant recovers about 3.2 Megagrams (3.5 tons) per year of mercury in this manner.

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3.0 EMISSION SOURCES AND CONTROL TECHNIQUES

3.1 INTRODUCTION

As stated in Chapter 2, four types of mercury emission sources may be present at a mercury cell chlor-alkali plant: by-product hydrogen streams, end-box ventilation system vents, mercury thermal recovery unit vents, and fugitive emission sources. Section 3.2 briefly describes the by-product hydrogen stream as the combined stream, prior to control. Section 3.3 discusses inputs to plant end-box ventilation systems and describes the stream, prior to control. Section 3.4 characterizes the mercury thermal recovery unit vents. Section 3.5 briefly describes fugitive emissions and cell room ventilation.

Mercury cell chlor-alkali plants are limited to emitting 2,300 grams per day of mercury to the atmosphere under the "National Emission Standard for Mercury" (40 CFR part 61, subpart E, §61.50 et. seq.),^a hereafter referred to as the part 61 NESHAP. To control mercury emissions from point sources, mercury cell chlor-alkali plants employ a variety of

^aThis regulatory program was originally set forth at 38 FR 8826, April 6, 1973; and amended at: 40 FR 48302, October 14, 1975; 47 FR 24704, June 8, 1982; 49 FR 35770, September 12, 1984; 50 FR 46294, November 7, 1985; 52 FR 8726, March 19, 1987; and, 53 FR 36972, September 23, 1988.

technologies, which are described in Section 3.6. As an alternative to measuring ventilation emissions from the cell room to demonstrate compliance, the part 61 NESHAP allows an owner or operator to assume a ventilation emission value of 1,300 grams per day of mercury provided that the owner/operator adheres to a suite of approved design, maintenance, and housekeeping practices.¹ All twelve mercury cell chlor-alkali plants carry out these eighteen practices instead of measuring mercury emissions from the cell room ventilation system. Section 3.7 provides specific examples of the implementation of these and other plant practices for limiting fugitive mercury emissions.

3.2 BY-PRODUCT HYDROGEN STREAM

The by-product hydrogen stream, which is a point source of mercury emissions, is the by-product hydrogen gas from each mercury cell decomposer that is manifolded and treated in the hydrogen system before being burned as fuel, transferred to another process as raw material, or discharged directly to the atmosphere. At the twelve mercury cell chlor-alkali plants, the temperature of the by-product hydrogen stream at the inlet to the control system ranges from 85 °F to 200 °F, with a mean of 132°F and a median of 124°F. The mercury composition of a stream at the median stream temperature would be no higher than the saturation concentration of 142 milligrams per cubic meter (mg/m³) (at 125°F). The volumetric flow rate of the stream upstream of the control system ranges from 930 standard cubic

feet per minute (scfm) to 5,064 scfm, with a mean of 2,721 scfm and a median of 2,535 scfm.

3.3 END-BOX VENTILATION SYSTEM AND END-BOX VENTILATION STREAM

The vent of the end-box ventilation system, which evacuates the head spaces of mercury cell end boxes and other vessels and equipment to the atmosphere, is also a point source of mercury emissions, when such a system is present at a plant. Ten of the twelve mercury cell chlor-alkali plants have end-box ventilation systems. The eighteen practices referenced in the part 61 NESHAP require maintaining end boxes of mercury cells under negative pressure by a ventilation system, unless the end boxes are equipped with fixed covers which are leak-tight. The practices also require each submerged mercury pump, which is used in a mercury pump tank for moving mercury regenerated in the decomposer back to the inlet end of the mercury cell, have a vapor outlet connected to the end-box ventilation system. Further, an aqueous layer is required to be maintained (at a temperature below its boiling point) over mercury in both inlet and outlet end boxes (unless they are closed) and over mercury in tanks associated with submerged mercury pumps. Occidental's Muscle Shoals, Alabama plant and Deer Park, Texas plant both have closed end boxes and have in-line mercury pumps with associated pump coolers and, thus, do not have end-box ventilation systems.

Inputs to end-box ventilation systems at the ten mercury cell chlor-alkali plants with these systems differ due to

different plant equipment designs. Table 3-1 identifies the points routed to the end-box ventilation system at each of the ten plants.

TABLE 3-1. POINTS ROUTED TO END-BOX VENTILATION SYSTEMS

| Plant Owner/Location | Make, Number of Mercury Cells | Ventilated Points | | | | | | | | |
|------------------------------|---|------------------------|----------------------|-----------------------|--------------------------|---------------------|---|-----------------------|----------------|---------------------------|
| | | Inlet/Outlet End Boxes | Inlet End Boxes Only | Outlet End Boxes Only | End-Box Wash Water Tanks | Caustic Tank/Header | Mercury Pump Tanks (Submerged Pumps) | Mercury Pump Seal Leg | Cell Room Sump | Graphite Treatment System |
| HoltraChem Orrington, ME | DeNora, 24 | X | | | X | X | | X | | |
| Pioneer St. Gabriel, LA | Uhde, 52 | | | X | | | | | | |
| OxyChem Delaware City, DE | DeNora, 88 | | | X | X | X | | X | | |
| Vulcan Port Edwards, WI | DeNora, 24 | X | | | X | X | | X | | |
| PFG Lake Charles, LA | DeNora, 70 | X | | | X | | | X | | X |
| Westlake Calvert City, KY | DeNora, 36 | X | | | | X | | X | X | |
| Olin Charleston, TN | Olin, 106 | | | X | | | X | | | |
| Olin Augusta, GA | Olin, 60 | | | X | | | X | | | |
| PFG Natrium, W | Uhde, 54 | | X | | X | X | | | | |
| ASHTA Ashtabula, OH | Olin, 24 | | | X | | | X | | | |

Both inlet and outlet end boxes are ventilated at four plants. Only inlet end-boxes are ventilated at one plant, as the aqueous and brine layers above mercury amalgam in the outlet end boxes are believed to sufficiently limit the evaporation of mercury. Only outlet end-boxes are ventilated at five plants, for the following reasons: (1) three plants have Olin cells, which do not have inlet end boxes; (2) one plant has closed inlet end boxes; and (3) one plant does not ventilate inlet end boxes due to safety concerns with hydrogen gas (this plant has closed end boxes, and although the plant is thus not required to do so, it operates outlet end boxes under negative pressure).

At the three plants with Olin cells, submerged pumps within mercury pump tanks or sumps are ventilated. For the remaining plants, DeNora or Uhde cells are not designed with submerged pumps. The plants with DeNora cells, however, do ventilate a section of piping preceding the in-line pump, which is referred to as the pump seal leg or loop.

End-box wash water (from the aqueous layer maintained over mercury in end boxes or pump tanks) may be held in tanks prior to wastewater treatment. At five plants, end-box wash water tanks are also ventilated. Other miscellaneous ventilated points include the caustic tank/header, cell room sump (via an opening in the sump cover), and graphite treatment system. Regarding this last point, in which graphite removed from decomposers is reactivated with a molybdate compound, the need for ventilation

arises due to mercury embedded in the graphite that is vaporized when a vacuum is exerted to impregnate molybdate. This point is not reported by more plants, as most add molybdate solution directly into the decomposer.

As discussed above, in inlet and outlet end boxes and in tanks associated with submerged mercury pumps that are ventilated, mercury is covered by an aqueous layer. Also discussed above was the ventilation of end-box wash water tanks, caustic tanks/headers, and a cell room sump, points in which mercury is inherently found beneath an aqueous layer. Thus, the end-box ventilation stream is never saturated with mercury, as air and liquid mercury are always separated by an aqueous layer and cannot attain equilibrium.

At the ten mercury cell chlor-alkali plants with an end-box ventilation system, the volumetric flow rate of the end-box ventilation stream upstream of the control system ranges from 202 scfm to 4,500 scfm, with a mean of 1,492 scfm and a median of 779 scfm. The stream temperature upstream of the control system ranges from 89°F to 158°F, with a mean of 118°F and a median of 110°F. The mercury concentration of the stream at this point ranges from 4 mg/m³ (for the 89°F stream) to 200 mg/m³ (for the 158°F stream). The mercury concentration of a stream at 120°F (before the control system) was reported as about 7 mg/m³. These values indicate a wide range in the degree of saturation of end-box ventilation streams, from about 6 percent to 41 percent.

3.4 MERCURY THERMAL RECOVERY UNIT OFF-GAS

The vent of the mercury thermal recovery unit, in which mercury-containing wastes are heated in retort(s) to volatilize mercury and the resulting retort off-gas is cooled to condense mercury for recovery as a liquid, is a point source of mercury emissions, when such a unit is present at a plant. Six mercury cell chlor-alkali plants have thermal recovery units on-site. Of these six plants, three plants have oven type units and three plants have non-oven type units, as discussed in Chapter 2, Section 2.4.1. The average volumetric flow rate of the gas stream upstream of the recovery/control system (i.e., the retort off-gas) is not known for all oven-type units. For non-oven type units, the average retort off-gas flow rate ranges from 700 scfm to 1,250 scfm, with a mean of 1,008 scfm and a median of 1,075 scfm. The temperature of the off-gas ranges from 600°F to 850°F, with a mean and median of 725°F, for oven-type units and from 1,850°F to 2,100°F, with a mean of 1,983°F and median of 2,000°F for non-oven units.

3.5 FUGITIVE EMISSIONS AND CELL ROOM VENTILATION

The majority of fugitive mercury emission sources at a mercury cell chlor-alkali plant are associated with cell rooms, which are structures in which mercury cells are situated and many process and housekeeping functions are carried out. Cell rooms bring together mercury, a large electrical load, and hot production equipment. Accordingly, most fugitive mercury

emission sources at mercury cell chlor-alkali plants are associated with cell rooms. Fugitive mercury emissions are the result of mercury released to air from various process events. The opening of a mercury cell for cleaning or other maintenance results in mercury vapor released to the cell room environment. Hydrogen/mercury vapor leaks from decomposers as well as other portions of hydrogen systems, particularly upstream of hydrogen headers, and mercury volatilization during liquid mercury leaks or caustic leaks also result in such emissions. In both cell rooms and waste storage areas, mercury volatilized from liquid mercury spilled as part of operational or maintenance activities also contributes to fugitive mercury emissions. Mercury may also volatilize from a liquid mercury accumulation situated on a surface exposed to the air or beneath an aqueous layer in an open container or trench. Liquid mercury exposed to the atmosphere evaporates at a rate depending on temperature, air flow, and other variables.

Cell rooms are ventilated in order to dissipate heat evolved by mercury cells and to reduce worker exposure to mercury vapor in the cell room environment. All cell rooms are ventilated along the length of the cell room roof, either by way of roof monitors or cupolas or through static or mechanically driven ventilators. Cell rooms in warm climates tend to also be ventilated through openings in the cell room walls. Due to these conditions, the reliable measurement of mercury emissions from

most cell rooms would be costly, owing to the need to measure both mercury vapor concentration and air flow rate at apertures with sophisticated equipment. The measurement of mercury emissions from mercury-containing waste storage areas is also impracticable, as these are usually located in several places throughout a plant, many of which are open areas. Not unexpectedly, emissions data on cell room emissions are very limited and are non-existent for waste storage areas.

3.6 VENT CONTROL TECHNIQUES AND SYSTEMS

To control mercury emissions from point sources, mercury cell chlor-alkali plants employ a variety of technologies, including condensation, absorption, and adsorption, and combinations of these technologies. These control systems are described in this section. Specifically, condensation is discussed in section 3.6.1, followed by absorption in 3.6.2 and adsorption in 3.6.3. Section 3.6.4 discussed the specific applications and combinations of these technologies at mercury cell chlor-alkali plants.

3.6.1 Condensation^{2,3}

Condensation is a technique in which a pollutant in a gas stream is separated from the remaining gas components through saturation followed by a phase change. Condensation of the pollutant actually occurs at its dew point, when the partial pressure of the pollutant in the gas stream equals its vapor pressure at the operating temperature.

The change from gas to liquid can be achieved by lowering the temperature of the mixture and/or increasing its pressure. Temperature reduction is used most often, as gas compression tends to be more expensive. When a hot gas stream contacts a cooler medium, heat is transferred from the hot gas mixture to the cooler medium, thereby lowering the average kinetic energy of the gas (i.e., lowering of gas temperature). Hence, gas molecules are slowed and the distance between them reduced such that van der Waals forces between molecules cause the formation of liquid.

Condensation devices, or condensers, may be of two types: (1) direct contact, in which the cooling medium and gas stream/condensate are combined, and (2) indirect contact, in which the cooling medium and gas stream (including condensate) are separated by some sort of surface (hence, the synonymous designation of a surface condenser).

The pollutant removal efficiency of a condenser with fixed coolant flow rate and temperature depends on the following parameters: (1) volumetric flow rate of gas stream, (2) inlet gas stream temperature, (3) pollutant concentration in gas stream, (4) absolute gas stream pressure, (5) gas stream moisture content, and (6) pollutant properties, including heat of condensation, heat capacity, and vapor pressure.

3.6.2 Absorption^{4,5}

Absorption is a technique in which a pollutant in a gas stream (the solute) is separated from the remaining gas components through diffusion and dissolution into a non-volatile liquid solution (the solvent). Mass transfer occurs due to the difference in the concentration in the gas (high) and the concentration in the liquid (low, below the equilibrium concentration). This physical absorption may be followed by chemical reaction between the absorbed pollutant and solvent, which enhances the rate of absorption. The rate of absorption is, however, typically limited by the diffusion rate.

Absorption devices, which are also called absorbers or scrubbers, are most commonly packed towers that contain packing materials providing a large surface area to maximize gas-liquid contact. The gas stream to be treated is introduced near the bottom of the tower and contacts a liquid scrubbing solution flowing countercurrently from the top of the column. Aqueous liquids are the most common solvents for inorganic pollutants. Mist eliminators are passive devices generally found at the tops of packed tower scrubbers. Mist eliminators provide surface area on which residual droplets or mists in the exiting gas stream may coalesce and fall back into the column.

For an absorber, pollutant removal efficiency depends on operational and design parameters such as: (1) pollutant concentrations in inlet gas and solvent, (2) pollutant

diffusivity in the gas and in the solvent and equilibrium solubility in the solvent (which are temperature dependent), (3) gas and solvent flow rates, (4) density and viscosity of the gas and the solvent (which are temperature dependent), and (5) operating pressure, (7) properties of packing elements (i.e., surface to volume ratio), (8) height of packing (based on the operating conditions and the equilibrium relationship between pollutant and solvent), and (9) dimensions of the absorber column.

3.6.3 Adsorption^{6,7}

Adsorption is a technique in which a pollutant in a gas stream (the adsorbate) is separated from the remaining gas components through adhesion at the surface of solid particles (adsorbent). Unbalanced forces at the adsorbent surface that are stronger than intermolecular forces between the pollutant gas molecules cause the retention (van der Waals attraction) of the pollutant on the solid surface. This physical adsorption may be followed by chemisorption, or chemical reaction between the pollutant and solid. Whereas pollutants physically adsorbed may be desorbed to regenerate the adsorbent, chemisorption is generally not reversible.

Many adsorbents are amorphous in the sense that they have a non-uniform internal structure. The most common amorphous adsorbent is activated carbon, typically obtained by heating coal or coconut/nut shells anaerobically to obtain particle surface

activity. Activated carbons may be impregnated with elements to promote chemical adsorption properties. Adsorbents with a crystalline internal structure are generally termed as molecular sieves, which are useful for adsorption of particular species. In all cases, the adsorbent is chosen for its large surface area relative to its mass.

Adsorbers, or adsorption devices, are most commonly vessels with a stationary (fixed) carbon bed. The pollutant removal efficiency of an adsorber is a function of the gas stream temperature and volumetric flow rate, inlet pollutant concentration in the gas stream, and the condition of the carbon bed. Since a key factor determining collection efficiency is the length of time the gas is in contact with the adsorbent, carbon bed depth and sorbent particle size are important design considerations. A significant operational consideration is the frequency at which the adsorbent is replaced in a non-regenerable adsorber, since the adsorption capacity decreases over time as adsorbent particle surfaces are saturated and breakthrough is approached.

3.6.4 Vent Control Systems

The technologies discussed in the previous sections are often combined into a mercury control "system" for a particular vent. Tables 3-2, 3-3, and 3-4 show by-product hydrogen stream, end-box ventilation system, and mercury thermal recovery

TABLE 3-2. BY-PRODUCT HYDROGEN CONTROL SYSTEMS AT
MERCURY CELL CHLOR-ALKALI PLANTS

| Plant Owner/ Location | By-Product Hydrogen Stream Control System | | | |
|------------------------------------|---|---|--|---|
| | Temperature at final cooling outlet (F) | Demister used? | Finishing device | Finishing device |
| ASHTA Ashtabula, OH | <70 | Yes - one | | |
| HoltraChem Orrington, ME | 68 | Yes - two, one between the two coolers and one after second cooler | Molecular Sieve Adsorber | |
| Occidental Muscle Shoals, AL | 46 | No | Carbon Adsorber (carbon impregnated with iodine and potassium iodide) | |
| Occidental Delaware City, DE | 55 | No | Series carbon adsorbers (carbon impregnated with iodine and potassium iodide) ^a | |
| Occidental Deer Park, TX | 75 | No | Two series carbon adsorbers (sulfur impregnated carbon) | |
| Olin Augusta, GA | 46 | Yes - one | Molecular sieve adsorber | Carbon adsorber (carbon impregnated with potassium iodide) |
| Olin Charleston, TN | 50 | Yes - one | Molecular sieve adsorber | |
| Pioneer St. Gabriel, LA | 79 | No | Molecular sieve adsorber | Carbon adsorber (sulfur impregnated) |
| PFG Lake Charles, LA | <58 | Yes - two | Molecular sieve adsorber | Carbon adsorber (sulfur impregnated) |
| PFG Natrium, WV | <70 | No | Packed tower scrubber (depleted brine) | Two parallel carbon adsorbers |
| Vulcan Port Edwards, WI | n/a (cooling not used) | No | Packed tower scrubber (chlorinated brine) | |
| Westlake Calvert City, KY | 90 | Yes - one | Carbon adsorber (sulfur impregnated) | |

^a Due to the presence of two mercury cell circuits, there are two hydrogen control systems. Circuit 1 is operated with two identical series adsorbers, while circuit 2 is operated with three series adsorbers.

TABLE 3-3. END-BOX VENTILATION CONTROL SYSTEMS AT
MERCURY CELL CHLOR-ALKALI PLANTS

| Plant Owner/ Location | End-Box Ventilation Control System | | |
|------------------------------------|--|-------------------|--|
| | Temperature at outlet of last cooling device (F) | Demister used? | Finishing device |
| ASHTA Ashtabula, OH | <90 | No | |
| HoltraChem Orrington, ME | 95 | Yes - one | Molecular sieve adsorber |
| Occidental Delaware City, DE | 60 | Yes - one | |
| Olin Augusta, GA | 46 | No | |
| Olin Charleston, TN | 40 | Yes - one | |
| Pioneer St. Gabriel, LA | n/a (cooling not used, inlet temp is 89) | Yes - one | |
| PPG Lake Charles, LA | <63 | Yes - one | |
| PPG Natrium, WV | 67 | No | |
| Vulcan Port Edwards, WI | n/a (cooling not used, inlet temp is 110) | No | Packed tower scrubber (chlorinated brine) |
| Westlake Calvert City, KY | n/a (cooling not used, inlet temp is 90) | No | Packed tower scrubber (aqueous sodium hypochlorite) |

TABLE 3-4. THERMAL RECOVERY UNIT CONTROL SYSTEMS AT
MERCURY CELL CHLOR-ALKALI PLANTS

| Plant Owner/ Location | Thermal Recovery Unit Recovery/Control System | |
|---------------------------------|--|--|
| | Temperature at outlet of last cooling device (F) | Finishing device |
| Occidental Muscle Shoals, AL | 100 | Carbon adsorber (iodine impregnated) |
| Occidental Delaware City, DE | 69 | Carbon adsorber |
| Occidental Deer Park, TX | 80 | Two series carbon adsorbers (sulfur impregnated) |
| Olin Charleston, TN | 50 | Two parallel carbon adsorbers (sulfur impregnated) |
| PPG Lake Charles, LA | 57 | Two series carbon adsorbers (sulfur impregnated and activated carbon) |
| Vulcan Port Edwards, WI | 80 | Packed tower scrubber (chlorinated brine) |

unit control systems at mercury cell chlor-alkali plants. In these control systems, condensers are used as initial control devices, upstream of absorption and adsorption "finishing" control devices. Packed tower scrubbers are used in several vent control systems. Molecular sieve adsorbers are used in some by-product hydrogen and end-box ventilation control systems. Carbon adsorbers are used in many by-product hydrogen and thermal recovery unit vent control systems.

A primary factor influencing the overall performance of these control systems is the temperature to which initial coolers/chillers/condensers/heat exchangers cool the gas stream prior to entering finishing control devices. Because of the volatile nature of elemental mercury, temperature has a direct effect on the concentration of mercury vapor that can exist in a gas stream. For example, the concentration of mercury vapor that could exist in a gas stream at 50°F is 5 mg/m³, while the maximum (saturation) concentration at 85°F is 30 mg/m³, a six-fold increase. At 100°F, the concentration could potentially be over 50 mg/m³.⁸

In by-product hydrogen stream control systems, the hydrogen gas temperature reduction effected by initial cooling devices ranges from 18 percent to 68 percent, with a mean of 47 percent and a median of 53 percent. For initial cooling devices in end-box ventilation control systems, the temperature reduction of the ventilation air stream ranges from 40 percent to 64 percent, with

a mean and median of 52 percent. In thermal recovery/control systems, the temperature reduction of the retort off-gas by initial control devices (primarily but not limited to coolers/chillers/condensers/heat exchangers) ranges from 89 percent to 91 percent, with a mean and median of 90 percent, for oven-type units and from 96 percent to 98 percent, with a mean and median of 97 percent, for non-oven units.

In the packed tower scrubbers used for mercury control in this industry, chlorinated brine (also referred to as depleted brine), or aqueous sodium hypochlorite solution are used as the liquid scrubbing medium. In the former case, the source of the liquid scrubbing medium is spent brine from mercury cells, which is maintained in a narrow pH range so that chlorine^b and water molecules in the solution react to form hypochlorous acid and hydrogen chloride. These reaction products are vital to the absorption mechanism, as hypochlorous acid and the elemental mercury in the gas stream to be treated initially react, and hydrogen chloride reacts with the resulting intermediate species to form mercuric chloride, a form of mercury more amenable to dissolution. With this mechanism, the absorbed mercury may be recycled directly into the mercury cell process with the return of the scrubber effluent to the brine system and, subsequently, the mercury cells, causing dissociation of the mercuric chloride

^bChlorine would normally be removed from the spent brine as part of brine preparation, hence the term "chlorinated brine" used by one plant.

into mercury cations and chlorine anions followed by reduction of the mercury cations at the cell cathode. With the use of sodium hypochlorite scrubbing liquid, the solution is formed using two chlor-alkali products, namely chlorine and sodium hydroxide. The resultant hypochlorite anions in the solution are used to chemically absorb elemental mercury in the gas stream to be treated, as both mercurous chloride (a slightly soluble species) followed by mercuric chloride (a more soluble species). Table 3-5 presents characteristics of packed tower scrubbers used in mercury cell chlor-alkali vent control systems.

The molecular sieve adsorbers used in by-product hydrogen and end-box ventilation control systems are part of PuraSiv® systems originally developed and supplied by Union Carbide Corporation. PuraSiv® systems consist primarily of two adsorber beds, containing a proprietary molecular sieve media, that alternate operation such that while one is treating the gas stream, the other is either being regenerated or waiting to be placed on-line, depending on the lengths of the adsorption and regeneration cycles. Bed regeneration is accomplished by heat-stripping, specifically by diverting a portion of the treated stream at an elevated temperature through the spent bed in order to volatilize mercury held by the molecular sieve adsorbent. This is followed by bed cooling as well as recycling of the regeneration gas into the control system for treatment.

TABLE 3-5. CHARACTERISTICS OF THE PACKED TOWER SCRUBBERS USED IN MERCURY CELL
CHLOR-ALKALI VENT CONTROL SYSTEMS FOR MERCURY CONTROL

| Plant | Vent | Gas Inlet Flow Rate (scfm) | Gas Inlet Mercury Concentration (mg/m3) | Liquid Scrubbing Medium | Scrubbing Liquid Inlet Flow Rate (cfm) | Gas Pressure Drop (inches water) | Reported Efficiency (percent) |
|---------------------------|--------------------------------|----------------------------|---|---|--|----------------------------------|-------------------------------|
| Vulcan Port Edwards, WI | Hydrogen | 1,594 ^a | 17.9 | chlorinated brine, pH 2.4, 0.11 grams per liter free chlorine | CBI | CBI | 99.9 |
| PPG Natrrium, WV | Hydrogen | 1,402 | 14.5 ^b | depleted brine, pH 2.7 | 3.7 | 8 ^c | unknown |
| Westlake Calvert City, KY | End-box | 3,832 | 7.1 | aqueous sodium hypochlorite, pH <8.8 | 1.2 ^d | 1.5 | 97.5 |
| Vulcan Port Edwards, WI | End-box | 950 | unknown | chlorinated brine, pH <3.4, >0.03 grams per liter free chlorine | CBI | CBI | approximately 99 |
| Vulcan Port Edwards, WI | Non-oven type thermal recovery | 1,250 | 17.4 | chlorinated brine | CBI | CBI | 97.7 |

^a This value is the nameplate gas inlet flow rate that was provided, as the actual value was claimed as confidential business information.

^b This value was estimated as a maximum value based on the maximum temperature at the exit to the preceding contact cooler (70°F) and saturation conditions, as the quantity was reported as unknown.

^c This value is average of the reported design gas stream pressure drop range of 5 to 10 inches of water.

^d This value for the liquid scrubbing media injection rate was reported as unknown but estimated as equivalent to the reported liquid recirculation "draw-off" of 8 to 10 gallons per minute, under the assumption that, at steady-state, draw-off would equal incoming liquid.

^e This quantity was estimated as equivalent to the average stream flow rate, as the actual value was claimed as confidential business information.

Table 3-6 presents characteristics of molecular sieve adsorbers used in mercury cell chlor-alkali vent control systems.

Carbon adsorbers used in by-product hydrogen and thermal recovery unit control systems are fixed bed, non-regenerable units and contain carbon media impregnated with sulfur, with potassium iodide, or with both iodine and potassium iodide. Differences in mercury removal efficiency between these types of carbon adsorbents are not significant, provided that a sufficient ratio is maintained between mercury loading to the adsorber and the carbon adsorbent available for adsorption.⁹ Certain product specifications may preclude the use of a particular impregnated adsorbent, such as customer applications that cannot tolerate residual sulfur in by-product hydrogen with the use of sulfur-impregnated carbon adsorbent. Table 3-7 presents characteristics of carbon adsorbers used in mercury cell chlor-alkali vent control systems.

3.7 EMISSION CONTROL TECHNIQUES FOR FUGITIVE EMISSION SOURCES¹⁰

Techniques practiced by mercury cell chlor-alkali plants to limit fugitive mercury emissions can be classified as design (equipment) specifications, operational practices, and diagnostic practices.

Examples of design specifications observed include using vessels in liquid mercury service that have a cone shaped bottom with a drain valve or other design that readily facilitates mercury collection and using piping in liquid mercury service

TABLE 3-6. CHARACTERISTICS OF THE MOLECULAR SIEVE ADSORBERS USED IN MERCURY CELL CHLOR-
ALKALI VENT CONTROL SYSTEMS

| Plant | Vent | Gas Inlet Flow Rate (scfm) | Gas Inlet Mercury Concentration (mg/m ³) | Amount of Adsorbent (pounds) | Bed Adsorption Cycle Time (hours) | Bed Regeneration Cycle Conditions | Reported Efficiency (percent) |
|--------------------------|----------|----------------------------|--|------------------------------|-----------------------------------|---|-------------------------------|
| Pioneer St. Gabriel, LA | Hydrogen | 4,600 | 18.2 ^a | 18,000 | 36 to 48 | Spent bed heated by 675-750 scfm stream at 450°F-475°F for at least 4 hours; total regeneration cycle is also between 36 and 48 hours | unknown |
| PPG Lake Charles, LA | Hydrogen | 5,004 | 6 ^b | 20,000 | 24 ^c | Spent bed heated by 700 cfm hydrogen stream at 600°F for 9 hours, then cooled for 15 hours | 97.7 |
| Olin Charleston, TN | Hydrogen | 5,064 | 5.8 | 49,000 | 24 | Spent bed heated by a stream at 450°F for 8 to 9 hours, then cooled for 15 to 16 hours | 62.3 to 95 |
| Olin Augusta, GA | Hydrogen | 2,257 | 4.5 ^d | 40,000 | 24 ^e | Spent bed heated to about 520°F for 8 hours, then cooled for 16 hours | unknown |
| HoltraChem Orrington, ME | Hydrogen | 1,336 | 8.5 | 3,000 | 24 | Spent bed heated by 500 cfm stream at about 390°F for about 16 hours, then cooled for 8 hours | greater than 90 |

TABLE 3-6. CHARACTERISTICS OF THE MOLECULAR SIEVE ADSORBERS USED IN MERCURY CELL CHLOR-
ALKALI VENT CONTROL SYSTEMS (CONTINUED)

| Plant | Vent | Gas Inlet Flow Rate (scfm) | Gas Inlet Mercury Concentration (mg/m ³) | Amount of Adsorbent (pounds) | Bed Adsorption Cycle Time (hours) | Bed Regeneration Cycle Conditions | Reported Efficiency (percent) |
|--------------------------------|---------|----------------------------|--|------------------------------|-----------------------------------|--|-------------------------------|
| HoltraChem Orrington, ME | End-box | 517 | 10 | 2,000 | 96 | Spent bed heated by 55 cfm steam at about 245°F for 36 hours, then cooled for 12 hours | greater than 90 |

- a This quantity was reported as unknown but was calculated based on the temperature (75°F) at the exit to a condenser (the previous device) and the assumption of saturation conditions.
- b This quantity was reported as unknown but was estimated (as a maximum value) as equivalent to the reported mercury concentration at the exit to the first demister preceding the molecular sieve adsorber.
- c This quantity was not reported but was estimated as equivalent to the length of the regeneration cycle.
- d The inlet mercury concentration was not reported but is calculated based on the temperature (46°F) at the exit to a condenser and saturation conditions. The value is a maximum because a demister follows the condenser and precedes the molecular sieve adsorber.
- e This quantity was not reported but was estimated as equivalent to the length of the regeneration cycle.

TABLE 3-7. CHARACTERISTICS OF THE CARBON ADSORBERS USED IN MERCURY CELL CHLOR-ALKALI VENT CONTROL SYSTEMS

| Plant Owner/ Location | Vent | Gas Inlet Mercury Concentration (milligrams mercury per cubic meter of hydrogen) | Gas Inlet Flow Rate (standard cubic feet of hydrogen per minute) | Amount of Adsorbent (pounds) | Carbon Media Replacement Frequency (years) | Reported Efficiency (percent) |
|------------------------------|--------------------------------|--|--|------------------------------|--|-------------------------------|
| Occidental Muscle Shoals, AL | Hydrogen | 2.4 | 3,075 | 10,000 | 2.5 | 99. |
| Occidental Delaware City, DE | Hydrogen Circuit 1 | 3.4 | 1,480 | 1,800 ^a | 0.5 | over 99 |
| | Hydrogen Circuit 2 | | 1,332 | 1,150 ^b | | |
| Occidental Deer Park, TX | Hydrogen | 10 | 2,010 | 4,500 ^c | 2 | 95 |
| Olin Augusta, GA | Hydrogen | 0.44 | 2,257 | 4,000 | 1 | not reported |
| Pioneer St. Gabriel, LA | Hydrogen | 0.25 | 3,660 | 800 | 2.5 | unknown |
| PPG Lake Charles, LA | Hydrogen | 1.5 | 5,004 | 10,350 | 1 | unknown |
| PPG Natrium, WV | Hydrogen | 3.5 ^d | 1,402 ^d | 47,100 ^e | 12 | not reported |
| Westlake Calvert City, KY | Hydrogen | 18.5 | 2,813 | 10,500 | 3 | 99.9 |
| Occidental Muscle Shoals, AL | Oven type thermal recovery | 28.3 ^f | 260 | 1,260 | 2.5 | unknown |
| Occidental Delaware City, DE | Oven type thermal recovery | 13.99 | 42 | 700 | 1 | over 99 |
| Occidental Deer Park, TX | Oven type thermal recovery | 27 | 100 | 200 ^h | 0.25 | over 99 (design) |
| Olin Charleston, TN | Non-oven type thermal recovery | 5.6 ⁱ | 1,075 | 2,000 ^j | 2.5 | not reported |
| PPG Lake Charles, LA | Non-oven type thermal recovery | 7.8 ^k | 2,000 ^l | unknown | | |

TABLE 3-7. CHARACTERISTICS OF THE CARBON ADSORBERS USED IN MERCURY CELL CHLOR-ALKALI VENT CONTROL SYSTEMS (CONTINUED)

- a This is the amount of carbon in a single carbon adsorber among two beds in series for Circuit 1.
- b This is the amount of carbon in a single carbon adsorber among three beds in series for Circuit 2.
- c This is the amount of carbon in a single carbon adsorber among two beds in series.
- d These values were estimated, as the quantities were reported to be unknown. The mercury inlet concentration was back-calculated from the 10/87 vent test result of 0.35 milligrams per cubic meter, assuming a conservative 90 percent reduction across the existing carbon adsorber. It was not possible to derive this concentration based on saturation conditions, as temperatures at various points in the control system were also reported as unknown. The inlet stream volumetric flow rate was reported as unknown but was estimated as equivalent to the inlet to the first finishing device (i.e., after the last cooling device).
- e This is the total amount of carbon in two parallel carbon adsorbers each containing 23,500 pounds of activated carbon.
- f This quantity was reported as unknown but was calculated based on the temperature at the outlet of the last cooling device (85 degrees Fahrenheit) and the assumption of saturation conditions.
- g This quantity was reported as unknown but was calculated based on the temperature at the outlet of the last cooling device (69 degrees Fahrenheit) and the assumption of saturation conditions.
- h This is the amount of carbon in a single carbon adsorber among two beds in series.
- i This quantity was reported as unknown but was calculated based on the temperature at the outlet of the last cooling device (50 degrees Fahrenheit) and the assumption of saturation conditions.
- j This is the total amount of carbon in two parallel carbon adsorbers each containing 1,000 pounds of sulfur-impregnated carbon.
- k This quantity was reported as unknown but was calculated based on the temperature at the outlet of the last cooling device (57 degrees Fahrenheit) and the assumption of saturation conditions.
- l This is the amount of carbon in a single carbon adsorber among two beds in series.

that has smooth interiors. Examples of operational practices include keeping decomposers closed and sealed (except for maintenance) and maintaining decomposer covers in good condition, allowing decomposers to cool before opening, either removing all visible mercury from an internal part from a decomposer or containing the part prior to transport to another work area, and washing down the area around the decomposer with water on a routine basis and cleaning up mercury spilled after maintenance.

Many of the diagnostic practices observed by mercury cell chlor-alkali plants are routine inspections, including regular and directed inspections for equipment problems, for leak detection, and for liquid mercury accumulations and spills. Examples of visual inspections include checking for amalgam seal pot covers not securely in place, for caustic leaks, and for accumulated mercury beads beneath decomposers. Inspecting for hydrogen/mercury vapor leaks from decomposers may involve visual or auditory methods or mercury vapor analyzer, combustible gas meter, or other instrumentation. Following the inspections, necessary operational and maintenance activities would be performed (i.e., cell shutdown, containment of caustic leaks, and wash down of area and clean up of exposed liquid mercury).

The routine measurement of mercury vapor levels in the cell room environment is another diagnostic practice observed by mercury cell chlor-alkali plants. Such measurements are typically conducted using mercury vapor analyzers or a wet

chemical assembly (permanganate impingers) at fixed locations, in order to establish normative levels. Readings higher than a certain level trigger follow-up activities such as more directed diagnostics to pinpoint mercury vapor leaks and washdowns.

3.8 REFERENCES

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4.0 REGULATORY ALTERNATIVES

4.1 INTRODUCTION

This chapter presents the regulatory alternatives considered for national emission standards for hazardous air pollutants (NESHAP) for limiting mercury emissions from mercury cell chlor-alkali plants. Section 4.2 provides background on the statutory authority of these NESHAP, and Section 4.3 presents the regulatory alternatives considered. This chapter does not include details on the development of these alternatives. These details, along with the rationale behind the selection of the regulatory alternatives for proposal, are provided in Chapter 7.

4.2 STATUTORY AUTHORITY

Section 112(d) of the Clean Air Act (CAA) requires that emission of hazardous air pollutants (HAP) from listed stationary sources be regulated by establishing national emission standards. The statute requires that standards established reflect the maximum degree of reduction in HAP emissions, taking into consideration the cost of achieving such emissions reductions, any non-air quality health and environmental impacts, and energy impacts. These standards are referred to as the maximum achievable control technology, or MACT, standards.

Section 112(d)(3) of the CAA requires that the standards established be no less stringent than a defined minimal level of control. This minimal level is referred to as the "MACT floor."

For new sources, the minimal level of control

. . . shall not be less stringent than the emission control that is achieved in practice by the best controlled similar source, as determined by the Administrator.

For existing sources in the same category or subcategory, the minimal level of control is specified as

. . . the average emission limitation achieved by the best performing 12 percent of the existing sources (for which the Administrator has emissions information) . . . in the category or subcategory for categories or subcategories with 30 or more sources, or . . . the average emission limitation achieved by the best performing 5 sources (for which the Administrator has or could reasonably obtain emissions information) in the category or subcategory for categories or subcategories with fewer than 30 sources.

"Average" is defined to mean a measure of central tendency, whether it be the arithmetic mean, median, or mode, or some other measure based on the best measure decided on for determining the central tendency of a data set (59 FR 29196).

Once the minimal (floor) level of control is determined, Section 112(d)(2) requires that the maximum degree of reduction in emissions of HAP be determined, taking into consideration options that would achieve greater emission reductions.

4.3 REGULATORY ALTERNATIVES

The mercury cell chlor-alkali plants currently in the U.S. each operate a mercury cell chlor-alkali process in which mercury cells (and ancillary operations) are used to manufacture chlorine

and caustic as co-products and hydrogen as a by-product. Six plants have mercury thermal recovery units in which mercury-containing wastes are heated to recover liquid mercury. For the purpose of developing regulatory alternatives, mercury cell chlor-alkali plants were separated into those operations associated with the production of chlorine and caustic and those associated with mercury recovery.

As discussed in Chapter 2, there may be up to four types of mercury emission sources at a mercury cell chlor-alkali plant:

(1) hydrogen by-product streams, (2) end-box ventilation system vents, (3) mercury thermal recovery unit vents, and (4) fugitive emission sources. The hydrogen by-product streams and end-box ventilation system vents are unique to chlorine production operations, and the mercury thermal recovery unit vents are unique to recovery operations. Fugitive emissions occur from both production and recovery operations.

Regulatory alternatives were developed for the emission source types cited above. Specifically, regulatory alternatives were developed for mercury emissions from: (1) hydrogen by-product streams and end-box ventilation system vents at plants with end-box ventilation systems, (2) mercury emissions from hydrogen by-product streams at plants without end-box ventilation systems (that is, those plants with "closed" end-boxes), (3) oven type mercury thermal recovery unit vents, (4) non-oven type mercury thermal recovery unit vents, and (5) fugitive emission

sources. Section 7.5.1 provides an explanation of the development of separate regulatory alternatives for hydrogen by-product streams and end-box ventilation system vents, and Section 7.5.3 provides an explanation of the development of separate alternatives for mercury thermal recovery unit vents.

Table 4-1 presents a summary of the regulatory alternatives for mercury emission sources at mercury cell chlor-alkali plants. For existing sources, Regulatory Alternative I represents the minimum level of control, or the MACT floor. Regulatory Alternative II represents a level of control identified above this minimum floor level. For new sources, the single alternative represents the only alternative identified, which in each case is at least equivalent to the "best controlled similar source."

TABLE 4-1. REGULATORY ALTERNATIVES FOR MERCURY EMISSION SOURCES
AT MERCURY CELL CHLOR-ALKALI PLANTS

| Emission Source Group | Regulatory Alternative I (MACT Floor) | Regulatory Alternative II |
|---|---|--|
| Existing Sources | | |
| Fugitive Emission Sources | Part 61 Housekeeping Procedures | Enhanced Work Practices |
| Hydrogen By-Product Streams/End-Box Ventilation System Vents ^a | 0.14 gram mercury emitted per Megagram chlorine produced | 0.067 gram mercury emitted per Megagram chlorine produced |
| Hydrogen By-Product Streams ^b | 0.10 gram mercury emitted per Megagram chlorine produced | 0.033 gram mercury emitted per Megagram chlorine produced |
| Oven Type Mercury Thermal Recovery Unit Vents | c | 23 milligrams mercury emitted per dry standard cubic meter of exhaust |
| Non-Oven Type Mercury Thermal Recovery Unit Vents | 3 milligrams mercury emitted per dry standard cubic meter of exhaust | 4 milligrams mercury emitted per dry standard cubic meter of exhaust |
| New Sources | | |
| Hydrogen By-Product Streams, End-Box Ventilation System Vents, and Fugitive Emission Sources at Operations Producing Chlorine | Prohibition of mercury emissions | |
| Oven Type Mercury Thermal Recovery Unit Vents | 23 milligrams mercury emitted per dry standard cubic meter of exhaust | |
| Non-Oven Type Mercury Thermal Recovery Unit Vents | 4 milligrams mercury emitted per dry standard cubic meter of exhaust | |
| Fugitive Emission Sources at Mercury Recovery Operations | Enhanced Work Practices | |

^a At plants with end-box ventilation systems.

^b At plants with no end-box ventilation systems (i.e., with closed end boxes)

^c Data were only available for the plant with the best performing control system on the oven type mercury thermal recovery unit vents.

5.0 ENVIRONMENTAL AND ENERGY IMPACTS

5.1 INTRODUCTION

This chapter presents the environmental and energy impacts of the existing source regulatory alternatives described in Chapter 4 for the mercury cell chlor-alkali industry.

Environmental and energy impacts were estimated on a plant-by-plant basis and then summed for the estimated nationwide annual impacts. Environmental impacts include primary impacts, or reductions of mercury air emissions, as well as secondary impacts, or alterations in the nature or amount of air pollution (other than mercury), water pollution, and solid waste. Energy impacts pertain to changes in electricity consumption.

As discussed in Chapter 4, Section 4.1, it is assumed that no new mercury cell chlor-alkali production facilities will be built in the United States (U.S.). In addition, it is anticipated that no new mercury recovery facilities will be built at mercury cell chlor-alkali plants in the U.S. in the near future. Therefore, no new or reconstructed source impacts were estimated.

Baseline mercury air emissions are discussed in Section 5.2. The overall methodology for estimating impacts of implementing the existing source regulatory alternatives is summarized in

Section 5.3. Primary environmental impacts, energy impacts, and secondary environmental impacts are discussed in Sections 5.4, 5.5, and 5.6, respectively. Details on impacts calculations may be found in a separate technical memorandum.¹

5.2 BASELINE MERCURY EMISSIONS

As discussed in Chapter 3, Section 3.1, the part 61 Mercury NESHAP (40 CFR part 61, subpart E, §61.50 et. seq.)^a limits mercury emissions from a mercury cell chlor-alkali plant to 2,300 grams per day (grams/day). If a suite of eighteen approved design, maintenance, and housekeeping practices² are followed, the rule allows the assumption of a 1,300 grams/day emission rate from the cell room ventilation system. This effectively creates a mercury emission limit of 1,000 grams/day for the point sources (vents) of mercury at a plant, namely by-product hydrogen streams end-box ventilation system vents, and mercury thermal recovery unit vents. Therefore, the nationwide level of annual baseline mercury emissions allowed by the part 61 Mercury NESHAP is 10,074 kilograms per year (kg/yr) (22,209 pounds per year, lb/yr). This was simply calculated by multiplying 2,300 grams per day by 365 days per year and by 12 plants. Of the 10,074 kg/yr total, fugitives account for 5,694 kg/yr (12,553 lb/yr) and point sources collectively make up 4,380 kg/yr (9,656 lb/yr).

^aThis regulatory program was originally set forth at 38 FR 8826, April 6, 1973; and amended at: 40 FR 48302, October 14, 1975; 47 FR 24704, June 8, 1982; 49 FR 35770, September 12, 1984; 50 FR 46294, November 7, 1985; 52 FR 8726, March 19, 1987; and, 53 FR 36972, September 23, 1988.

For the point sources of mercury, mercury cell chlor-alkali plants reported annual mercury vent emissions that were lower than the level allowed in the part 61 Mercury NESHAP. The nationwide reported mercury emissions for points sources were estimated to be about 933 kg/yr (2,057 lb/yr). Summing this value with 5,694 kg/yr (12,553 lb/yr) of fugitive mercury emissions, the nationwide annual actuals baseline emissions total about 6,627 kg/yr (14,610 lb/yr).

5.3 OVERALL IMPACTS ESTIMATION METHODOLOGY

Table 5-1 shows the existing source regulatory alternatives. Regulatory Alternative II is more stringent than Regulatory Alternative I for by-product hydrogen streams, end-box ventilation system vents, non-oven type mercury thermal recovery unit vents, and fugitive emission sources. As discussed in Chapter 4, Regulatory Alternative I represents the MACT floor level of control for these emission sources, while Regulatory Alternative II represents a beyond-the-floor level.

The primary environmental impacts are based on the differences in the baseline emissions and the mercury emissions that would occur upon implementation of the regulatory alternative. For estimating secondary environmental and energy impacts for point sources, the control system enhancements needed to meet the emission limits associated with the regulatory alternatives were assumed, considering actual existing vent

TABLE 5-1. REGULATORY ALTERNATIVES FOR EXISTING MERCURY EMISSION SOURCES AT MERCURY CELL CHLOR-ALKALI PLANTS

| Emission Source Group | Regulatory Alternative I (MACT Floor) | Regulatory Alternative II |
|---|--|---|
| Fugitive Emission Sources | Part 61 Housekeeping Procedures | Enhanced Work Practices |
| Hydrogen By-Product Streams/End-Box Ventilation System Vents ^a | 0.14 gram mercury emitted per Megagram chlorine produced | 0.067 gram mercury emitted per Megagram chlorine produced |
| Hydrogen By-Product Streams ^b | 0.10 gram mercury emitted per Megagram chlorine produced | 0.033 gram mercury emitted per Megagram chlorine produced |
| Oven Type Mercury Thermal Recovery Unit Vents | ^c | 23 milligrams mercury emitted per dry standard cubic meter of exhaust |
| Non-Oven Type Mercury Thermal Recovery Unit Vents | 5 milligrams mercury emitted per dry standard cubic meter of exhaust | 4 milligrams mercury emitted per dry standard cubic meter of exhaust |

^a At plants with end-box ventilation systems.

^b At plants with no end-box ventilation systems (i.e., with closed end boxes)

^c Data were only available for the plant with the best performing control system on the oven type mercury thermal recovery unit vents.

controls. Tables 5-2, 5-3, and 5-4 present the enhancement assumed for each vent at each mercury cell chlor-alkali plant to meet the regulatory alternatives. Background information on these assumptions may be found in a separate technical memorandum.³

5.4 PRIMARY ENVIRONMENTAL IMPACTS

The implementation of Regulatory Alternative II for fugitive emission sources and the implementation of Regulatory Alternative I or Regulatory Alternative II for point sources would result in lower mercury emissions released to the air. These mercury emissions reductions are discussed below for fugitive emission sources, by-product hydrogen streams and end-box ventilation system vents, and mercury thermal recovery unit vents.

5.4.1 Fugitive Emissions

For fugitive emission sources, Regulatory Alternative I represents a level of control that is currently required at every plant. Therefore, there would be no associated additional reduction in fugitive mercury emissions.

Regulatory Alternative II represents a compilation of the most stringent work practices applied in the industry. Hence, every plant will likely need to enhance its existing housekeeping program in some manner. While a decrease in fugitive mercury emissions is expected, it is not possible to quantify the reduction. Therefore, no reduction in mercury fugitive emissions is attributed to Regulatory Alternative II.

TABLE 5-2. ASSUMED CONTROL SYSTEM ENHANCEMENTS TO MEET THE REGULATORY ALTERNATIVES FOR
FOR BY-PRODUCT HYDROGEN STREAMS AND END-BOX VENTILATION SYSTEMS AT PLANTS WITH END-BOX
VENTILATION SYSTEMS

| Plant Owner/ Location | Assumed Enhancement to Meet Regulatory Alternative I | | Assumed Enhancement to Meet Regulatory Alternative II | |
|---------------------------------|--|------------------------------------|---|------------------------------------|
| | By-Product Hydrogen Stream | End-Box Ventilation System Vent | By-Product Hydrogen Stream | End-Box Ventilation System Vent |
| ASHTA Ashtabula, OH | new carbon adsorber | new packed scrubber | new carbon adsorber ^a | new packed scrubber ^a |
| HoltraChem Orrington, ME | none | none | none | none |
| Occidental Delaware City, DE | none | none | none | new packed scrubber |
| Olin August, GA | new carbon adsorber | new packed scrubber | new carbon adsorber ^a | new packed scrubber ^a |
| Olin Charleston, TN | new carbon adsorber | new packed scrubber | new carbon adsorber ^a | new packed scrubber ^a |
| Pioneer St. Gabriel, LA | none | none | none | new packed scrubber |
| PPG Lake Charles, LA | none | new packed scrubber | none | new packed scrubber ^a |
| PPG Natrium, WV | change first to impregnated carbon in existing adsorber, followed by more frequent replacement | new packed scrubber | change first to impregnated carbon in existing adsorber, followed by more frequent replacement ^b | new packed scrubber ^a |
| Vulcan Port Edward, WI | new carbon adsorber | none | new carbon adsorber ^a | none |
| Westlake Calvert City, KY | replace existing carbon adsorber with new, larger adsorber | none | replace existing carbon adsorber with new, larger adsorber ^a | none |

^aRefers to the same type of new control device assumed to meet Regulatory Alternative I, except that carbon adsorbers would have higher carbon charge and more efficient packed scrubbers would be used.

^bRefers to more frequent carbon replacement than that assumed to meet Regulatory Alternative I.

TABLE 5-3. ASSUMED CONTROL SYSTEM ENHANCEMENTS TO MEET THE REGULATORY ALTERNATIVES FOR
 BY-PRODUCT HYDROGEN STREAMS AT PLANTS WITHOUT END-BOX VENTILATION
 SYSTEMS FOR HYDROGEN BY-PRODUCT STREAMS AND END-BOX VENTILATION SYSTEMS

| Plant Owner/ Location | Assumed Enhancement to Meet Regulatory Alternative I | | Assumed Enhancement to Meet Regulatory Alternative II | |
|---------------------------------|--|------------------------------------|--|------------------------------------|
| | By-Product Hydrogen Stream | End-Box Ventilation System Vent | By-Product Hydrogen Stream | End-Box Ventilation System Vent |
| Occidental Muscle Shoals, AL | none | not applicable | none | not applicable |
| Occidental Deer Park, TX | more frequent replacement of carbon in existing adsorber | not applicable | replace existing carbon adsorber with new, larger adsorber | not applicable |

TABLE 5-4. ASSUMED CONTROL SYSTEM ENHANCEMENTS TO MEET THE
REGULATORY ALTERNATIVES FOR MERCURY THERMAL RECOVERY UNIT VENTS
AT PLANTS WITH SUCH UNITS

| Plant Owner | Plant Location | Assumed Enhancement to Meet Regulatory Alternative I | Assumed Enhancement to Meet Regulatory Alternative II |
|-------------|-------------------|--|---|
| Occidental | Muscle Shoals, AL | replace existing carbon adsorber with new, larger adsorber | |
| Occidental | Delaware City, DE | none | |
| Occidental | Deer Park, TX | replace existing carbon adsorber with new, larger adsorber. | |
| Olin | Charleston, TN | more frequent replacement of carbon in existing adsorber | more frequent replacement of carbon in existing adsorber ^a |
| PPG | Lake Charles, LA | none | none |
| Vulcan | Port Edwards, WI | none | none |

^aRefers to more frequent carbon replacement than that assumed to meet
Regulatory Alternative I.

5.4.2 By-Product Hydrogen Streams and End-Box Ventilation System Vents

The Regulatory Alternative I includes an emission limit of 0.14 gram mercury emitted per Megagram chlorine produced (g Hg/Mg Cl₂) for plants with end-box ventilation systems and an emission limit of 0.10 g Hg/Mg Cl₂ for plants without end-box ventilation systems. For each plant, the emissions level at this MACT floor level was calculated by multiplying the annual chlorine production (in Mg) by either 0.14 or 0.10 g Hg/Mg Cl₂ and converting to kg. The same calculation was performed for Regulatory Alternative II (using either 0.067 g Hg/Mg Cl₂ for plants with end-box ventilation systems or 0.033 g Hg/Mg Cl₂ for plants without end-box ventilation systems). Table 5-5 presents combined by-product hydrogen stream and end-box ventilation system vent mercury emissions at Regulatory Alternatives I and II and the estimated mercury emission reductions from combined actual baseline emissions at each of the levels.

5.4.3 Mercury Thermal Recovery Unit Vents

Regulatory Alternative I for mercury thermal recovery unit vents includes mercury emission limits of 23 milligrams per dry standard cubic meter (mg/dscm) for oven type vents and 5 mg/dscm for non-oven type vents. For each plant, mercury emissions at the regulatory alternative level were calculated by multiplying either 23 or 5 mg/dscm by the reported vent exhaust flow rate and

TABLE 5-5.. ESTIMATED COMBINED MERCURY EMISSIONS FROM BY-PRODUCT HYDROGEN STREAMS AND END-BOX VENTILATION SYSTEM VENTS AT REGULATORY ALTERNATIVE LEVELS

| Plant Owner/Location | Chlorine Production (Megagrams per yr) | Combined Actual Baseline Emissions ^a (kilograms per year) | At Regulatory Alternative I (kilograms per year) | | At Regulatory Alternative II (kilograms per year) | |
|--------------------------------|--|--|--|--|---|--|
| | | | Annual Emissions ^b | Emission Reductions from Actual Baseline | Annual Emissions ^c | Emission Reductions from Actual Baseline |
| ASHTA, Ashtabula, OH | 43,110 | 147.4 | 6.2 | 141.2 | 2.9 | 144.5 |
| HoltraChem Orrington, ME | 65,860 | 4.4 | 4.4 | 0.0 | 4.4 | 0.0 |
| Occidental Muscle Shoals, AL | 127,322 | 4.2 | 4.2 | 0.0 | 4.2 | 0.0 |
| Occidental Delaware City, DE | 132,450 | 10.1 | 10.1 | 0.0 | 8.8 | 1.3 |
| Occidental Deer Park, TX | 88,146 | 15.4 | 9.2 | 6.2 | 2.9 | 12.5 |
| Olin August, GA | 108,210 | 122.9 | 15.6 | 107.3 | 7.2 | 115.7 |
| Olin Charleston, TN | 238,592 | 204.1 | 34.3 | 169.8 | 15.9 | 188.2 |
| Pioneer St. Gabriel, LA | 173,274 | 19.1 | 19.1 | 0.0 | 11.6 | 7.5 |
| PPG Lake Charles, LA | 234,056 | 74.5 | 33.7 | 40.8 | 15.6 | 58.9 |
| PPG Natrium, WV | 66,225 | 48.2 | 9.5 | 38.7 | 4.4 | 43.8 |
| Vulcan Port Edward, WI | 71,092 | 10.5 | 10.2 | 0.3 | 4.7 | 5.8 |
| Westlake Calvert City, KY | 111,041 | 73.4 | 16.0 | 57.4 | 7.4 | 66.0 |
| Nationwide Totals ^d | | 734.3 | 172.4 | 561.9 | 90.1 | 644.2 |

^aThese baseline emissions are based on annual vent mercury emission releases reported by the plants. Part 61 NESHAP, of potential-to-emit, baseline emissions are not shown, since only a value of 365 kg/yr for all point sources at a plant is available (i.e., NESHAP baseline emissions specifically for by-product hydrogen streams and end-box ventilation system vents cannot be determined).

^bEmissions are calculated by multiplying the emission limit (either 0.14 or 0.10 g Hg/Mg Cl₂) by the annual chlorine production and dividing by 1,000.

^cEmissions are calculated by multiplying the emission limit (either 0.067 or 0.033 g Hg/Mg Cl₂) by the annual chlorine production and dividing by 1,000.

^dTotals may not always appear to be the sum of values shown due to rounding.

the annual operating time and employing appropriate unit conversions. The same calculation was performed for Regulatory Alternative II, using either 23 mg/dscm for oven type vents or 4 mg/dscm for non-oven type plants. Table 5-6 presents the mercury thermal recovery unit vent emissions at the regulatory alternative levels and the estimated mercury emission reduction from actual baseline emissions at each of the levels.

5.4.4 All Emission Sources

Table 5-7 summarizes the estimated primary environmental impacts of the regulatory alternatives for point sources as the total reductions in mercury air emissions in units of kilograms per year. The estimated nationwide reduction in mercury emissions with Regulatory Alternative I for point sources is around 4,045 kg/yr (a 92.3 percent reduction) from the vent part 61 NESHAP (or potential-to-emit) baseline level and around 598 kg/yr (a 64 percent reduction) from the actual baseline level. The estimated absolute reduction in mercury emissions also represents total reductions for all sources (fugitives and point sources) with Regulatory Alternative I, since, by definition there is no emission reduction associated with the MACT floor level of control for fugitive emission sources (overall estimated percentage reduction values are 40 percent from the part 61 NESHAP baseline level and 9 percent from the actual baseline level). Thus, total mercury emissions

TABLE 5-6. ESTIMATED MERCURY EMISSIONS FROM MERCURY THERMAL RECOVERY UNIT VENTS AT THE REGULATORY ALTERNATIVE LEVELS

| Plant Owner/ Location | Reported Vent Exhaust Flow Rate (dry standard cubic meters per minute) | Annual Operating Hours (hours per year) | Actual Baseline Emissions ^a (kilograms per year) | At Regulatory Alternative At Regulatory Alternative | | |
|---------------------------------|---|---|---|---|----------------------------------|---|
| | | | | Level I (kilograms per year) | Level II (kilograms per year) | Emission Reductions from Actual Baseline |
| Occidental Muscle Shoals, AL | 7.4 | 7,000 | 90.3 | 71.1 | 19.2 | 71.1 |
| Occidental Delaware City, DE | 1.1 | 6,570 | 10.0 | 10.0 | 0 | 10.0 |
| Occidental Deer Park, TX | 2.8 | 6,584 | 39.9 | 25.7 | 14.2 | 25.7 |
| Olin Charleston, TN | 20.5 | 4,800 | 31.8 | 29.5 | 2.3 | 23.6 |
| PPG Lake Charles, LA | 23.0 | 2,839 | 15.7 | 15.7 | 0 | 15.7 |
| Vulcan Port Edward, WI | 31.1 | 1,458 | 10.9 | 10.9 | 0 | 10.9 |
| Nationwide Total ^d | | | 198.7 | 162.9 | 35.8 | 157.0 |
| | | | | | | 41.7 |

^aThese baseline emissions are based on annual vent mercury emission releases reported by the plants. Part 61 NESHAP, or potential-to-emit, baseline emissions are not shown, since only a value of 365 kg/yr for all point sources at a plant is available (i.e., NESHAP baseline emissions specifically for mercury thermal recovery unit vents cannot be determined).

^bEmissions are calculated by multiplying the emission limit (either 23 or 5 mg/dscm) by the reported vent exhaust flow rate and the annual operating time and employ appropriate conversions.

^cEmissions are calculated by multiplying the emission limit (either 23 or 5 mg/dscm) by the reported vent exhaust flow rate and the annual operating time and employ appropriate conversions.

^dTotal may not always appear to be the sum of values shown due to rounding.

TABLE 5-7. ESTIMATED PRIMARY ENVIRONMENTAL IMPACTS OF REGULATORY ALTERNATIVES FOR POINT SOURCES

| Plant Owner | Location | Vent Baseline | | At Regulatory Alternative I | | At Regulatory Alternative II | |
|-------------------------------|-------------------|-------------------------------|--|------------------------------|------------------|--|--|
| | | Part 61 NESHAP Baseline | Mercury Emissions (kilograms per year) | Actual Baseline Emissions | Annual Emissions | Emission Reduction from Part 61 NESHAP Actual | Emission Reduction from Part 61 NESHAP Actual |
| | | | | | | | |
| ASHTA | Ashtabula, OH | 365 | 147.4 | 6.2 | 358.8 | 141.2 | 2.9 |
| HoltraChem | Orrington, ME | 365 | 4.4 | 4.4 | 360.6 | 0 | 362.1 |
| Occidental | Muscle Shoals, AL | 365 | 94.6 | 75.3 | 289.7 | 19.3 | 360.6 |
| Occidental | Delaware City, DE | 365 | 20.1 | 20.1 | 344.9 | 0 | 289.7 |
| Occidental | Deer Park, TX | 365 | 55.4 | 34.9 | 330.1 | 20.5 | 346.2 |
| Olin | Augusta, GA | 365 | 122.9 | 15.6 | 349.4 | 107.3 | 336.3 |
| Olin | Charleston, TN | 365 | 236.0 | 63.8 | 301.2 | 172.2 | 357.8 |
| Pioneer | St. Gabriel, LA | 365 | 19.1 | 19.1 | 345.9 | 0 | 325.5 |
| PPG | Lake Charles, LA | 365 | 90.2 | 49.4 | 315.6 | 40.8 | 353.4 |
| PPG | Natrium, WV | 365 | 48.2 | 9.5 | 355.5 | 38.7 | 333.7 |
| Vulcan | Port Edwards, WI | 365 | 21.4 | 21.1 | 343.9 | 0.3 | 360.6 |
| Westlake | Calvert City, KY | 365 | 73.4 | 16.0 | 349.0 | 57.4 | 349.4 |
| Nationwide Total ^a | | 4,380 | 933.0 | 335.3 | 4,045 | 597.7 | 357.6 |
| | | | | | | | 4,133 |
| | | | | | | | 685.9 |

corresponding to Regulatory Alternative I would be 6,029 kg/yr (13,292 lb/yr).

The estimated nationwide reduction in annual mercury emissions with Regulatory Alternative II for point sources is around 4,133 kg/yr (a 94.4 percent reduction) from the vent part 61 NESHAP (or potential-to-emit) baseline level and around 686 kg/yr (a 74 percent reduction) from the actual baseline level. The estimated absolute reduction in annual mercury emissions again represents total reductions for all emission sources with Regulatory Alternative II. As previously discussed, it is not possible to quantify the reduction in fugitive mercury emissions, although a decrease is expected with the level of control associated with Regulatory Alternative II. The overall estimated percentage reduction values are 41 percent reduction from the part 61 NESHAP baseline level and 10 percent from the actual baseline level. Thus, total mercury emissions corresponding to Regulatory Alternative II would be 5,941 kg/yr (13,098 lb/yr).

5.5 ENERGY IMPACTS

Regulatory Alternative I for fugitive emission sources represents a level of control that is currently required at every plant, as discussed in Chapter 4, Section 4.5. Therefore, there would be no associated energy impacts. The implementation of Regulatory Alternative II for fugitive emission sources would be likely to cause every mercury cell chlor-alkali plant to enhance

its existing housekeeping program in some manner, as discussed in Section 5.4.1. However, only the additional electrical power consumed by new monitoring equipment assumed for plant cell rooms could be quantified and, thus were attributed to observing the Regulatory Alternative II work practices.

The implementation of the regulatory alternatives for point sources would result in increased energy consumption. This increase was estimated as the additional electrical (fan) power per year expended in conveying gas streams through new carbon adsorbers and new packed scrubbers at a plant (see Tables 5-2, 5-3, and 5-4). Specifically, device costing procedures detailed in the *OAQPS Control Cost Manual*⁴ were used to compute the energy requirement of a carbon adsorber or packed tower scrubber system fan as the product of the stream flowrate, calculated pressure drop through the vessel, and various factors accounting for units conversions and assumed efficiencies; the hourly energy requirement was then multiplied by the number of operating hours per year to give the annual power consumption. The additional electrical power per year consumed by new monitoring equipment for plant vents was also included.

The estimated nationwide annual energy impacts of Regulatory Alternative II for fugitive emission sources are about 53 thousand kilowatt-hours per year (kW-hr/yr). The estimated nationwide annual energy impacts of Regulatory Alternative I and

Regulatory Alternative II for point sources are about 1,362 thousand and about 1,724 thousand kW-hr/yr, respectively.

5.6 SECONDARY IMPACTS

Regulatory Alternative I for fugitive emission sources represents a level of control that is currently required at every plant, as discussed in Chapter 4, Section 4.5. Therefore, there would be no associated secondary impacts. The implementation of Regulatory Alternative II for fugitive emission sources would be likely to cause every mercury cell chlor-alkali plant to enhance its existing housekeeping program in some manner, as discussed in Section 5.4.1. However, only secondary air pollution impacts could be quantified and were attributed to observing the Regulatory Alternative II practices.

The implementation of regulatory alternatives for point sources would result alterations in the nature or amount of air pollution (other than mercury), water pollution, and solid waste attributed to mercury cell chlor-alkali plants. These are separately discussed below.

5.6.1 Secondary Air Pollution Impacts

Indirect air pollutant emissions could result from the production of electricity required to operate new finishing devices (see Tables 5-2, 5-3, and 5-4) and new monitoring equipment for plant vents as well as new monitoring equipment for plant cell rooms.

Electricity production was assumed to be entirely from coal combustion to correspond to a worst-case estimate. The combustion of hydrocarbons yields carbon dioxide (CO_2), water, and particulate matter (PM); incomplete combustion generates, in addition, carbon monoxide (CO) and sulfur dioxide (SO_2). All types of combustion in air yield nitrogen oxides (NO_x), with more generated during incomplete combustion. Accordingly, secondary air emissions estimates were developed for these pollutants, using the following emission factors: 1.9 lb NO_x per thousand kW-hr, 4.25 lb SO_2 per thousand kW-hr, 702 lb CO_2 per thousand kW-hr,⁵ 0.078 lb CO per thousand kW-hr, and 0.081 lb PM per thousand kW-hr.⁶

The estimated nationwide secondary air impacts for all pollutants combined are about 17 Megagrams per year (19 tons per year) for Regulatory Alternative II for fugitive emission sources. The estimated nationwide secondary air impacts for all pollutants combined are about 438 Megagrams per year (483 tons per year) and about 554 Megagrams per year (611 tons per year) for Regulatory Alternative I and Regulatory Alternative II for point sources, respectively.

5.6.2 Water Pollution Impacts

The implementation of the regulatory alternatives for point sources could result in an increased amount of mercury-containing waters from the heightened use of packed tower scrubbing. This increase was estimated as the total wastewater generated per year

by five new packed tower hypochlorite scrubbers installed on end-box ventilation system vents to meet Regulatory Alternative I. For Regulatory Alternative II, this increase was estimated total wastewater generated annually by the five new packed tower hypochlorite scrubbers installed to meet the MACT floor level and operated to give higher performance and two new packed tower hypochlorite scrubbers (see Tables 5-2 and 5-3). Specifically, the gas absorber costing procedure detailed in the *OAQPS Control Cost Manual*⁷ was used to compute the annual volume of wastewater as the product of the calculated scrubbing liquid flow rate through the column, the fraction of scrubbing liquid wasted, and number of operating hours per year.

The estimated nationwide annual water pollution impacts of Regulatory Alternative I and Regulatory Alternative II for point sources are about 1.2 million liters (320 thousand gallons) and about 1.8 million liters (466 thousand gallons), respectively.

5.6.3 Solid Waste Impacts

The implementation of the regulatory alternatives for point sources could result in an increased amount of mercury-containing solid wastes due to the heightened use of carbon adsorption. This increase was estimated as the amount of spent carbon generated per year by seven new non-regenerative impregnated carbon adsorbers installed and three existing non-regenerative carbon adsorbers in which the carbon would be replaced more frequently to meet Regulatory Alternative I. For Regulatory

Alternative II, this increase was estimated as the amount of spent carbon generated per year by a 25 percent higher carbon charge in five of the seven new carbon adsorbers installed to meet the MACT floor level, still more frequent replacement in two existing carbon adsorbers, and three new carbon absorbers (see Tables 5-2, 5-3, and 5-4). Specifically, the carbon adsorber costing procedure in the *OAQPS Control Cost Manual*⁸ and appropriate modifications were used to compute the carbon charge based on a optimum mercury-to-carbon ratio (see Chapter 6, Section 6.3).

The estimated nationwide annual solid waste impacts of Regulatory Alternative I and Regulatory Alternative II for point sources are about 23 Megagrams (26 tons) and about 34 Megagrams (38 tons), respectively.

5.7 SUMMARY OF ENERGY AND SECONDARY ENVIRONMENTAL IMPACTS

Table 5-8 summarizes the estimated nationwide energy impacts and secondary environmental impacts of the regulatory alternatives for all emission sources.

TABLE 5-8. ESTIMATED ANNUAL ENERGY AND SECONDARY ENVIRONMENTAL IMPACTS FOR REGULATORY ALTERNATIVES FOR ALL EMISSION SOURCES

| Nationwide Impacts | Regulatory Alternative I | Regulatory Alternative II |
|---|-----------------------------|------------------------------|
| Energy, electrical power consumed (kiloWatt-hours per year) | 1,361,716 | 1,776,162 |
| Secondary air pollution, additional pollutants emitted (kilograms per year) | | |
| NO _x | 1,180 | 1,540 |
| SO ₂ | 2,629 | 3,430 |
| CO ₂ | 433,971 | 566,053 |
| CO | 48 | 63 |
| PM | 50 | 66 |
| Water pollution, additional mercury-contaminated wastewater (Liters per year) | 1,212,768 | 1,763,001 |
| Solid waste, additional spent carbon media (kilograms per year) | 23,206 | 34,043 |

5.8 REFERENCES

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2. Review of National Emission Standards for Mercury. EPA-450/3-84-014a. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. December 1984.
3. Memorandum. Bhatia, K., EC/R Incorporated, to Rosario, I., U.S. Environmental Protection Agency. Background on Vent Control System Enhancements to Meet Regulatory Alternatives for Existing Mercury Emission Sources at Mercury Cell Chlor-Alkali Plants. September 26, 2001.
4. OAQPS Control Cost Manual (Fifth Edition), EPA, Office of Air Quality Planning and Standards, Emission Standards Division, February 1996 (EPA 453/B-96-001).
5. Data from EPA's Acid Rain program
(www.epa.gov/acidrain/score97/es1997.html).
6. Data from EPA's National Pollutant Emission Trends Update, 1970-1997 on EPA's TTN CHIEF site (www.epa.gov/ttn/chief/trends97).
7. Reference 4.
8. Reference 4.

6.0 COST IMPACTS

6.1 INTRODUCTION

This chapter presents the cost impacts of implementing the existing source regulatory alternatives described in Chapter 4 for the mercury cell chlor-alkali industry. Total annual cost impacts were estimated on a plant-by-plant basis and then summed for the estimated nationwide total annual cost impacts.

As discussed in Section 7.6, it is assumed that no new mercury cell chlor-alkali production facilities will be built in the United States (U.S.). In addition, it is anticipated that no new mercury recovery facilities will be built at mercury cell chlor-alkali plants in the U.S. in the near future. Therefore, no new or reconstructed source impacts were estimated.

Costs incurred by a plant in complying with a standard consist of emissions control costs and monitoring, recordkeeping, and reporting (MR&R) costs. The former are associated with the purchase, installation, and operation of pollution control devices, while the latter pertain to monitoring emissions or the performance of control measures, keeping records of required information, and submitting required reports.

Each of these cost categories may be divided into capital and annual costs. Capital costs represent the one-time purchase of equipment. Annual costs, which are recurrent, are the sum of

direct and indirect costs. Direct costs tend to vary with the level of emissions or production and include costs of raw materials, utilities, waste treatment and disposal, maintenance materials, replacement parts, and operating, supervisory, and maintenance labor. Indirect costs are independent of the level of emissions or production and include property taxes, insurance, and administrative charges. Indirect costs also include the capital recovery cost, or capital cost "annualized" over the life of the equipment. The sum of direct and indirect costs minus annualized capital costs correspond to operating and maintenance (O&M) costs.

The overall methodology for estimating cost impacts of implementing the existing source regulatory alternatives at mercury cell chlor-alkali plants is summarized in Section 6.2. Control and MR&R cost impacts estimated for fugitive sources and point sources (vents) are discussed in Sections 6.3 and 6.4, respectively. Total cost impacts for all mercury emission sources and estimated cost per unit of mercury emission reduction are discussed in Section 6.5. Details on impact calculations may be found in a separate technical memorandum.¹

6.2 OVERALL IMPACTS ESTIMATION METHODOLOGY

Table 6-1 shows the existing source regulatory alternatives. Regulatory Alternative II is more stringent than Regulatory

TABLE 6-1. REGULATORY ALTERNATIVES FOR EXISTING MERCURY EMISSION SOURCES AT MERCURY CELL CHLOR-ALKALI PLANTS

| Emission Source Group | Regulatory Alternative I (MACT Floor) | Regulatory Alternative II |
|---|--|---|
| Fugitive Emission Sources | Part 61 Housekeeping Procedures | Enhanced Work Practices |
| Hydrogen By-Product Streams/End-Box Ventilation System Vents ^a | 0.14 gram mercury emitted per Megagram chlorine produced | 0.067 gram mercury emitted per Megagram chlorine produced |
| Hydrogen By-Product Streams ^b | 0.10 gram mercury emitted per Megagram chlorine produced | 0.033 gram mercury emitted per Megagram chlorine produced |
| Oven Type Mercury Thermal Recovery Unit Vents | c | 23 milligrams mercury emitted per dry standard cubic meter of exhaust |
| Non-Oven Type Mercury Thermal Recovery Unit Vents | 5 milligrams mercury emitted per dry standard cubic meter of exhaust | 4 milligrams mercury emitted per dry standard cubic meter of exhaust |

^a At plants with end-box ventilation systems.

^b At plants with no end-box ventilation systems (i.e., with closed end boxes)

^c Data were only available for the plant with the best performing control system on the oven type mercury thermal recovery unit vents.

Alternative I for by-product hydrogen streams, end-box ventilation system vents, non-oven type mercury thermal recovery unit vents, and fugitive emission sources. As discussed in Chapter 4, Regulatory Alternative I represents the MACT floor level of control for these emission sources, while Regulatory Alternative II represents a beyond-the-floor level.

6.2.1 Cost Impacts for Fugitive Emission Sources

Regulatory Alternative I for fugitive emission sources represents a level of control that is currently required at every plant. Thus, there would be no associated cost impacts.

Regulatory Alternative II represents a compilation of the most stringent work practices applied in the industry. These work practices consist largely of monitoring and inspection requirements, and costs incurred in implementing them are most appropriately classified as MR&R cost impacts.

6.2.2 Control Cost Impacts for Point Sources

Control system enhancements, considering existing vent controls, were assumed in order to estimate control cost impacts, for point sources to meet the emission limits associated with the regulatory alternatives. Tables 6-2, 6-3, and 6-4 present the enhancement assumed for each vent at each mercury cell chlor-alkali plant to meet the regulatory alternatives. Background information on these assumptions may be found in a separate technical memorandum.²

TABLE 6-2. ASSUMED CONTROL SYSTEM ENHANCEMENTS TO MEET THE REGULATORY ALTERNATIVES FOR
BY-PRODUCT HYDROGEN STREAMS AND END-BOX VENTILATION SYSTEMS AT PLANTS WITH END-BOX
VENTILATION SYSTEMS

| Plant Owner/ Location | Assumed Enhancement to Meet Regulatory Alternative I | | Assumed Enhancement to Meet Regulatory Alternative II | |
|---------------------------------|--|------------------------------------|---|------------------------------------|
| | By-Product Hydrogen Stream | End-Box Ventilation System Vent | By-Product Hydrogen Stream | End-Box Ventilation System Vent |
| ASHTA Ashtabula, OH | new carbon adsorber | new packed scrubber | new carbon adsorber ^a | new packed scrubber ^a |
| HoltraChem Orrington, ME | none | none | none | none |
| Occidental Delaware City, DE | none | none | none | new packed scrubber |
| Olin August, GA | new carbon adsorber | new packed scrubber | new carbon adsorber ^a | new packed scrubber ^a |
| Olin Charleston, TN | new carbon adsorber | new packed scrubber | new carbon adsorber ^a | new packed scrubber ^a |
| Pioneer St. Gabriel, LA | none | none | none | new packed scrubber |
| PPG Lake Charles, LA | none | new packed scrubber | none | new packed scrubber ^a |
| PPG Natrium, WV | change first to impregnated carbon in existing adsorber, followed by more frequent replacement | new packed scrubber | change first to impregnated carbon in existing adsorber, followed by more frequent replacement ^b | new packed scrubber ^a |
| Vulcan Port Edward, WI | new carbon adsorber | none | new carbon adsorber ^a | none |
| Westlake Calvert City, KY | replace existing carbon adsorber with new, larger adsorber | none | replace existing carbon adsorber with new, larger adsorber ^a | none |

^aRefers to the same type of new control device assumed to meet Regulatory Alternative I, except that carbon adsorbers would have higher carbon charge and more efficient packed scrubbers would be used.

^bRefers to more frequent carbon replacement than that assumed to meet Regulatory Alternative I.

TABLE 6-3. ASSUMED CONTROL SYSTEM ENHANCEMENTS TO MEET THE REGULATORY ALTERNATIVES FOR
BY-PRODUCT HYDROGEN STREAMS AT PLANTS WITHOUT END-BOX VENTILATION SYSTEMS

| Plant Owner/ Location | Assumed Enhancement to Meet Regulatory Alternative I | | Assumed Enhancement to Meet Regulatory Alternative II | |
|---------------------------------|--|------------------------------------|--|------------------------------------|
| | By-Product Hydrogen Stream | End-Box Ventilation System Vent | By-Product Hydrogen Stream | End-Box Ventilation System Vent |
| Occidental Muscle Shoals, AL | none | not applicable | none | not applicable |
| Occidental Deer Park, TX | more frequent replacement of carbon in existing adsorber | not applicable | replace existing carbon adsorber with new, larger adsorber | not applicable |

TABLE 6-4. ASSUMED CONTROL SYSTEM ENHANCEMENTS
FOR MERCURY THERMAL RECOVERY UNIT VENTS AT PLANTS WITH SUCH UNITS
TO MEET THE REGULATORY ALTERNATIVES

| Plant | | Assumed Enhancement to Meet Regulatory | Assumed Enhancement to |
|------------|----------------------|---|---|
| Occidental | Muscle Shoals, AL | replace existing carbon adsorber with new, larger adsorber | |
| Occidental | Delaware City, | none | |
| Occidental | Deer Park, TX | replace existing carbon adsorber with new, larger adsorber | |
| Olin | Charleston, TN | more frequent replacement of carbon in existing | more frequent replacement of carbon in existing |
| PPG | Lake Charles, | none | none |
| Vulcan | Port Edwards, | none | none |

^aRefers to more frequent carbon replacement than that assumed to
meet Regulatory Alternative I.

Generally, the main type of enhancement assumed was the addition of a new, final control device. The devices included non-regenerative adsorbers with an impregnated carbon media suited for mercury removal for by-product hydrogen stream and mercury thermal recovery unit control systems and packed tower hypochlorite scrubbers for end-box ventilation control systems. For a vent control system having an existing carbon adsorber but not meeting the emission level associated with a regulatory alternative, it was assumed that either more frequent replacement of the carbon (with first switching to an impregnated carbon media in some cases) or replacement of the existing adsorber with a new, larger adsorber would be necessary.

For estimating control cost impacts of Regulatory Alternative I for point sources at all twelve plants, seven out of ten plants with end-box ventilation systems were assumed to enhance their by-product hydrogen streams and/or end-box ventilation system controls as follows: (1) two plants would need to install new carbon adsorbers on their by-product hydrogen streams (one plant would be replacing an existing adsorber with a new, larger adsorber), (2) one plant would need to install a new packed scrubber on its end-box ventilation system vent, (3) one plant would need to change the type of carbon in its existing adsorber (to an impregnated carbon) and then, replace the carbon more frequently than its current practice (this plant would also need to add a new packed scrubber on its end-box ventilation.

system vent), and (4) three plants would need to install a new carbon adsorber on their by-product hydrogen stream and a new packed scrubber on their end-box ventilation system vent. One of two plants without end-box ventilation systems was assumed to enhance its by-product hydrogen stream controls by replacing the carbon in its existing adsorber more frequently than its current practice. Three out of six plants with thermal recovery units were assumed to enhance their mercury thermal recovery unit controls as follows: (1) two plants with oven type units would need to replace their existing carbon adsorbers with new, larger carbon adsorbers, and (2) one plant with a non-oven type unit would need to replace the carbon in its existing carbon adsorber more frequently than its current practice.

For estimating control cost impacts of Regulatory Alternative II for point sources at all twelve plants, it was assumed that all seven plants with end-box ventilation systems enhancing their controls for by-product hydrogen streams and/or end-box ventilation system vents to meet Regulatory Alternative I would undertake the same types of control measures with the following additional enhancements: (1) a 25 percent higher carbon charge would be used in the five new carbon adsorbers, (2) carbon replacement frequency would be further increased in one existing carbon adsorber, and (3) the five new packed scrubbers needed would be designed and operated more efficiently. Two additional plants with end-box ventilation systems were assumed to install

new packed scrubbers, for a total of nine affected plants for meeting Regulatory Alternative II for combined by-product hydrogen streams and end-box ventilation system vents (for plants with end-box ventilation systems). The plant without an end-box ventilation system enhancing its controls to meet Regulatory Alternative I for by-product hydrogen streams (by replacing the carbon in its existing adsorber more frequently than its current practice) was assumed to need to replace its existing carbon adsorber with a new, larger carbon adsorber. Since there is a single level of control for oven type mercury thermal recovery unit vents in both regulatory alternatives, the assumptions previously discussed for meeting Regulatory Alternative I apply to meeting Regulatory Alternative II for these vents. The one plant assumed to enhance its non-oven mercury thermal recovery unit controls to meet Regulatory Alternative I would further increase carbon replacement frequency in its existing carbon adsorber.

6.2.3 MR&R Cost Impacts for Point Sources

As part of the regulatory alternatives for point sources, continuous compliance with emission limits would be demonstrated through the monitoring of mercury concentration in the vent exhaust streams (as an indicator of control system performance). Accordingly, the MR&R cost impacts for point sources were estimated based on the installation and operation and maintenance

(including repeat performance testing) of a mercury concentration continuous monitoring system (CMS) for each vent at a plant.³

6.3 CONTROL COST IMPACTS

Emission control costs are associated with the purchase, installation, and operation of pollution control equipment. As discussed in Section 6.2.1, no control cost impacts were associated with fugitive emission sources. Control cost impacts for point sources were estimated based on assumed vent control system enhancements needed to meet Regulatory Alternative I and Regulatory Alternative II (Section 6.2.2), respectively.

Capital and annual costs for new carbon adsorbers were estimated using the EPA carbon adsorbers spreadsheet⁴ and procedures detailed in the EPA *OAQPS Control Cost Manual*.⁵ As the former focuses on regenerative systems with activated carbon, modifications were made to accommodate non-regenerative devices with impregnated carbon media for mercury removal. Capital and annual costs for new packed scrubbers were estimated based on the EPA gas absorbers spreadsheet⁶ and procedures detailed in the EPA *OAQPS Control Cost Manual*.⁷

Costs for replacing carbon in existing adsorbers were estimated based on the replacement frequency needed to meet an appropriate optimum mercury-to-carbon ratio among plants with existing carbon adsorbers. In calculating this ratio for each plant, the mercury concentration at the inlet of the carbon adsorber and stream flow rate were multiplied and unit

conversions applied for the mercury loading in milligrams of mercury per minute. This value was then multiplied by operating time per year, divided by the mass of carbon in the adsorber, and multiplied by the existing carbon media replacement frequency (in years) to yield the quotient of mercury mass to carbon mass.

Tables 6-5 and 6-6 present the estimated capital cost and annual control cost impacts, respectively, for implementing Regulatory Alternative I for point sources. The nationwide annual control cost impact is estimated to be \$743,482.

Tables 6-7 and 6-8 present the estimated capital cost and annual control cost impacts, respectively, for implementing Regulatory Alternative II for point sources. The nationwide annual control cost impact is estimated to be \$1,026,508.

6.4 MR&R COST IMPACTS

The MR&R cost impacts for fugitive sources and point sources are discussed below.

6.4.1 MR&R Cost Impact for Fugitive Sources

As discussed in Section 6.2.1, there are no estimated cost impacts for Regulatory Alternative I for fugitive emission sources. As part of Regulatory Alternative II for fugitive emission sources, cell room inspections and associated recordkeeping would be conducted at specified frequencies. The measurement of mercury vapor levels in the cell room, in order to detect elevated levels and enable prompt corrective action, would also be conducted. Additionally, recordkeeping would be

TABLE 6-5. ESTIMATED CAPITAL CONTROL COST IMPACTS OF
REGULATORY ALTERNATIVE I FOR POINT SOURCES

| Plant Owner | Location | By-Product Hydrogen Stream | | End-Box Ventilation System Vent | Mercury Thermal Recovery Unit Vent | | Total Capital Control Cost |
|-------------------------------|-------------------|--------------------------------------|---|---------------------------------|--------------------------------------|---|----------------------------|
| | | New Non-Regenerative Carbon Adsorber | Switch to Impregnated Carbon in Existing Adsorber | | New Non-Regenerative Carbon Adsorber | Switch to Impregnated Carbon in Existing Adsorber | |
| ASHTA | Ashtabula, OH | \$32,959 | | \$13,083 | | | \$46,042 |
| HoltraChem | Orrington, ME | | | | | | \$0 |
| Occidental | Muscle Shoals, AL | | | | \$166,272 | | \$166,272 |
| Occidental | Delaware City, DE | | | | | | \$0 |
| Occidental | Deer Park, TX | | | | \$50,478 | | \$50,478 |
| Olin | Augusta, GA | \$24,936 | | \$13,083 | | | \$38,019 |
| Olin | Charleston, TN | \$89,339 | | \$26,167 | | | \$115,506 |
| Pioneer | St. Gabriel, LA | | | | | | \$0 |
| PPG | Lake Charles, LA | | | \$85,285 | | | \$85,285 |
| PPG | Natrium, WV | | \$44,023 | \$13,083 | | | \$57,106 |
| Vulcan | Port Edwards, WI | \$22,882 | | | | | \$22,882 |
| Westlake | Calvert City, KY | \$298,169 | | | | | \$298,169 |
| Nationwide Total ^a | | \$468,285 | \$44,023 | \$150,701 | \$216,750 | \$0 | \$879,759 |

^a Totals may not appear to be the sum of the values shown due to rounding.

TABLE 6-6. ESTIMATED ANNUAL CONTROL COST IMPACTS OF
REGULATORY ALTERNATIVE I FOR POINT SOURCES

| Plant Owner | Location | By-Product Hydrogen Stream | | End-Box Ventilation System Vent | Mercury Thermal Recovery Unit Vent | | Total Annual Control Cost |
|-------------------------------|-------------------|--|---|---------------------------------------|---|--|------------------------------|
| | | New Non- Regenerative Carbon Adsorber | More Frequent Replacement of Impregnated Carbon in Existing Adsorber | | New Non- Regenerative Impregnated Carbon Adsorber | More Frequent Replacement of Impregnated Carbon in Existing Adsorber | |
| ASHTA | Ashtabula, OH | \$34,318 | | \$23,674 | | | \$57,992 |
| HoltraChem | Orrington, ME | | | | | | \$0 |
| Occidental | Muscle Shoals, AL | | | | \$120,339 | | \$120,339 |
| Occidental | Delaware City, DE | | | | | | \$0 |
| Occidental | Deer Park, TX | | \$13,005 | | \$42,267 | | \$55,272 |
| Olin | Augusta, GA | \$28,216 | | \$23,674 | | | \$51,890 |
| Olin | Charleston, TN | \$66,495 | | \$47,347 | | \$1,156 | \$114,998 |
| Pioneer | St. Gabriel, LA | | | | | | \$0 |
| PPG | Lake Charles, LA | | | \$36,785 | | | \$36,785 |
| PPG | Natrium, WV | | \$17,856 | \$23,674 | | | \$41,530 |
| Vulcan | Port Edwards, WI | \$26,314 | | | | | \$26,314 |
| Westlake | Calvert City, KY | \$238,364 | | | | | \$238,364 |
| Nationwide Total ^a | | \$393,707 | \$30,861 | \$155,153 | \$162,606 | \$1,156 | \$743,482 |

^a Totals may not appear to be the sum of the values shown due to rounding.

TABLE 6-7. ESTIMATED CAPITAL CONTROL COST IMPACTS OF
REGULATORY ALTERNATIVE II FOR POINT SOURCES

| Plant Owner | Location | By-Product Hydrogen Stream | | End-Box Ventilation System Vent | Mercury Thermal Recovery Unit Vent | | Total Capital Control Cost |
|-------------------------------|-------------------|--|---|---------------------------------|--|---|----------------------------|
| | | New Non-Regenerative Impregnated Carbon Adsorber | Switch to Impregnated Carbon in Existing Adsorber | | New Non-Regenerative Impregnated Carbon Adsorber | Switch to Impregnated Carbon in Existing Adsorber | |
| ASHTA | Ashtabula, OH | \$36,219 | | \$14,537 | | | \$50,756 |
| HoltraChem | Orrington, ME | | | | | | \$0 |
| Occidental | Muscle Shoals, AL | | | | \$166,272 | | \$166,272 |
| Occidental | Delaware City, DE | | | \$14,537 | | | \$14,537 |
| Occidental | Deer Park, TX | \$182,387 | | | \$50,478 | | \$232,865 |
| Olin | Augusta, GA | \$26,142 | | \$14,537 | | | \$40,679 |
| Olin | Charleston, TN | \$102,380 | | \$29,074 | | | \$131,454 |
| Pioneer | St. Gabriel, LA | | | \$94,761 | | | \$94,761 |
| PPG | Lake Charles, LA | | | \$94,761 | | | \$94,761 |
| PPG | Natrium, WV | | \$44,023 | \$14,537 | | | \$58,560 |
| Vulcan | Port Edwards, WI | \$23,403 | | | | | \$23,403 |
| Westlake | Calvert City, KY | \$365,982 | | | | | \$365,982 |
| Nationwide Total ^a | | \$736,513 | \$44,023 | \$276,744 | \$216,750 | \$0 | \$1,274,030 |

^a Totals may not appear to be the sum of the values shown due to rounding.

TABLE 6-8. ESTIMATED ANNUAL CONTROL COST IMPACTS OF
REGULATORY ALTERNATIVE II FOR POINT SOURCES

| Plant Owner | Location | By-Product Hydrogen Stream | | End-Box Ventilation System Vent | Mercury Thermal Recovery Unit Vent | | Total Annual Control Cost |
|-------------------------------|-------------------|--|---|--|--|--|---------------------------|
| | | New Non-Regenerative Impregnated Carbon Adsorber | More Frequent Replacement of Impregnated Carbon | New Packed Tower Hypochlorite Scrubber | New Non-Regenerative Impregnated Carbon Adsorber | More Frequent Replacement of Impregnated Carbon in Existing Adsorber | |
| ASHTA | Ashtabula, OH | \$36,505 | | \$26,304 | | | \$62,809 |
| HoltraChem | Orrington, ME | | | | | | \$0 |
| Occidental | Muscle Shoals, AL | | | | \$120,339 | | \$120,339 |
| Occidental | Delaware City, DE | | | \$26,304 | | | \$26,304 |
| Occidental | Deer Park, TX | \$139,240 | | | \$42,267 | | \$181,507 |
| Olin | Augusta, GA | \$29,025 | | \$26,304 | | | \$55,329 |
| Olin | Charleston, TN | \$75,242 | | \$52,608 | | \$6,936 | \$134,786 |
| Pioneer | St. Gabriel, LA | | | \$40,872 | | | \$40,872 |
| PPG | Lake Charles, LA | | | \$40,872 | | | \$40,872 |
| PPG | Natrium, WV | | \$26,874 | \$26,304 | | | \$53,178 |
| Vulcan | Port Edwards, WI | \$26,664 | | | | | \$26,664 |
| Westlake | Calvert City, KY | \$283,850 | | | | | \$283,850 |
| Nationwide Total ^a | | \$590,526 | \$26,874 | \$239,565 | \$162,606 | \$6,936 | \$1,026,508 |

^a Totals may not appear to be the sum of the values shown due to rounding.

associated with the routine washdown of surfaces where liquid mercury accumulates, as well as for the storage of mercury-containing wastes. Regulatory Alternative II cost impacts for fugitive emission sources were estimated as costs of these additional monitoring, inspections, recordkeeping, and reporting activities.

Table 6-9 presents these estimated MR&R cost impacts. The capital MR&R cost impact for fugitive mercury emission sources was estimated based on one cell room mercury monitoring system for each plant. A vendor quotation of about \$31,800⁸ per system

TABLE 6-9. ESTIMATED COST IMPACTS OF REGULATORY ALTERNATIVE II FOR FUGITIVE EMISSION SOURCES

| MR&R For Work Practices | Annual Costs Per Plant | Nationwide Annual Costs |
|---|------------------------|-------------------------|
| Annualized Capital Cost for Mercury Monitoring System | \$7,870 | \$94,442 |
| Labor Cost for Monitoring, Inspections, and Recordkeeping | \$61,336 | \$736,037 |
| Utility Cost for Mercury Monitoring System | \$180 | \$2,155 |
| Cost of Replacement Parts for Mercury Monitoring System | \$624 | \$7,488 |
| Total ^a | \$70,010 | \$840,122 |

^a Totals may not appear to be the sum of the values shown due to rounding.

was multiplied by 1.08 to account for taxes and freight, and then by 1.61 to account for direct and indirect installation costs, based on the estimation methodology in the EPA *CAQPS Control Cost Manual*.⁹

The annual MR&R cost impact for fugitive mercury emission sources was estimated as the sum of the annualized capital cost of each cell room mercury monitoring system, plus operation and maintenance costs. The O&M costs consist of labor costs for monitoring, inspections, and recordkeeping, utility costs for mercury monitoring systems, and costs of replacement parts for these systems. The labor hour burden for each plant was approximated as an additional 3.75 technical labor hours per day, consisting of the following: (1) 0.1 hour per day for recordkeeping for washdowns, (2) 0.5 hour per day for measuring and recording cell room mercury vapor levels, (3) 1.5 hours per day for twice daily inspections for vessel and process equipment problems, as well as for hydrogen/mercury vapor leaks at decomposers and at equipment up to the hydrogen header, (4) an equivalent of 0.07 hours per day for monthly inspections for cracks, spalling, or other deficiencies in cell room floors, (5) an equivalent of 0.04 hours per day for semiannual inspections for cracks, spalling, or other deficiencies in cell room pillars and beams, (6) 1.25 hours per day for daily cell room inspections for caustic leaks, liquid mercury spills and accumulations, and liquid mercury leaks, (7) an equivalent of

0.04 hours per day for quarterly inspections for hydrogen/mercury vapor leaks in the hydrogen system, from the the hydrogen header to the last control device, and (8) 0.25 hours per day for recordkeeping for handling and storage of mercury-containing wastes. An hourly compensation value of \$34.44 for technical labor was obtained from the U.S. Bureau of Labor Statistics¹⁰ and multiplied by a factor of 1.3 to account for overhead expenditure. The labor hour burden was then extrapolated to 365 days per year at a technical labor rate of \$44.77 per hour. Utility costs for a mercury monitoring system were estimated as the product of the device power consumption of 500 Watts,¹¹ continuous operation for 8,760 hours per year, and energy cost of \$0.04 per kiloWatt-hour.¹² Replacement part costs for a mercury monitoring system were estimated based on monthly changeout of a \$2 device sample filter and annual changeout of sampling valve tubes at a cost of \$600.¹³ Thus, the estimated annual cost impact of Regulatory Alternative II for fugitive sources is \$70,010 for each plant, and the nationwide annual cost impact is \$840,122.

6.4.2 MR&R Cost Impacts for Point Sources

As stated in Section 6.2.3, MR&R cost impacts for point sources were estimated based on a mercury concentration CMS for each plant vent. An average vendor quotation of about \$9,760¹⁴ per CMS was multiplied by 1.08 to account for taxes and freight, and then by 1.61 to account for direct and indirect installation

costs, based on the estimation methodology in the EPA *OAQPS Control Cost Manual*.¹⁵ This value for cost per CMS was then multiplied by the number of vents at the plant, on which individual CMS would be installed. Table 6-10 presents the estimated capital MR&R cost impacts of implementing the regulatory alternatives for point sources.

The annual MR&R cost impact for point sources was estimated as the sum of the annualized capital cost of vent mercury concentration CMS plus operation and maintenance costs. The O&M costs consist of labor costs for monitoring, inspections (including calibrations), and recordkeeping, CMS utility costs, CMS replacement part costs, and annualized vent performance test costs. The labor hour burden for each plant was approximated as an additional 0.54 technical labor hours per day, consisting of the following: (1) 0.5 hour per day for daily vent monitoring and recording of CMS data, averages, and deviations, and (2) the equivalent of 0.04 hour per day for semiannual CMS inspections and calibrations and recording of results. As previously done, the labor hour burden was then extrapolated to 365 days per year at a technical labor rate of \$44.77 per hour. Utility costs for a CMS were estimated as the product of the device power consumption of 40 Watts,¹⁶ continuous operation for 8,760 hours per year, and energy cost of \$0.04 per kiloWatt-hour.¹⁷

TABLE 6-10. ESTIMATED CAPITAL MR&R COST IMPACTS OF
REGULATORY ALTERNATIVES FOR POINT SOURCES

| Plant Owner | Location | Number of Vents | Total Capital MR&R Cost |
|-------------------------------|-------------------|--------------------|----------------------------|
| ASHTA | Ashtabula, OH | 2 | \$33,937 |
| HoltraChem | Orrington, ME | 2 | \$33,937 |
| Occidental | Muscle Shoals, AL | 2 | \$33,937 |
| Occidental | Delaware City, DE | 5 | \$84,841 |
| Occidental | Deer Park, TX | 2 | \$33,937 |
| Olin | Augusta, GA | 2 | \$33,937 |
| Olin | Charleston, TN | 4 | \$67,873 |
| Pioneer | St. Gabriel, LA | 2 | \$33,937 |
| PPG | Lake Charles, LA | 3 | \$50,905 |
| PPG | Natrium, WV | 2 | \$33,937 |
| Vulcan | Port Edwards, WI | 3 | \$50,905 |
| Westlake | Calvert City, KY | 2 | \$33,937 |
| Nationwide Total ^a | | | \$526,016 |

^a Total may not appear to be the sum of the values shown due to rounding.

Replacement part costs for a CMS were estimated based on monthly changeout of a \$2 device sample filter.¹⁸ Table 6-11 presents the estimated annual MR&R cost impacts for implementing the regulatory alternatives for point sources.

6.5 ESTIMATE OF TOTAL ANNUAL COSTS AND COST PER UNIT EMISSION REDUCTION

Tables 6-12 and 6-13 present the estimated total annual cost impacts of the regulatory alternatives for all mercury emission sources (i.e., fugitive emission plus point sources) at each plant and on a nationwide basis. The total estimated annual cost impact of Regulatory Alternative I for all mercury emission sources at a plant ranges from \$20,689 to \$251,053, and the estimated nationwide total is \$1,033,041. The estimated total annual cost impact of Regulatory Alternative II for all plant mercury emission sources ranges from \$90,699 to \$374,549, and the estimated nationwide total is \$2,156,189.

Table 6-14 shows the estimated cost impact per unit of estimated mercury emission reduction (see Chapter 5, Table 5-7) for the regulatory alternatives for point sources. Using estimated reductions from the baseline level of emissions allowed by the part 61 Mercury NESHAP, this computes to about \$255 per kilogram (\$116 per pound) of mercury for Regulatory Alternative I for point sources. For Regulatory Alternative II, the cost per unit of mercury emission reduction for point sources is about \$318 per kilogram (\$144 per pound) of mercury. The

TABLE 6-11. ESTIMATED ANNUAL MR&R COST IMPACTS OF
REGULATORY ALTERNATIVES FOR POINT SOURCES

| Plant Owner | Location | Annualized Capital MR&R Cost | MR&R O&M Cost | Total Annual MR&R Cost |
|-------------------------------|-------------------|------------------------------------|------------------|---------------------------|
| ASHTA | Ashtabula, OH | \$4,832 | \$15,857 | \$20,689 |
| HoltraChem | Orrington, ME | \$4,832 | \$15,857 | \$20,689 |
| Occidental | Muscle Shoals, AL | \$4,832 | \$15,857 | \$20,689 |
| Occidental | Delaware City, DE | \$12,079 | \$26,308 | \$38,387 |
| Occidental | Deer Park, TX | \$4,832 | \$15,857 | \$20,689 |
| Olin | Augusta, GA | \$4,832 | \$15,857 | \$20,689 |
| Olin | Charleston, TN | \$9,664 | \$22,824 | \$32,488 |
| Pioneer | St. Gabriel, LA | \$4,832 | \$15,857 | \$20,689 |
| PPG | Lake Charles, LA | \$7,248 | \$19,341 | \$26,589 |
| PPG | Natrium, WV | \$4,832 | \$15,857 | \$20,689 |
| Vulcan | Port Edwards, WI | \$7,248 | \$19,341 | \$26,589 |
| Westlake | Calvert City, KY | \$4,832 | \$15,857 | \$20,689 |
| Nationwide Total ^a | | \$74,893 | \$214,666 | \$289,559 |

^a Totals may not appear to be the sum of the values shown due to rounding.

TABLE 6-12. ESTIMATED TOTAL ANNUAL COST IMPACTS OF REGULATORY ALTERNATIVE I FOR ALL MERCURY EMISSION SOURCES

| Plant Owner | Location | Total Annual Control Cost | Total Annual MR&R Cost | Total Annual Cost |
|-------------------------------|-------------------|---------------------------|------------------------|-------------------|
| ASHTA | Ashtabula, OH | \$57,992 | \$20,689 | \$78,681 |
| HoltraChem | Orrington, ME | \$0 | \$20,689 | \$20,689 |
| Occidental | Muscle Shoals, AL | \$120,339 | \$20,689 | \$141,028 |
| Occidental | Delaware City, DE | \$0 | \$38,387 | \$38,387 |
| Occidental | Deer Park, TX | \$55,272 | \$20,689 | \$75,961 |
| Olin | Augusta, GA | \$51,890 | \$20,689 | \$72,579 |
| Olin | Charleston, TN | \$114,998 | \$32,488 | \$147,486 |
| Pioneer | St. Gabriel, LA | \$0 | \$20,689 | \$20,689 |
| PPG | Lake Charles, LA | \$36,785 | \$26,589 | \$63,374 |
| PPG | Natrium, WV | \$41,530 | \$20,689 | \$62,219 |
| Vulcan | Port Edwards, WI | \$26,314 | \$26,589 | \$52,903 |
| Westlake | Calvert City, KY | \$238,364 | \$20,689 | \$259,053 |
| Nationwide Total ^a | | \$743,482 | \$289,559 | \$1,033,041 |

^a Totals may not appear to be the sum of the values shown due to rounding.

TABLE 6-13. ESTIMATED TOTAL ANNUAL COST IMPACTS OF REGULATORY ALTERNATIVE II FOR ALL MERCURY EMISSION SOURCES

| Plant Owner | Location | Total Annual Control Cost | Total Annual MR&R Cost | Total Annual Cost |
|-------------------------------|-------------------|---------------------------|------------------------|-------------------|
| ASHTA | Ashtabula, OH | \$62,809 | \$90,699 | \$153,508 |
| HoltraChem | Orrington, ME | \$0 | \$90,699 | \$90,699 |
| Occidental | Muscle Shoals, AL | \$120,339 | \$90,699 | \$211,038 |
| Occidental | Delaware City, DE | \$26,304 | \$108,397 | \$134,701 |
| Occidental | Deer Park, TX | \$181,507 | \$90,699 | \$272,206 |
| Olin | Augusta, GA | \$55,329 | \$90,699 | \$146,028 |
| Olin | Charleston, TN | \$134,786 | \$102,498 | \$237,284 |
| Pioneer | St. Gabriel, LA | \$40,872 | \$90,699 | \$131,571 |
| PFG | Lake Charles, LA | \$40,872 | \$96,599 | \$137,471 |
| PFG | Natrium, WV | \$53,178 | \$90,699 | \$143,877 |
| Vulcan | Port Edwards, WI | \$26,664 | \$96,599 | \$123,264 |
| Westlake | Calvert City, KY | \$283,850 | \$90,699 | \$374,549 |
| Nationwide Total ^a | | \$1,026,508 | \$1,129,681 | \$2,156,189 |

^a Totals may not appear to be the sum of the values shown due to rounding.

TABLE 6-14. ESTIMATED COST PER UNIT MERCURY EMISSION REDUCTION OF
REGULATORY ALTERNATIVES FOR MERCURY CELL CHLOR-ALKALI PLANTS

| | Nationwide Total Annual Cost Impact (dollars per year) | Nationwide Emission Reduction from Part 61 NESHAP Baseline (kilograms per year) | Nationwide Emission Reduction from Actuals Baseline (kilograms per year) | Cost Per Unit Emission Reduction from Part 61 NESHAP Baseline (dollars per kilogram mercury reduced) | Cost Per Unit Emission Reduction from Actuals Level (dollars per kilogram mercury reduced) |
|------------------------------|---|---|--|--|--|
| Regulatory Alternative I | | | | | |
| Fugitive Emission Sources | \$0 | 0 | 0 | not applicable | not applicable |
| Point Sources | \$1,033,041 | 4,045 | 598 | \$255 | \$1,727 |
| All Emission Sources | \$1,033,041 | 4,045 | 598 | \$255 | \$1,727 |
| Regulatory Alternative II | | | | | |
| Fugitive Emission Sources | \$840,122 | cannot be quantified | cannot be quantified | not applicable | not applicable |
| Point Sources | \$1,316,067 | 4,133 | 686 | \$318 ^a | \$1,918 |
| All Emission Sources | \$2,156,189 | 4,133 | 686 | not appropriate ^a | not appropriate ^a |

^aCalculating a cost per unit of mercury emission reduction would not be appropriate since emission reductions cannot be quantified for Regulatory Alternative II for fugitive emission sources.

difference in estimated point source cost impacts divided by the difference in estimated vent mercury emission reductions at the two alternatives, is approximately \$3,200 per kilogram (\$1,450 per pound) of mercury.

Using estimated reductions from the actuals baseline, the cost per unit of mercury emission reduction computes to about \$1,727 per kilogram (\$783 per pound) of mercury for Regulatory Alternative I for point sources. For Regulatory Alternative II, the cost per unit of mercury emission reduction for point sources is about \$1,918 per kilogram (\$870 per pound) of mercury. The difference in estimated point source cost impacts divided by the difference in estimated vent mercury emission reductions at the two alternatives, is approximately \$3,200 per kilogram (\$1,450 per pound) of mercury.

6.6 REFERENCES

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7.0 RATIONALE FOR SELECTING THE PROPOSED STANDARDS

7.1 INTRODUCTION

This chapter provides the detailed rationale for the selection of the national emission standards for hazardous air pollutants (NESHAP) regulatory requirements that we are proposing to reduce mercury emissions from mercury cell chlor-alkali plants. Section 7.2 discusses the selection of the source category, Section 7.3 discusses the selection of the affected sources and emission points, and Section 7.4 discusses the selection of the form of the standards. The basis and level for the proposed standards for existing and new sources are presented in Sections 7.5 and 7.6, respectively. This is followed by discussions on the selection of testing and initial compliance requirements in Section 7.7, continuous compliance requirements in Section 7.8, and notification, recordkeeping, and reporting requirements in Section 7.9. Section 7.10 lists references.

7.2 SELECTION OF THE SOURCE CATEGORY

The chlor-alkali production source category was among the categories and subcategories of major and area sources listed for regulation under Section 112(c)(6) of the Clean Air Act (CAA) (63 FR 17838, April 10, 1998), to assure that sources accounting for not less than 90 percent of the aggregate mercury emissions

nationwide are subject to standards under Section 112(d). We estimate that the chlor-alkali production source category accounts for over 5 percent of all stationary source emissions of mercury and over 25 percent of the emissions from stationary non-combustion sources. The source category is comprised of 43 facilities engaged in the manufacture of chlorine and caustic in electrolytic cells.¹ Cell types employed include the diaphragm cell, membrane cell, and mercury cell. Of these, only the mercury cell subcategory has the potential to emit mercury. Mercury emissions occur at process vents and as fugitive emissions from the cell room and other areas. Therefore, this rulemaking focuses only on mercury cell chlor-alkali plants.

For the 1997 base year of the maximum achievable control technology (MACT) analysis, twelve facilities employed mercury cells. We are aware that one of the twelve facilities ceased operations permanently in September 2000.² Nonetheless, we considered it to be part of the source category for the development of MACT standards since it was in operation in 1997, which is the base year of the analysis.

7.3 SELECTION OF THE AFFECTED SOURCES AND EMISSION POINTS TO BE REGULATED

For the purposes of implementing a NESHAP, an affected source is defined to mean the stationary source, the group of stationary sources, or the portion of a stationary source, that is regulated by a relevant standard or other requirement

established under Section 112 of the CAA. An affected source specifies the group of unit operations, equipment, and emission points that are subject to the standard. Under each relevant standard, we designate one or more affected sources for the purpose of implementing that standard. We can define an affected source as narrowly as a single piece of equipment or as broadly as all equipment at a plant site.

We decided to separate the unit operations and emission points related to the production of chlorine and caustic from the unit operations and emissions points related to mercury recovery. Mercury cell chlor-alkali production facilities include a number of integrated operations dedicated to the production, storage, and transfer of product chlorine, product caustic, and by-product hydrogen. In contrast, mercury recovery facilities are operations dedicated to the recovery of mercury from mercury-containing wastes. These operations are independent of the chlor-alkali process and are thus not integral to production. As a result, the proposed rule addresses emissions from two separate affected sources: mercury cell chlor-alkali production facilities and mercury recovery facilities.

Unit operations and emission points grouped within the mercury cell chlor-alkali production facilities affected source are by-product hydrogen streams, end-box ventilation system vents, and fugitive mercury emissions associated with cell rooms, hydrogen systems, caustic systems, and storage areas for mercury-

containing wastes. As described previously in Chapter 3, each is a potentially significant source of mercury emissions. Chlorine purification, brine preparation, and wastewater treatment operations are believed to have low mercury emissions to the air. Accordingly, the proposed rule contains no requirements for these operations.

Unit operations and emission points grouped within the mercury recovery facilities affected source include all mercury thermal recovery unit vents and fugitive mercury emissions associated with mercury-containing waste storage areas. Chemical mercury recovery and recovery in a batch purification still are believed to have low mercury emissions to the air. Accordingly, the proposed rule contains no requirements for these operations.

Therefore, the proposed rule contains requirements for four basic emission sources. These are (1) hydrogen by-product streams, (2) end-box ventilation system vents, (3) mercury thermal recovery unit vents, and (4) fugitive emission sources.

7.4 SELECTION OF THE FORM OF THE STANDARDS

Section 112 of the CAA requires that standards be specified as numerical emission standards, whenever possible. However, if it is determined that it is not feasible to prescribe or enforce a numerical emission standard, Section 112(h) indicates that a design, equipment, work practice, or operational standard may be specified.

With the exception of standards for fugitive emission sources, we are proposing numerical emission limits for all other mercury emission sources. Specifically, the proposed standards include numerical emission limits for by-product hydrogen streams, end-box ventilation system vents, and mercury thermal recovery unit vents.

Most fugitive mercury emission sources at mercury cell chlor-alkali plants are associated with cell rooms and storage areas for mercury-containing wastes. Cell rooms are ventilated in order to dissipate heat evolved by mercury cells and to reduce worker exposure to mercury vapor in the cell room environment. All cell rooms are ventilated along the length of the cell room roof, either by way of roof monitors or cupolas or through static or mechanically driven ventilators. Many are also ventilated through openings in the cell room walls. These conditions make the reliable measurement of mercury emissions from most cell rooms extremely difficult, if not totally impracticable, due to the number of openings needed to be sampled concurrently and the low flow of air through individual openings.

The measurement of mercury emissions from mercury-containing waste storage areas is also impracticable, as these are usually located in several places throughout a plant, many of which are open areas.

Not unexpectedly, emissions data on cell room and waste storage emissions are very limited, as in the case of cell rooms,

or non-existent, as in the case of waste storage areas. As such, we believe that it is not feasible to either prescribe or enforce numerical emission limit(s) for fugitive mercury emissions from cell rooms and waste storage areas. Consequently, the proposed standards address fugitive emission sources at mercury cell chlor-alkali plants through the establishment of work practice standards.

7.5 SELECTION OF THE BASIS AND LEVEL OF THE PROPOSED STANDARDS FOR EXISTING SOURCES

Section 112 of the CAA establishes a minimum baseline or "floor" for MACT standards. For new sources, the standards for a source category or subcategory cannot be less stringent than the emission control that is achieved in practice by the best-controlled similar source. The standards for existing sources may be less stringent than standards for new sources, but they cannot be less stringent than the average emission limitation achieved by the best-performing 12 percent of existing sources for categories and subcategories with 30 or more sources, or the average emission limitation achieved by the best-performing 5 sources for categories or subcategories with fewer than 30 sources for which the Administrator has emissions information.

After the floor has been determined for a category or subcategory, we must set MACT standards that are technically achievable and no less stringent than the floor. Such standards must then be met by all sources within the category or

subcategory. The regulatory alternatives selected for new and existing sources may be different because of different MACT floors, and separate emission limits may be established for new and existing sources.

We generally determine the MACT floor and then consider beyond-the-floor control options. Here, we consider the achievable reductions in emissions of HAPs (and possibly other pollutants that are co-controlled), cost and economic impacts, energy impacts, and other non-air environmental impacts. The objective is to achieve the maximum degree of HAP emission reduction without incurring unreasonable cost or other impacts.

The remainder of this section discusses the proposed standards for mercury emission sources at existing sources. Specifics on the environmental and energy impacts cited in this section may be found in Chapter 5, and specifics on costs may be found in Chapter 6.

7.5.1 By-Product Hydrogen Streams and End-Box Ventilation System Vents

The fundamental unit in the mercury cell chlor-alkali process is a mercury cell. The by-product hydrogen stream and the end-box ventilation system vent represent the mercury emission point sources that originate from a mercury cell. Hydrogen gas is incidentally produced as a result of the catalyzed reaction of sodium/mercury amalgam and deionized water to produce caustic in a decomposer. The end-box ventilation

stream is a collection of vapors from head spaces of end boxes and possibly other vessels, including pump tanks and seal legs, wash water tanks, and caustic tanks and headers. The mercury content of the by-product hydrogen stream and the end-box ventilation stream, prior to control, is a direct function of the design of the mercury cell. As discussed in Section 2.3, ten different mercury cell models are used by the twelve mercury cell chlor-alkali plants. Given these differences in cell design and their effect on potential vent mercury emissions, we opted to develop a cell-wide standard for mercury emissions from both points.

Given the large variation among the plants in terms of production that was shown in Table 2-1 (the largest plant produces over five times as much chlorine as the smallest) and mercury emissions potential, we concluded that any equitable assessment of MACT should account for this disparity. We selected the actual amount of chlorine produced by weight as the uniform parameter for our analysis for the following reasons: (1) chlorine is the primary product generated; (2) chlorine production can be accurately determined; and (3) chlorine and hydrogen are generated in the same stoichiometric quantities, that is one molecule of hydrogen is produced for each molecule of chlorine produced.

We then considered the fact that two plants do not have end-box ventilation systems, as discussed in Chapter 3. Both plants

operate cells with closed end boxes. Consequently, there is no need for end-box ventilation and therefore no end-box ventilation system emission point. Next, we examined whether the mercury cells at the ten plants equipped with end-box ventilation systems could be reconfigured with closed end boxes. We concluded that the use of an end-box ventilation system is an inherent feature of the original design of a cell, and that it is not technically feasible to eliminate end-box ventilation systems at these plants. We have, therefore, decided to distinguish plants with end-box ventilation systems and plants without these systems for purposes of establishing MACT.

Accordingly, we are proposing, for plants with end-box ventilation systems, a single emission limit for mercury emissions from all by-product hydrogen streams and mercury emissions from all end-box ventilation system vents, in units of mass of mercury emissions per mass of chlorine produced. For plants without end-box ventilation systems, we are proposing an emission limit for mercury emissions from all by-product hydrogen streams, also in units of mass of mercury emissions per mass of chlorine produced.

7.5.1.1 Emission Limit for Plants With End-Box Ventilation Systems. In order to establish MACT for the combined mercury emissions from by-product hydrogen streams and end-box ventilation system vents, we relied on estimates of annual mercury emissions for each vent and information on annual

chlorine production provided by the ten plants with end-box ventilation systems. A total of twenty mercury emission estimates were provided, one emission estimate for all by-product hydrogen streams and one emission estimate for all end-box ventilation system vents at each of the ten plants. A summary of each emission estimate and its basis is shown in Table 7-1.⁴

Of the twenty emission estimates, fourteen (six for by-product hydrogen streams and eight for end-box ventilation system vents) are based on stack tests performed in accordance with established EPA reference methods specific to chlor-alkali plants. These include Method 101 for the determination of particulate and gaseous mercury from air streams (i.e., end-box ventilation system vents) and Method 102 for the determination of mercury in hydrogen streams. We obtained and reviewed copies of all available test reports and determined that the tests were conducted correctly.

Six emission estimates (four for by-product hydrogen streams and two for end-box ventilation system vents) are based on periodic measurements of mercury concentration in the vent streams. These methods, which are all very similar, involve pulling a gas sample through impingers containing potassium permanganate solution, followed by cold vapor atomic absorption analysis in a laboratory setting. These methods are adaptations of EPA Method 101A and Method 102. One difference is that sampling for these methods is not isokinetic, which is required

TABLE 7-1. BY-PRODUCT HYDROGEN STREAM AND END-BOX VENTILATION SYSTEM VENT MERCURY EMISSIONS FOR PLANTS WITH END-BOX VENTILATION SYSTEMS

| Plant | Mercury Emissions (grams per year) | | | | | Annual Chlorine Production (megagrams per year) | Normalized Mercury Emissions (grams mercury emitted per megagram chlorine produced) |
|--------------------------------------|------------------------------------|------------------------------------|---------------------------------|------------------------------------|----------|---|---|
| | By-product hydrogen Stream | Bas's | End-Box Ventilation System Vent | Basis | Combined | | |
| Holtrachem - Or.ington, ME | 3,298 | Testing (Method 102, 12/97) | 1,093 | Testing (Method 101, 12/97) | 4,391 | 65,859 | 0.067 |
| Occidental - Delaware City, DE | 562 | Modified Method 102 sampling | 9,526 | Modified Method 101 sampling | 10,088 | 132,449 | 0.076 |
| Pioneer - St. Gabriel, LA | 8,618 | Modified Method 102 sampling | 10,433 | Testing (Method 101A, 1988) | 19,051 | 173,273 | 0.11 |
| Vulcan - Port Edwards, WI | 6,804 | Testing (Method 102, 10/98) | 3,720 | Testing (Method 101A, 10/98) | 10,524 | 71,092 | 0.15 |
| PPG - Lake Charles, LA | 136 | OSHA-based sampling | 74,390 | Testing (Method 101, 3/88) | 74,526 | 234,054 | 0.32 |
| Westlake - Calvert City, KY | 70,308 | Modified Method 101 sampling | 3,130 | Testing (Method 101, 12/98) | 73,437 | 111,040 | 0.66 |

TABLE 7-1. BY-PRODUCT HYDROGEN STREAM AND END-BOX VENTILATION SYSTEM VENT MERCURY EMISSIONS FOR PLANTS WITH END-BOX VENTILATION SYSTEMS (continued)

| Plant | Mercury Emissions (grams per year) | | | | Annual Chlorine Production (megagrams per year) | Normalized Mercury Emissions (grams mercury emitted per megagram chlorine produced) |
|-----------------------|------------------------------------|----------------------------------|---------------------------------|----------------------------------|---|---|
| | By-product hydrogen Stream | Basis | End-Box Ventilation System Vent | Basis | Combined | |
| PPG - Natrrium, WV | 9,390 | Testing (10/87) | 38,783 | Testing (3/88) | 48,172 | 0.73 |
| Olin - Charleston, TN | 181,439 | Testing (in-house method, 09/88) | 22,680 | Modified Method 101 sampling | 204,119 | 0.86 |
| Olin - Augusta, GA | 104,554 | Testing (in-house method, 12/87) | 18,371 | Testing (in-house method, 10/87) | 122,925 | 1.14 |
| ASHTA - Ashtabula, OH | 45,360 | Testing (Method 102, 4/97) | 102,059 | Testing (Method 101, 4/97) | 147,419 | 3.42 |

for valid Method 101A and 102 tests. Although generally desirable, isokinetic sampling is not critical for gases and fine particulate, such as mercury vapor and condensate that is believed to comprise most of the mercury in these exhaust streams. Based on our review of the sampling and analytical procedures employed in these methods, we believe that this "potassium permanganate non-isokinetic" methods are capable of producing measurements of reasonable accuracy. As such, we believe that they provide reasonably accurate results consistent with what would otherwise be obtained with the EPA reference test methods. Our conclusion is that these data represent the best information available on mercury emissions from these vents, and that they are appropriate for use in establishing MACT.

The MACT floor was calculated as follows. For each plant, we divided the sum of the reported annual mercury emissions from all by-product hydrogen streams and end-box ventilation system vents by the annual chlorine production. The chlorine production values used are largely representative of actual annual chlorine production levels. We then ranked the plants from lowest to highest emitters for combined normalized mercury emissions. The resulting plant-specific values are shown in Table 7-1. The normalized mercury emission values range from 0.067 grams Hg/Mg Cl_2 to 3.42 grams Hg/Mg Cl_2 . We should note that the lowest value, 0.067 grams Hg/Mg Cl_2 , is from the plant that closed permanently in September 2000 (Holtrachem in Orrington, Maine).

Nonetheless, we believe that it is appropriate to retain it in the pool of existing sources used to determine existing source MACT. This plant closure is a recent event, and prior to closure, the plant was the lowest-emitting and best-performing source. The average (mean) of the best (lowest) five normalized values results in a floor value for existing sources of 0.14 grams Hg/Mg Cl₂.

Of the ten plants with by-product hydrogen streams and end-box ventilation systems, we project that seven would need to install additional controls or upgrade existing controls to meet the 0.14 grams Hg/Mg Cl₂ floor level. We assume that the plant-specific actions that were shown in Table 5-2 could reduce mercury emissions at least to the 0.14 gm Hg/Mg Cl₂ floor option.

We estimate that the total installed capital control costs needed to meet the existing source MACT floor to be about \$660,000. We estimate total annual control costs, including costs for labor, materials, electricity, capital recovery, taxes, insurance, and administrative charges (excluding costs for monitoring, reporting, and recordkeeping), to be about \$570,000 per year. Mercury emission reductions against actual emissions, as represented by the emission estimates in Table 7-1, would total 556 kg/yr (1,225 lbs/yr). Mercury emission reductions against the potential-to-emit baseline, as represented by the allowable emissions under the part 61 NESHAP, would total over 3,400 kg/yr (over 7,500 lbs/yr). The associated annual cost per

unit of mercury emission reduction values would be approximately \$465 per pound (actuals baseline) and under \$80 per pound (potential-to-emit baseline), respectively.

Water pollution impacts, due to the increased use of packed bed scrubbers involving aqueous hypochlorite scrubbing solution on end-box ventilation systems, are estimated to total 1.2 million liters (320 thousand gallons) of additional wastewater. Impacts on solid waste, due to increased use of carbon adsorption for by-product hydrogen streams, are estimated to total 17 Mg/yr (19 tons/yr) of mercury-containing spent carbon. Energy requirements are estimated to total an additional 878 thousand kilowatt-hours per year (kW-hr/yr). Estimated secondary air pollution impacts due to heightened energy consumption total 282 Mg/yr (311 tons/yr), with carbon dioxide emissions comprising 99 percent of the estimate.

We then examined beyond-the-floor MACT options. We selected the lowest normalized value among the ten plants; namely 0.067 grams Hg/Mg Cl_2 assigned to Holtrachem in Orrington, Maine, as a beyond-the-floor option. This corresponds to 0.05 grams Hg/Mg Cl_2 from the by-product hydrogen stream, which is controlled by a condenser coupled with a molecular sieve adsorber, and 0.017 grams Hg/Mg Cl_2 from the end-box ventilation system vent, which is also controlled by a condenser coupled with a molecular sieve adsorber. It is our understanding that molecular sieve technology for mercury vapor emission control is

no longer commercially available.⁵ We, thus, acknowledge some uncertainty associated with the achievability of this level of control. However, we believe that other technologies and operating practices exist that can achieve this level of emissions control.

Due to the very low volumetric flow rates associated with both by-product hydrogen streams and end-box ventilation system vents (typically less than 5,000 scfm and 4,500 scfm, respectively), we believe that the retrofit of control equipment to reduce mercury emissions is both practical and reasonable. We project that the nine plants with emissions above 0.067 grams Hg/Mg Cl₂ could install additional controls or upgrade existing controls to meet the 0.067 grams Hg/Mg Cl₂ beyond-the-floor option, as was shown in Table 5-2.

In evaluating regulatory options that are more stringent than the floor, we must consider the cost of achieving such emission reduction, and any non-air quality health and environmental impacts and energy requirements. The beyond-the-floor option would result in an additional 65 kg/yr (143 lb/yr) of total mercury emission reductions (a 48 percent incremental reduction from the floor option). The incremental installed capital costs are estimated to total around \$210,000, and the incremental annual costs are estimated to total around \$150,000 per year. The incremental cost per unit of incremental mercury emission reduction is \$900 per pound.

The incremental water pollution impacts are estimated to total 550 thousand liters (145 thousand gallons) of additional wastewater. The incremental solid waste impacts are estimated as 5.1 Mg/yr (5.6 tons/yr) of mercury-containing spent carbon in total. The incremental energy impacts are estimated as 110 thousand kW-hr/yr in total. The incremental secondary air pollution impacts are estimated to total 35 Mg/yr (39 tons/yr), with carbon dioxide emissions comprising 99 percent of the estimate.

We believe the additional emission reduction that would be achieved by the beyond-the-floor option is warranted. Further, we believe that the incremental costs of achieving such emission reduction, as well as incremental non-air environmental impacts and energy requirements, are reasonable for mercury. Therefore, we selected the 0.067 grams Hg/Mg Cl₂ beyond-the-floor option as MACT for plants with end-box ventilation systems.

If comments are received on the proposed rule that lead us to conclude that this level of control is unachievable, we retain the option of setting the standard at the next lowest normalized emission value. Accordingly, we have evaluated the impacts of an alternative 0.076 grams Hg/Mg Cl₂ mercury emission limit for plants with end-box ventilation systems.

We project that the eight plants with baseline emissions greater than 0.076 grams Hg/Mg Cl₂ would need to install new controls or upgrade existing controls to meet this level. This

would result in an additional 65 kg/yr (143 lb/yr) of total mercury emission reductions (a 41 percent incremental reduction) from the floor option. We assume the same plant-specific actions as those assumed to meet the 0.067 grams Hg/Mg Cl₂ value, given the small difference in emission reductions at the two levels. The incremental installed capital costs are estimated to total around \$197,000, and the incremental annual costs are estimated to total around \$125,000 per year. The incremental cost per unit of incremental mercury emission reduction is \$875 per pound.

The incremental water pollution impacts are estimated to total 317 thousand liters (84 thousand gallons) of additional wastewater. The incremental solid waste impacts are estimated as 5.1 Mg/yr (5.6 tons/yr) of mercury-containing spent carbon in total. The incremental energy impacts are estimated as 105 thousand kW-hr/yr in total. The incremental secondary air pollution impacts are estimated to total 34 Mg/yr (37 tons/yr), with carbon dioxide emissions comprising 99 percent of the estimate.

7.5.1.2 Emission Limit for Plants Without End-Box Ventilation Systems. In order to establish MACT for mercury emissions from by-product hydrogen streams for the two plants without end-box ventilation systems (Occidental in Muscle Shoals, Alabama and Occidental in Deer Park, Texas), we used estimates of annual mercury emissions from by-product hydrogen streams and information on actual chlorine production provided by the two

plants for 1997.⁶ Both emission estimates are based on periodic measurements of mercury concentration in the vent streams obtained using potassium permanganate non-isokinetic methods, which we believe provide reasonably accurate results consistent with what would otherwise be obtained with EPA reference test methods, as discussed in Section 7.5.1.1.

For each plant, we divided the reported annual mercury emissions from by-product hydrogen streams by the annual chlorine production. The normalized values are 0.033 grams Hg/Mg Cl₂ for Occidental/Muscle Shoals and 0.17 grams Hg/Mg Cl₂ for Occidental/Deer Park. Although there are fewer than five sources from which to constitute a MACT floor, we opted to take the average (mean) of the two normalized values, resulting in 0.10 grams Hg/Mg Cl₂ as the floor value for existing sources. We assume that Occidental/Deer Park could reduce mercury emissions to the 0.10 gm Hg/Mg Cl₂ floor option by replacing the carbon in its existing carbon adsorbers on by-product hydrogen streams more frequently than current practice. No capital costs are associated with meeting this level, as more frequent carbon media replacement was estimated as only a recurring (annual) cost of \$13,000 per year. Mercury emission reductions against actual emissions would total 6 kg/yr (14 lbs/yr). Mercury emission reductions against the potential-to-emit baseline, as represented by the allowable emissions under the part 61 NESHAP, would total over 600 kg/yr (over 1,300 lbs/yr). The associated annual cost

per unit of mercury emission reduction values would be approximately \$940 per pound and under \$10 per pound, respectively. With the assumption of more frequent carbon media replacement at Occidental/Deer Park, there are no associated secondary air pollution, water pollution, and energy impacts. Estimated solid waste impacts, due to increased use of carbon adsorption, total 1.0 Mg/yr (1.1 tons/yr).

We then examined beyond-the-floor MACT options. We selected the lowest normalized value among the two plants, namely 0.033 grams Hg/Mg Cl₂ assigned to Occidental/Muscle Shoals, as a beyond-the-floor option. This corresponds to this plant's by-product hydrogen stream controlled by a condenser coupled with a carbon adsorber.

As stated above, we believe that the retrofit of control equipment to reduce mercury emissions is quite practical and reasonable largely due to the low volumetric flow rates associated with by-product hydrogen streams. For purposes of estimating impacts, we assumed that Occidental/Deer Park would replace its existing carbon adsorber with a new, larger adsorber to meet the 0.033 grams Hg/Mg Cl₂ level.

In evaluating regulatory options that are more stringent than the floor, we must consider the cost of achieving such emission reduction, and any non-air quality health and environmental impacts and energy requirements. The beyond-the-floor option would result in an additional 6 kg/yr (14 lb/yr) of

total mercury emission reductions for the two plants (a 47 percent incremental reduction from the floor option). The incremental installed capital costs are estimated to total around \$182,000. The incremental annual costs are estimated to total around \$126,000 per year. The incremental cost per unit of incremental mercury emission reduction is approximately \$9,000 per pound. There are no associated incremental water pollution impacts. The estimated incremental solid waste impacts total an additional 5.3 Mg/yr (5.8 tons/yr) of mercury-containing spent carbon. The incremental energy impacts are estimated as 252 thousand kW-hr/yr in total. The incremental secondary air pollution impacts are estimated to total 81 Mg/yr (89 tons/yr), with carbon dioxide emissions comprising 99 percent of the estimate.

We believe the additional emission reduction that would be achieved by the beyond-the-floor option is warranted. Further, we believe that the incremental costs of achieving such emission reduction, as well as incremental non-air environmental impacts and energy requirements, are reasonable for mercury. Therefore, we selected the 0.033 grams Hg/Mg Cl₂ level as MACT for plants without end-box ventilation systems, which is approximately half the level selected for plants with end-box ventilation systems.

7.5.2 Sources of Fugitive Mercury Emissions

As explained above, we have determined that work practice standards provide the most appropriate approach for addressing

fugitive mercury emissions at mercury cell chlor-alkali plants. Every mercury cell chlor-alkali plant is currently subject to the part 61 NESHAP and implements the design, maintenance, and housekeeping practices referenced in the NESHAP to control fugitive cell room emissions. We believe that these existing requirements represent the MACT floor for existing mercury fugitive emission sources. Since these floor requirements are currently observed at each existing plant, a standard based on this floor level of control would not be expected to reduce mercury emissions from current levels, or produce any associated cost, non-air environmental, or energy impacts.

We then examined beyond-the-floor options. We noted that many of the existing work practice requirements are general in nature and non-specific relative to the frequency and scope of inspections, as well as recordkeeping and reporting. We decided that clarification and elaboration on these general practices was warranted to make them more explicit and to improve assurance of compliance. Accordingly, we initiated a thorough examination of specific measures employed across the industry to limit fugitive mercury emissions.

In the summer of 1998, we conducted site visits, lasting from one to four days each, to five mercury cell chlor-alkali plants to observe and document their design, operational, maintenance, housekeeping, and recordkeeping practices.^{7,8,9,10,11} The five plants were selected to provide a

broad representation of ownership (the five plants are owned by five different companies) and different mercury cell models (mercury cells made by all three manufacturers and of varying sizes are represented). We also selected plants in different areas of the United States to account for geographical variations, such as climate. In addition to the site visits, we obtained current standard operating procedures for mitigating sources of fugitive mercury emissions from all twelve plants. We used this knowledge and information to develop a detailed compilation of practices currently used across the industry to control fugitive mercury emissions.¹²

We used this compilation to identify explicit practices for each individual plant area, equipment type, and inspection procedure, and assembled them as beyond-the-floor work practice requirements. We feel that the resulting work practice standards represent the most stringent practices applied in the industry.

The types of enhancements from the MACT floor level requirements that are included in the beyond-the-floor option may be generally classified in three categories. First, the beyond-the-floor requirements add considerable specificity. The equipment and areas to be inspected are identified, along with the required frequency of the inspections and the conditions that trigger corrective action. Response time intervals for when the corrective actions must occur are also included. Second, some types of inspections are required at more frequent intervals than

required by the part 61 NESHAP (e.g., inspecting decomposers for hydrogen leaks once each 12 hours rather than once each day).

Third, the beyond-the-floor option includes additional requirements not included in the floor level. The two most obvious examples of this are the detailed recordkeeping procedures and reporting provisions, which are more fully developed than those in the part 61 NESHAP, and the requirements for storage of mercury-containing wastes.

Also included in the beyond-the-floor option is a requirement for owners and operators to develop and implement a plan for the routine washdown of accessible surfaces in the cell room and other areas. All plants currently wash down cell room surfaces regularly. However, due to plant-specific considerations, we are uncomfortable with issuing a specific set of requirements for washdowns that would apply at all plants. As a result, the beyond-the-floor option establishes the duty for owners or operators to prepare and implement a written plan for washdowns and identifies elements to be addressed in the plan. Although washdowns are an ongoing practice at all plants, we believe that including such a requirement in the beyond-the-floor option will elevate the importance of washdowns as part of an overall approach to reducing cell room fugitive emissions.

As a final element of the beyond-the-floor option, we considered the extent to which measurement of ambient mercury levels in the cell room air should be incorporated. Currently,

all mercury cell chlor-alkali plants periodically monitor mercury vapor levels at the cell room floor plane, in keeping with Occupational Safety and Health Administration (OSHA) standards for worker exposure to mercury. Typically, on a daily basis, a plant operator measures and records the mercury vapor level in the cell room. Some plants use technologies that measure the mercury vapor level at a single point, such as portable mercury vapor analyzers based on ultraviolet light absorption or gold film amalgamation detection. Plant operators using these technologies take readings at specified locations in the cell room. Other plants utilize procedures that provide an aggregate reading, such as chemical absorption into potassium permanganate solution followed by separate cold vapor atomic absorption analysis in a laboratory setting. This composite sample is most often obtained by a plant operator walking through the cell room with a small sampling pump.

When a mercury vapor level above the OSHA personal exposure limit is measured, plant operators require the use of respirators in the area. They also take action to determine and eliminate the cause of the elevated mercury level.

Given the fact that all plants conduct cell room mercury vapor measurements, we determined that it was appropriate to include requirements to conduct cell room monitoring as a means to identify and correct situations resulting in elevated mercury levels (and obviously, increased mercury emissions) as part of

the beyond-the-floor option for fugitive mercury emission sources. We considered basing such a program on periodic measurement, which would correspond to the programs currently in place at mercury cell chlor-alkali plants. We also considered basing such a program on the continuous measurement of mercury vapor levels in the upper portions of the cell room. We are aware of technologies, including extractive, cold vapor spectroscopy systems and open-path, differential optical absorption spectroscopy systems, designed for such continuous monitoring applications.

Upon consideration of the benefits of periodic versus continuous monitoring of the cell room mercury vapor levels, we selected continuous monitoring as part of the beyond-the-floor option monitoring program for the following reasons. First, we believe that continuous monitoring would identify hydrogen leaks or other situations that result in elevated mercury levels in the cell room much more promptly than periodic monitoring. If periodic monitoring was conducted on a daily basis, hours could pass before such a leak was detected. We also believe that the continuous monitoring of mercury vapor levels during maintenance activities would provide information to help plant operators refine and improve such maintenance activities to reduce mercury emissions.

Finally, we believe that the monitoring on the cell room floor plane could fail to detect hydrogen leaks, or other

situations resulting in mercury vapor leaks, that may occur at higher elevations. Continuous monitoring in the upper portion of the cell room would provide a representation of all areas of the cell room at all levels.

Therefore, we have included a program involving the continuous monitoring of mercury vapor levels in the cell room as part of the beyond-the-floor option. We envision the basic elements for this program to be as follows. Each owner or operator would be required to install a mercury monitoring system in each cell room and continuously monitor the elemental mercury concentration in the upper portion of the cell room. The type of technology, whether an extractive, cold vapor spectroscopy system or an open-path, differential optical absorption spectroscopy system, would be at the discretion of the owner or operator, provided that performance criteria, such as a minimum detection limit, were met. A sampling configuration would be specified to acquire a composite measurement representative of the entire cell room air. For example, the sampling configuration may involve sampling at least three points along the center aisle of the cell room and above the mercury cells at a height sufficient to ensure representative readings.

For each cell room, the owner or operator would need to establish an action level, which would be based on preliminary monitoring to determine normal baseline conditions. The onset and duration of this preliminary monitoring would be specified,

as well as guidelines for setting the action level. Continuous monitoring would commence after a specified time period following establishment of the action level and its documentation in a notification to us. A minimum data acquisition requirement would be established, such as a requirement to collect and record data for at least a certain percent of the time in any six-month period.

Actions to correct the situation as soon as possible would be required when measurements above the action level were obtained over a defined duration, such as a certain number of consecutive measurements or an average over a certain time period above the action level. If the elevated mercury vapor level was due to a maintenance activity, the owner or operator would need to keep records describing the activity and verifying that all work practices related to that maintenance activity are followed. If a maintenance activity was not the cause, then inspections and other actions would need to be conducted within specific time periods to identify and correct the cause of the elevated mercury vapor level.

In evaluating whether to establish the beyond-the-floor option as MACT, we looked at the incremental impacts on emissions, cost, energy, and other non-air effects. Relative to emissions, we firmly believe that although we are unable to actually quantify the reductions expected with the implementation of the beyond-the-floor option, substantial reductions would

nonetheless occur. We know from experience and inference that the added scrutiny inherent in the suite of beyond-the-floor practices will of necessity result in fewer fugitive emissions. In considering the cost impacts of the beyond-the-floor option, we attempted to estimate the cost associated with the equipment needed to carry out cell room monitoring as well as increased demand for labor and overhead needed to fully implement the proposed monitoring, inspection, recordkeeping, and reporting activities. We estimate the total installed capital costs needed to meet the beyond-the-floor option for fugitive mercury emissions to be around \$663,000. We estimated the total annual costs to be around \$840,000, consisting of about \$94,000 for annualized capital expenditure on mercury monitoring systems, about \$736,000 per year for labor for monitoring, inspections and recordkeeping, about \$2,100 per year for mercury monitoring system utilities, and about \$7,500 for mercury monitoring system replacement parts. We are unable to estimate increases in wastewater associated with washdown and clean-up activities for liquid mercury spills and accumulations as well as increases in solid waste, since these would be highly plant-specific. Energy requirements for mercury monitoring systems are estimated to total an additional 53 thousand kW-hr/yr. Estimated secondary air pollution impacts due to heightened energy consumption total 17 Mg/yr (19 tons/yr), with carbon dioxide emissions comprising 99 percent of the estimate.

We believe the additional emission reduction that would be achieved by the beyond-the-floor option is warranted and that the estimated incremental costs to meet this level are reasonable. Therefore, we are selecting the beyond-the-floor work practice standards as MACT for fugitive mercury emission sources.

With regard to the cell room monitoring program, we acknowledge that there are uncertainties associated with the use of mercury monitoring systems for continuous monitoring that can only be addressed through actual field validation. In the preamble for the proposed rule, we are specifically requesting comment on the feasibility of using such systems for continuous monitoring to prompt corrective actions for elevated mercury vapor levels in the cell room. We are also requesting comment on the detailed elements of the cell room monitoring program, which we are unable to delineate in its entirety at this time.

Following publication of the proposed rule, we will involve the public in defining this program. Specifically, we will enter into a joint effort with industry, monitoring instrument suppliers, and other interested parties, to detail the elements and requirements of this program. We will take additional appropriate rulemaking steps as necessary to fully implement this program, including assuring opportunity for industry and the public to comment.

7.5.3 Mercury Thermal Recovery Unit Vents

Nine of the twelve mercury cell chlor-alkali plants have mercury recovery processes. Six of the nine plants operate a thermal recovery unit, in which mercury-containing wastes are heated and the resulting mercury-laden off-gas is cooled and treated for mercury removal prior to being discharged to the atmosphere. Two plants recover mercury with a chemical process and one plant recovers mercury in a purification still; in both cases, mercury air emissions are believed to be low.

In establishing MACT for mercury thermal recovery units, we obtained information from all six plants with these units.^{13,14} Each plant provided descriptions of its thermal recovery operation, including the types of wastes processed and the control devices applied. Where available, plants also provided results of performance testing or periodic sampling, and an estimate of their mercury emissions.^{15,16,17,18}

Each of the six plants operates one or more retorts (as part of its mercury thermal recovery unit) in which mercury-containing wastes are heated to a temperature sufficient to volatilize the mercury. The off-gas containing mercury vapor is then cooled in the mercury recovery/control system, causing the mercury to condense to liquid. The liquid mercury condensate is then collected from recovery devices for reuse in the mercury cells. The primary emission source is the mercury thermal recovery unit vent, where off-gas that has passed through the recovery/control

system is discharged to the atmosphere. Retorts used include three basic designs: batch oven (three plants), rotary kiln (two plants), and single hearth (one plant).

The batch ovens are D-tube retorts, which are so named because each resembles an uppercase letter "D" on its side. Pans are filled with waste, typically around 10 cubic feet, and then placed into an oven. After inserting three or four pans, the oven door is closed and the retort is indirectly heated to about 1,000°F. The residence time varies from about 24 to 48 hours, depending on the type of waste being processed. While heating, the oven is kept under a vacuum and the mercury vapors are pulled into the mercury recovery/control system. After the cycle is completed, the unit is allowed to cool and the pans are then removed.

The rotary kilns are long, refractory-lined rotating steel cylinders in which the waste charge to be treated flows counter current to hot combustion gases used for heating. Wastes to be treated are conveyed into a ram feeder, which inserts a waste charge into the kiln at regular intervals, typically about every five minutes. Each is directly fired with natural gas and is heated to over 1300°F. The rotation of the kiln provides for mixing and transfer of the waste to the discharge end. The residence time is about 3 hours. The gas stream leaving the kiln passes through an afterburner, where the temperature is increased

to around 2,000°F to complete combustion reactions involving sulfur and carbon, and then to a mercury recovery/control system.

The single hearth retort is comprised of a vertically-mounted, refractory lined vessel with a single hearth and a rotating rabble. Waste is charged onto the hearth through a charge door by way of a conveyor. Once charged, the conveyor is withdrawn, the charge door is closed, and the heating or treatment cycle begins. The waste is stirred by the rabble rake, which turns continuously, and is heated to around 1,350°F. The residence time, which ranges according to waste type, is typically much longer than for rotary kilns. Similar to rotary kilns, the gas stream leaving the hearth retort passes through an afterburner, where the temperature is increased to around 2,000°F to complete combustion reactions involving sulfur and carbon, and then to a mercury recovery/control system.

As noted above, there are several important differences between the oven retorts, and the non-oven (rotary kiln and single hearth) retorts related to operating temperature and residence time. There are also significant differences in the volumetric flow rates produced by the oven and the non-oven retorts. Oven retorts typically have volumetric flow rates around 100 scfm, which is an order of magnitude lower than flow rates for non-oven retorts, which are around 1,000 scfm. Together, these differences can have a material impact on mercury concentration, mass flow rate of mercury, and other factors that

influence mercury loadings to the recovery/control system. After evaluation of these technical and operational differences between oven retorts and non-oven retorts, and their potential effect on emissions characteristics and control device applicability, we are proposing to distinguish between retort types for the purpose of establishing MACT.

With the exception of the plant with a single hearth retort that is controlled with a scrubber as the final control device, the recovery/control system at each plant consists of condensation and carbon adsorption. The amount and type of carbon adsorbent used in the fixed bed, non-regenerative carbon adsorbers varies among the five plants. One plant uses activated carbon, one uses iodine-impregnated carbon, and three use sulfur-impregnated carbon. We believe that each type is effective in removing mercury, provided the adsorbent is replaced at a frequency appropriate to prevent breakthrough.

In contrast, the plant with the single hearth retort utilizes a chlorinated brine packed-tower scrubber for final mercury control. In this scrubber, elemental mercury vapor is removed by chemically reacting with the chlorinated brine solution to form mercuric chloride, a non-volatile mercury salt which is readily soluble in aqueous solutions. The resulting scrubber effluent is returned to the brine system, causing the absorbed mercury to be recycled back to the mercury cells. Performance data (i.e., outlet concentration) for this brine

scrubber system shows that the effectiveness is comparable to that of the condenser/carbon adsorber systems used at the other five plants.¹⁹

While examining the performance capabilities of the condenser/carbon adsorber systems, we identified several factors that influence performance. We believe that a primary factor affecting mercury recovery and control is the temperature to which retort off-gas is cooled prior to entering the final control device. Because of the volatile nature of elemental mercury, temperature has a direct effect on the concentration of mercury vapor that can exist in a gas stream. For example, the concentration of mercury vapor that could exist in a gas stream at 50°F is 5 mg/m³, while the predicted concentration at 85°F is 30 mg/m³, a six-fold increase. At 100°F the concentration could potentially be over 50 mg/m³.²⁰

A key factor relative to the performance of carbon adsorbers is contact time. As noted previously, we believe that generally each of the carbon adsorbents presently used in the industry can effectively collect mercury vapor. However, it is essential for optimum performance that the contact time between the gas stream to be treated and the carbon adsorbent be long enough to allow for maximum adsorption. Consequently, design and operational factors such as carbon bed depth, sorbent particle size, and gas velocity have an appreciable impact on collection efficiency. Another key consideration is the frequency at which the adsorbent

is replaced, since the adsorbing capacity of any sorbent decreases as saturation and breakthrough are approached.

In assessing potential formats for a numerical emission limit we considered a limit on emissions in a specified time period, a limit normalized on the amount of wastes processed, and an outlet mercury concentration limit. The amounts and types of wastes processed at each plant and among plants vary considerably. We believe, generally, that mercury emissions from the thermal recovery unit vent are proportional to the amount of mercury-containing wastes processed and the amount of mercury contained in these wastes. Therefore, we concluded that limiting emissions over a specified time period would unfairly impact plants that process larger amounts of wastes and/or wastes that contain more mercury. A mercury emission limit normalized on the amount of wastes processed would eliminate this inequity. However, given the wide variation in the mercury content of different types of wastes and the varying mix of waste types processed at different plants, we concluded that setting and enforcing such an emissions limit is impractical.

Several factors influence the concentration of mercury in the thermal recovery unit vent exhaust. The most significant include the mercury content of the wastes being processed and the volumetric flow rate through the system. Volumetric flow rate is dependent on process rate, fuel usage, and the volume of combustion gas generated. The mercury concentration may also

vary depending on the stage of the heating cycle. The mercury content of the exhaust stream leaving the condenser(s) or other type of cooling unit should remain relatively constant, provided that the outlet temperature is constant and the residence time is sufficient. Depending on the effectiveness of the carbon adsorber or brine scrubber, the mercury concentration would be further reduced. As a result, we conclude that concentration at the outlet of the final control device is the most meaningful and practical measure of the combined performance of each element of the mercury recovery/control system. Therefore, we selected concentration for the format of the MACT standard for mercury thermal recovery units.

Finally, we evaluated how, or if, the proposed regulation should address different waste types; that is, should different emission limits be set for different waste types or should one limit be set for the waste type shown to be the highest emitting. We analyzed all the available data but were unable to ascertain any relationship between the type of waste (K106, D009 debris, or D009 non-debris) being treated during testing or sampling and the outlet mercury concentration measured across all plants.²¹ As a result, we are proposing an outlet mercury concentration limit that is neutral to the type of waste being processed. This analysis also influenced our decision on the proposed requirements for performance testing. We are proposing that testing be conducted during conditions representative of the most

extreme, relative to potential mercury concentration, expected to occur under normal operation. While we would have preferred that the proposed rule specify the type of waste to be processed during testing, our inability to discern a relationship between waste type and outlet mercury concentration across plants caused us not to do so. Therefore, the proposed rule obligates owners and operators to process mercury-containing wastes that result in the highest vent mercury concentration during performance testing.

In summary, our review and analysis of all the available information on mercury thermal recovery units leads us to the following conclusions:

- (1) Separate MACT emission limits should be developed for oven type and non-oven (rotary kiln and single hearth) type mercury thermal recovery units.
- (2) These emission limits should not distinguish among waste types processed.
- (3) Concentration is the appropriate format for the numerical emission limits.

The following describes how we selected the proposed emission limits for oven type and non-oven type mercury thermal recovery units.

7.5.3.1 Emission Limit for Oven Type Mercury Thermal Recovery Unit Vents. There are three plants that use oven retorts. All are owned and operated by the same company

(Occidental Chemical). The Occidental Plant in Delaware City, Delaware operates five ovens, the one in Muscle Shoals, Alabama operates three ovens, and the one in Deer Park, Texas operates two ovens. Thermal recovery at all three plants is conducted between 6,000 to 7,000 hours per year. The amounts of waste processed and the amounts of mercury recovered range from 90 to almost 300 tons per year and from 3 to 20 tons per year, respectively. At all three plants, the mercury-laden off-gas leaving the retort is cooled and treated for particulates and acid gases in a wet scrubber with caustic solution, followed by further cooling in a condenser. The cooled gas is then routed through one or more fixed-bed, non-regenerative carbon adsorbers before being discharged to the atmosphere. We conducted an evaluation of the mercury recovery/control systems at all three plants considering the condenser outlet temperature and the amount of carbon in the beds. This evaluation indicated that the Delaware City plant is the best-controlled of the three plants.²²

Occidental/Delaware City provided mercury emissions data (periodic sampling results) over three years.²³ The Occidental plants in Muscle Shoals and Deer Park were unable to provide reliable emissions data. Therefore, data from the Delaware City plant were used to establish MACT. Since an emission limit based on the best controlled plant would obviously be more stringent than the floor level, the selection of a level associated with the best performing recovery/control system for this retort type

clearly meets our statutory requirement regarding the minimum level allowed for NESHAP.

Occidental/Delaware City has five ovens and two separate (but identical) mercury recovery/control systems. One, designated as Stack 1, treats the exhaust gas from three ovens while the second, designated as Stack 2, services two ovens. Together, the five ovens process about 90 tons of mix waste annually, and recover about 3 tons of mercury per year. Each system is comprised of a wet scrubber and condenser, which cool the exhaust gases to around 70°F, followed by a carbon adsorber with about 700 pounds of activated carbon. The volumetric flow rate of the exhaust stream ranges from about 10 scfm to 110 scfm and averages about 40 scfm.

The data from Occidental/Delaware City consist of bimonthly measurements for 1997, 1998, and 1999 on each stack. Samples were collected at a single point using a potassium permanganate non-isokinetic method, which we believe provides reasonably accurate results consistent with what would otherwise be obtained with EPA reference test methods, as discussed in Section 7.5.1.1. Sampling times ranged from one-half to one hour in duration. Waste processed during sampling included all three basic waste types.

Each data set for the two stacks at Occidental/Delaware City is comprised of 70 data points. Each data set appears to have at least three unrepresentative high data points. We believe that

each of these six points is an outlier. In an attempt to affirm this judgment, we evaluated the data by way of Rosner's Test, an established statistical method for evaluating the probability that data points at the extreme ends of a sample might be so unrepresentative as to be considered statistical outliers and thus rejectable. The results of applying Rosner's Test to each data set affirmed our conclusion that the three highest data points in each data set are indeed statistical outliers, and that all six points should be rejected and dismissed from further consideration. Our evaluation of the amended data sets, containing 67 data points for each stack, is as follows.

Lacking any evidence to the contrary, we assumed that all the remaining data points in the Stack 1 and Stack 2 data sets are representative of the full range of normal operating conditions for both recovery and control. Based on the fact that the stacks are associated with essentially identical retort operation and mercury recovery/control systems, we combined the stack data into one data base of 134 data points. This decision is strongly supported by the similarities between the two data sets including measures of center and variability.

We are proposing that performance tests for mercury thermal recovery units be conducted under the most challenging conditions, which we are defining as the processing of wastes that result in the highest mercury concentration in the vent exhaust. Each performance test would consist of at least three

runs, and the average concentration measured would be compared with the emission limit to determine compliance. Given our inability to establish a discernible correlation between waste type processed and emissions, and our obligation to set standards that are achievable under the full range of normal acceptable operating conditions, we chose to set the standard based on the average of the three highest individual data points in the combined data base for Occidental/Delaware City. The result is 23 mg/dscm as the proposed mercury concentration emission limit for oven type units.

Due to the very low volumetric flow rates associated with oven type mercury thermal recovery unit exhaust streams (typically less than 300 scfm), we believe that the retrofit of control equipment to reduce mercury emissions is both practical and reasonable. For purposes of estimating the impacts of the proposed emission limit, we assumed that the Occidental plants in Muscle Shoals, Alabama and Deer Park, Texas would need to install carbon adsorbers that are larger than their existing units to meet the 23 mg/dscm level. The total installed capital control costs are estimated to be around \$217,000, and the total annual control costs are estimated to be around \$163,000 per year. Estimated mercury emission reductions against actual baseline emissions would total 33 kg/yr (74 lbs/yr). The associated annual cost per unit of mercury emission reduction would be approximately \$2,200 per pound.

Impacts on solid waste, due to increased use of carbon adsorption, are estimated total 5.2 Mg/yr (5.7 tons/yr) of mercury-containing spent carbon. Energy requirements are estimated to be an additional 473 thousand kW-hr/yr. Estimated secondary air pollution impacts due to heightened energy consumption are 152 Mg/yr (168 tons/yr), with carbon dioxide emissions comprising 99 percent of the estimate.

7.5.3.2 Emission Limit for Non-Oven Type Mercury Thermal Recovery Unit Vents. As noted previously, three plants operate retorts other than oven-type retorts. The mercury recovery/control systems operated at the two plants with rotary kiln retorts (PPG in Lake Charles, Louisiana and Olin in Charleston, Tennessee) consist of direct contact cooling, particulate and acid gas scrubbing, condensation, and carbon adsorption. The mercury recovery/control system at the plant with a single hearth retort (Vulcan in Port Edwards, Wisconsin) employs a chlorinated brine scrubber as the final control device. The following are more detailed descriptions of these recovery/control systems, the emissions data available, and our approach to determining MACT for non-oven type units.

At PPG/Lake Charles, over 300 tons of waste are processed annually, and over 12 tons of mercury are recovered. In addition to processing waste generated at this site, wastes from other sites are also processed in this rotary kiln unit. The off-gas from the rotary kiln is routed to a direct contact water quench

tower and a direct contact condenser, followed by a caustic packed-tower scrubber which has an outlet temperature of around 57°F. Subsequently, the stream is routed through filtration equipment for particulate collection and two carbon adsorbers (which are used in series) containing a total of 6,000 pounds of sulfur-impregnated carbon, which is replaced about every 2½ years. The volumetric flow rate of the exhaust stream ranges from about 490 scfm to 990 scfm and averages about 720 scfm.

Daily, personnel at this plant measure the mercury concentration at the outlet of the last carbon bed using a company-developed procedure derived from an Occupational Safety and Health Administration (OSHA) method for determining worker exposures in the workplace. A personal air sampler is used to pull a 1 to 2 hour sample from the carbon adsorber exhaust at a rate of around 0.2 liters/minute through a small tube containing about 200 milligrams of molecular sieve media. The sample is recovered from the media through digestion in small amounts of nitric and hydrochloric acids. The mercury content is determined by atomic absorption analysis. Data were submitted by PPG/Lake Charles for 1997, 1998, and 1999. When submitting these data, the company cautioned that although the routine sampling with the modified OSHA procedure produces credible information on relative changes in performance, it does not produce accurate information on actual mercury releases.²⁴ Specifically, we believe the data obtained using this method are biased low.²⁵ The average

measured mercury concentration for PPG/Lake Charles is an order of magnitude lower than averages for Vulcan/Port Edwards and Olin/Charleston, and the minimum measured value is two orders of magnitude lower than the minimum values for the Vulcan and Olin plants.^{26,27} It is our conclusion that data from PPG are unsuitable for standard setting, as they understate emissions and thus overstate the performance of the mercury recovery/control system.

The rotary kiln unit at Olin/Charleston processes around 500 tons of waste per year and recovers about 10 tons of mercury. This plant processes wastes generated on-site, as well as wastes from other sites. Similar to the unit at PPG/Lake Charles discussed above, the vapor stream from the kiln is routed to a direct contact water quench tower and then to a venturi unit and caustic packed-tower scrubber. This is followed by a indirect contact condenser and two carbon adsorbers in series. The outlet temperature of the condenser is around 57°F. Each carbon adsorber contains 1,000 pounds of sulfur-impregnated carbon, which is replaced about every 2½ years. The volumetric flow rate of the exhaust stream ranges from about 310 scfm to 1,560 scfm and averages about 720 scfm. Concentration measurements are made monthly using a potassium permanganate non-isokinetic method, which we believe provides reasonably accurate results consistent with what would otherwise be obtained with EPA reference test methods, as discussed in Section 7.5.1.1. Data were provided for

each month in 1998. The measured mercury concentrations range from 1.4 mg/m³ to 6.0 mg/m³, with a mean of 2.8 mg/m³.²⁸

At Vulcan/Port Edwards, the off gas from the single hearth retort is routed through a direct contact water quench tower, a venturi scrubber, then to a caustic packed-tower scrubber with an outlet temperature of around 80°F. As noted previously, the final control device is a chlorinated brine packed-tower scrubber. Mercury control is accomplished by chemically absorbing mercury from the gas stream and converting it to mercuric chloride, which is soluble in aqueous solutions. The resulting scrubber effluent is recycled back to the mercury cells with the brine. The volumetric flow rate of the exhaust stream ranges from about 590 scfm to 2,030 scfm and averages about 1,100 scfm.

Personnel at Vulcan/Port Edwards conduct monthly measurements of the mercury concentration in the brine scrubber exhaust gas. The measurement method used is a potassium permanganate non-isokinetic method, which we believe provides reasonably accurate results consistent with what would otherwise be obtained with EPA reference test methods, as discussed in Section 7.5.1.1. Data were provided for 1997, 1998, and 1999. The measured mercury concentrations range from 0.2 mg/m³ to 10.8 mg/m³, with a mean and median value of 1.6 and 2.2 mg/m³, respectively.²⁹

In addition, a separate Method 101 stack test was conducted in October 1998. The test consisted of three two-hour sample runs in accordance with Method 101 test procedures. The results compare favorably with the monthly periodic measurements cited above, enhancing our belief that the potassium permanganate method provides reasonably accurate results that can be used in setting MACT.³⁰

In establishing the MACT floor and subsequently MACT, we focused on the two plants (Vulcan/Port Edwards and Olin/Charleston) for which we have credible emissions data. As noted above, the data from Vulcan consists of 3 years of monthly measurements. There are 35 data points. We examined these data and noticed what appear to be two unrepresentative high data points, one at 10.8 mg/m³ and the other at 6.7 mg/m³. We evaluated whether the two points are outliers and should be rejected. In an attempt to affirm this judgment, we again used Rosner's Test. The results support our conclusion that the two data points are outliers, and thus should be dismissed. We believe that the remaining 33 data points are representative of the full range of normal operating conditions, including reasonable worst-case circumstances, for both recovery and control at the Vulcan plant. The data from Olin/Charleston includes 12 monthly measurements conducted in 1998, each lasting between 30 to 60 minutes in duration. There are no apparent outliers in the Olin data.

Although there are fewer than five sources from which to constitute a MACT floor, we opted to take the mean of Vulcan/Port Edwards data and Olin/Charleston data as the MACT floor option for existing sources. We averaged the three highest concentration data points for each plant (3.9 mg/dscm for Vulcan and 5.4 mg/dscm for Olin) and took the mean of the two plant averages (5 mg/dscm) as the floor value.

Of the three plants with non-oven type mercury thermal recovery unit vents, we project that only Plant H would need to upgrade existing controls to meet the 5 mg/dscm floor level. We project that PPG/Lake Charles would not need to upgrade its existing controls to meet the floor level. We assume that Olin/Charleston could reduce mercury emissions to the floor level by replacing the carbon in its existing carbon adsorbers more frequently than current practice. No capital costs are associated with meeting this level, as more frequent carbon media replacement was estimated as only a recurring (annual) cost of \$1,200 per year. Mercury emission reductions against actual baseline emissions would total about 2 kg/yr (5 lbs/yr) for the three plants. The associated annual cost per unit of mercury emission reduction would be approximately \$240 per pound. With the assumption of more frequent carbon media replacement at Olin/Charleston, there are no associated secondary air pollution, water pollution, and energy impacts. Estimated solid waste

impacts, due to increased use of carbon adsorption, total 0.09 Mg/yr (0.1 tons/yr).

We then examined beyond-the-floor MACT options. A direct comparison of the data for Vulcan/Port Edwards and Olin/Charleston indicates that the emission levels recorded at the Vulcan plant are about half that recorded at the Olin plant. The mean and median values recorded by Vulcan are 1.2 and 0.7 mg/m³,³¹ respectively, while the same values by Olin are 2.8 and 1.9 mg/m³,³² respectively. The highest monthly value recorded at Vulcan is 4.3 mg/m³, while the highest value recorded at Olin is 5.9 mg/m³. Given the better performance (lower emissions) recorded at the Vulcan plant, we used the data from Vulcan to establish a beyond-the-floor option. We averaged the three highest values for Plant D, for a beyond-the-floor value of 4 mg/dscm.

Due to the very low volumetric flow rates associated with non-oven type mercury thermal recovery unit exhaust streams (typically less than about 2,000 scfm), we believe that the retrofit of control equipment to reduce mercury emissions is both practical and reasonable. For purposes of estimating impacts, we assumed that Olin/Charleston could further increase its carbon replacement frequency to meet the 4 mg/dscm level. We assume that PPG/Lake Charles would not need to upgrade its existing controls to meet the beyond-the-floor level.

In evaluating regulatory options that are more stringent than the floor, we must consider the cost of achieving such emission reduction, and any non-air quality health and environmental impacts and energy requirements. The beyond-the-floor option would result in an additional 6 kg/yr (13 lbs/yr) of total mercury emission reductions (a 10 percent incremental reduction from the floor option). The incremental annual costs are estimated to total around \$5,800 per year. The incremental cost per unit of incremental mercury emission reduction is approximately \$450 per pound. The estimated incremental environmental and energy impacts are an additional 0.4 Mg/yr (0.5 tons/yr) of solid waste in the form of mercury-containing spent carbon.

We believe the additional emission reduction that would be achieved by the beyond-the-floor option is warranted. Further, we believe that the incremental costs of achieving such emission reduction, as well as incremental non-air environmental impacts and energy requirements, are reasonable for mercury. Therefore, we selected 4 mg/dscm as MACT for non-oven type mercury thermal recovery unit vents.

7.6 SELECTION OF THE BASIS AND LEVEL OF THE PROPOSED STANDARDS FOR NEW SOURCES

Section 112(d)(3) of the CAA specifies that standards for new sources cannot be less stringent than the emission control

that is achieved in practice by the best-controlled similar source, as determined by the Administrator.

In the case of mercury cell chlor-alkali production facilities, of the 43 chlor-alkali production facilities in operation in the U.S. at the time of this analysis, 32 use cell technologies other than mercury (23 use diaphragm cells and 9 use membrane cells). As explained further below, we consider these chlor-alkali facilities using non-mercury cell technology to be "similar sources," and, as such, a suitable basis for the standard for new source MACT. Such a standard would effectively eliminate mercury emissions from new source chlor-alkali production facilities.

The impact of such a standard would be negligible given that in terms of cost, economic and air and non-air environmental impacts, we don't believe that a new mercury cell chlor-alkali plant would otherwise ever be constructed. No new mercury cell chlor-alkali plant has been constructed in the U.S. in over 30 years, and we have no indication of any plans for future construction.^{33,34} In addition, we believe that any future demand for new or replacement chlor-alkali production capacity would be met easily through the construction of new production facilities that do not use or emit mercury. Consequently, we believe it is appropriate to consider non-mercury cell facilities as similar sources and the prohibition of new mercury cell chlor-alkali production facilities achievable. Accordingly, we are

proposing a prohibition on mercury emissions for new source MACT for mercury cell chlor-alkali production facilities. We are not proposing any initial and continuous compliance requirements related to this emission limit, as we believe they are unnecessary, since the emissions prohibition effectively precludes the new construction or reconstruction of a mercury cell chlor-alkali production facility.

As highlighted in the previous discussion on the selection of standards for existing sources, the emission levels achieved by the best-controlled sources at thermal recovery processes were selected as the proposed existing source MACT levels for mercury recovery facilities. These best levels of control for point sources are 23 milligrams of total mercury emitted per dry standard cubic meter of exhaust from an oven type mercury thermal recovery unit vent, and 4 milligrams of total mercury emitted per dry standard cubic meter of exhaust from a non-oven type mercury thermal recovery unit vent. For fugitive emission sources, the best level of control identified is the work practice standard represented in the beyond-the-floor option selected for the proposed rule for existing sources.

In the case of mercury recovery facilities, we know of three plants that employ low emitting mercury recovery processes. These processes include chemical mercury recovery used at two plants and recovery in a batch purification still used at a third plant. Unlike thermal recovery units, however, which are capable

of treating a variety of waste types, the chemical recovery and the purification still processes have limited application. Both are suitable to treating only certain waste types, K106 wastes for chemical recovery and end-box residues for purification still. Plants using these non-thermal recovery processes transfer their remaining wastes off-site for treatment, which typically involves thermal recovery. Given this limitation, we do not believe that these non-thermal recovery processes qualify as a suitable basis for new source MACT. Consequently, for new source MACT for mercury recovery facilities, we are proposing numerical mercury emission limits consistent with that achieved by the best similar sources, 23 mg/dscm for oven type thermal recovery unit vent and 4 mg/dscm for non-oven type thermal recovery units.

7.7 SELECTION OF THE TESTING AND INITIAL COMPLIANCE REQUIREMENTS

We selected the proposed testing and initial and continuous compliance requirements based on requirements specified in the NESHAP General Provisions (40 CFR part 63, subpart A). These requirements were adopted for mercury cell chlor-alkali plants to be consistent with other part 63 NESHAP. These requirements were chosen to ensure that we obtain or have access to sufficient information to determine whether an affected source is complying with the standards specified in the proposed rule.

The proposed rule requires initial and periodic compliance tests for determining compliance with the emission limits for by-

product hydrogen streams and end-box ventilation system vents, and the emission limits for oven type and non-oven type mercury thermal recovery unit vents. The proposed rule requires the use of published EPA methods for measuring total mercury.

Specifically, the proposed rule allows the use of Method 101 or 101A (of Appendix A of 40 CFR part 61) for end-box ventilation system vents and mercury thermal recovery unit vents and Method 102 for by-product hydrogen streams. Methods 101 and 102 were developed in the 1970s specifically for use at mercury cell chlor-alkali plants. Although Method 101A was developed to measure mercury emissions from sewage sludge incinerators, it is appropriate for use for end-box ventilation system vents and mercury thermal recovery unit vents.

The NESHAP General Provisions specify at §63.7(e)(3) that each test consist of three separate test runs. The proposed rule adopts this requirement. Further, the proposed rule requires that each test run be at least 2 hours long. This is the duration specified in Method 101 and referenced in Methods 101A and 102.

In the stack test data that were provided to us, there were numerous incidents where the results were reported as "less than" a certain level. We believe that this is primarily related to the sensitivity of the analytical instrument (that is, the absorption spectrophotometer) used to measure the amount of mercury in the collected sample. Method 101 states that the

absorption spectrometer must be the "Perkin Elmer 303, or equivalent, containing a hollow-cathode mercury lamp and the optical cell" It is our understanding that this particular model is no longer commercially available, and that newer, more sensitive absorption spectrophotometers are available.³⁵ We considered whether it was necessary to specify, either in the proposed rule or through a modification to the test method, that Perkin Elmer 303 did not have to be used. We concluded that the "or equivalent" language contained in Method 101 allows for the use of newer, more sensitive instruments and as a result, adding rule language or amending Method 101 was unnecessary.

Even with the 2-hour minimum test run period and the clarification that newer, more sensitive absorption spectrophotometers are allowed to be used, we remain concerned that quantifiable results of mercury emissions may not be obtained during performance tests. As a result, the proposed rule includes a requirement that the amount of mercury collected during each test run be at least 2 times the limit of detection for the analytical method used. This will assure that a reliably quantifiable amount of mercury is collected for each test run.

The emission limits for by-product hydrogen streams and end-box ventilation system vents are in the form of mass of mercury emissions per mass of chlorine produced. Therefore, criteria for the measurement of chlorine production during performance testing

are also necessary. It is our understanding that instrumentation used to measure actual chlorine production, as well as the location and frequency of measurement, varies from plant to plant. Types of instruments used include rail car weigh scales, weigh cells on liquid storage tanks, and gas flow meters.

Calibration procedures for these instruments are plant-specific and dependent on the involvement of third-parties concerned with quantifying actual chlorine production for billing and other purposes. Moreover, at a given plant, an accurate value for actual chlorine production based on these measurements is generally obtained at the end of an operating month, when mass balance calculations are performed to verify measurements.^{36,37}

For a compliance test run on the order of several hours, we therefore needed to rely on some other reasonable indicator of chlorine production. All mercury cell chlor-alkali plants measure the electric current through on-line mercury cells, also known as the cell line load or cell line current load, with a digital monitor that provides readings continuously. This cell line current load measurement can be used in conjunction with a theoretical chlorine production rate factor to obtain the instantaneous chlorine production rate. The theoretical factor is based on a statement of Faraday's Law, that 96,487 Coulombs (Faraday's constant, where a Coulomb is a fundamental unit of electrical charge) are required to produce one gram equivalent weight of the electrochemical reaction product (chlorine). It is

our understanding that chlorine production calculated in this manner would differ from the actual quantity produced at the plant by about 3 to 7 percent, due to electrical conversion efficiency and reaction efficiency determined by equipment characteristics and operating conditions. We consider this degree of variability acceptable.

We therefore stipulated in the proposed rule that the cell line current load be continuously measured during a performance test run and that measurements be recorded at least every 15 minutes over the duration of the test run. We further specified equations for computing the average cell line current load and for calculating the quantity of chlorine produced over the test run.

In addition to the requirement to conduct performance tests to demonstrate compliance with the emission limits, owners or operators would be required to establish a mercury concentration operating limit for each vent as part of the initial compliance demonstration. Then, at least twice a permit term (at mid-term and renewal), they would conduct subsequent compliance demonstrations and at the same time reestablish operating limit values. The proposed rule requires that these mercury concentration operating limits be determined directly from the concentration monitoring data collected concurrent with the initial performance test.

For the work practice standards, initial compliance is demonstrated by documenting and certifying that the standards are being met or will be met, by submitting a Washdown Plan, and by certifying that the plan is being followed or will be followed. This approach assures initial compliance by requiring the owner or operator to submit a certified statement in the Notification of Compliance Status report.

7.8 SELECTION OF THE CONTINUOUS COMPLIANCE REQUIREMENTS

For each of the proposed emission limits, which consist of the limits on mercury emissions from hydrogen streams, end-box ventilation systems, and thermal recovery units, we considered the feasibility and suitability of continuous emission monitors (CEM) as the means of demonstrating continuous compliance. While we were unable to identify any mercury cell chlor-alkali plant currently using a mercury CEM on any vent, we did determine that there are mercury CEM commercially available that may be suitable for use at mercury cell chlor-alkali plants.³⁸ To date, most of the development work on mercury CEM has focused on the development of monitors for the continuous measurement of mercury air emissions from either coal-fired utility boilers or hazardous waste incinerators. Most mercury CEM are extractive monitors which extract a continuous or nearly continuous sample of gas then transfer the gas to an instrument for spectroscopic analysis by way of either cold vapor atomic absorption or cold vapor atomic fluorescence.

These cold vapor techniques have similar limitations. Both detect mercury vapor only in its elemental form. To measure other forms of mercury vapor (e.g., oxidized/inorganic/divalent mercury, such as mercuric chloride), the sampled gases must first pass through a converter which reduces any non-elemental mercury vapor present to the elemental form prior to analysis. None of the available monitors based on the cold vapor techniques are capable of measuring particulate or non-vapor phase mercury, since the sample gas must be filtered to remove any particulate matter present prior to conversion and analysis. This would include elemental mercury condensed on particulate matter and any mercury compounds in particulate form. Monitors that are capable of measuring total vapor phase mercury range in price from \$50,000 to \$80,000. Simpler monitors that measure only elemental mercury vapor average about \$10,000.

For the proposed emission limits for by-product hydrogen streams and end-box ventilation system vents, which are expressed in grams of mercury per megagram of chlorine produced, we evaluated two options: (a) continuous compliance against the proposed gram per megagram standards, and (b) continuous compliance against plant and vent specific operating limits expressed in terms of concentration. In addition to monitoring mercury concentration, the first option would require continuous monitoring of volumetric flow rate and a continuous, or at least periodic, measurement of chlorine production. The operating

limits for the second option would be set at the time that initial compliance with the emission limit is demonstrated.

Since the predominant form of liquid mercury in mercury cells and other production facilities is elemental, we assumed that the mercury contained in the vent gas from either by-product hydrogen streams or end-box ventilation system vents is similarly largely in the elemental vapor form. Thus, the simpler, less expensive monitors for measuring elemental mercury vapor only should be suitable.

We concluded that monitoring only elemental mercury concentration provides a simpler, less expensive, and more reliable alternative to demonstrating continuous compliance than monitoring against the gram per megagram standards. As a result, we are proposing that continuous compliance for by-product hydrogen streams and end-box ventilation system vents be demonstrated through the continuous monitoring of elemental mercury concentration in the vent exhaust.

To the best of our knowledge, mercury contained in the exhaust gas of thermal recovery units, both oven and non-oven types, should exist as both vapor (elemental or non-elemental) and fine particulate matter. As highlighted above, none of the currently available monitors are capable of measuring particulate mercury. Consequently, continuous monitoring to demonstrate continuous compliance with the total mercury concentration limit would not be possible.

Similar to the by-product hydrogen streams and end-box ventilation system vents, we also considered the feasibility and usefulness of monitoring vapor phase mercury, specifically the elemental form. We concluded that the continuous monitoring of elemental mercury vapor as a surrogate to the total mercury emission limit using the simpler of the available monitors, provides an acceptable and cost-effective means of tracking relative changes in emissions and control device performance. Therefore, as proposed for by-product hydrogen streams and end-box ventilation system vents, we are proposing for oven type and non-oven type mercury thermal recovery units that continuous compliance be demonstrated through continuous monitoring of elemental mercury concentration against an applicable concentration operating limit established as part of the initial compliance demonstration.

Another important aspect of continuous compliance is the time period over which continuous compliance is determined. One option would be an instantaneous period, where any measurement outside of the established range (that is, above the established concentration limit) would constitute a deviation. More commonly, the average of the monitoring data over a specified time period, for example an hour, is compared to the established limit.

While mercury cell chlor-alkali production facilities are generally operated continuously, there are process fluctuations

that impact emissions. Mercury recovery facilities are operated intermittently, depending on the amount of mercury-containing waste to be treated and other factors. We believe that an averaging period is necessary for both situations. We considered a daily averaging period and concluded that daily averaging would accommodate process variations while precluding avoidable periods of high emissions. Therefore, we are proposing a daily averaging period for demonstrating continuous compliance.

We also considered how to address monitoring data collected during startups, shutdowns, and malfunctions. We believe that it is important to continue to monitor the outlet mercury concentration during startups, shutdowns, and malfunctions to minimize emissions and to demonstrate that the plant's startup, shutdown, and malfunction plan is being followed. However, as provided for in the NESHAP General Provisions (40 CFR part 63, subpart A), we do not believe that the data collected during these periods should be used in calculating the daily average values. The emission limits were developed based on normal operation, and the performance tests will be conducted during representative operating conditions. Therefore, the inclusion of monitoring data collected during startups, shutdowns, and malfunctions into the daily averages would be inconsistent with the data used to develop the emission limits and subsequently, the mercury concentration operating limits.

While we did not identify situations in the mercury cell chlor-alkali industry where elemental mercury concentration is being continuously monitored, we believe that continuous elemental mercury concentration monitoring devices are available for use at mercury cell chlor-alkali plants. We recognize that the transfer of this monitoring technology to applications at mercury cell chlor-alkali plants will introduce uncertainties that can only be addressed through actual field demonstration. We are specifically requesting comment on the technical feasibility of using continuous elemental mercury concentration monitors for indicating relative changes in control system performance. We are also requesting comment on the proposed specifications for these devices.

Continuous compliance with the proposed work practice standards for the fugitive emission sources would be demonstrated by maintaining the required records documenting conformance with the standards and by maintaining the required records showing that the Washdown Plan was followed.

7.9 SELECTION OF THE NOTIFICATION, RECORDKEEPING, AND REPORTING REQUIREMENTS

We selected the proposed notification, recordkeeping, and reporting requirements based on requirements specified in the NESHAP General Provisions (40 CFR part 63, subpart A). As with the proposed initial and continuous compliance requirements, these requirements were adapted for mercury cell chlor-alkali

plants to be consistent with other part 63 national emission standards.

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APPENDIX A.
EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

The purpose of this study was to develop a basis for supporting proposed national emission standards for hazardous air pollutants (NESHAP) for mercury emissions from mercury cell chlor-alkali plants. To accomplish the objectives of this program, technical data were acquired on the following aspects of the mercury cell chlor-alkali industry: (1) the mercury cell chlor-alkali process that produces chlorine and caustic, (2) processes that are used to recovery mercury from wastes generated in the mercury cell and related processes, (3) mercury emissions from the mercury cell and mercury recovery processes, (4) methods for reducing mercury emissions, (5) methods to monitor the performance of control devices in reducing mercury emissions, and (6) housekeeping and work practices to reduce mercury emissions. The bulk of the information was gathered from the following sources:

1. Technical literature;
2. Plant visits;
3. Industry representatives;
4. The Chlorine Institute, which is a trade organization representing chlor-alkali manufacturers; and
5. Equipment vendors.

Significant events relating to the evolution of the background information document are itemized in Table A-1.

TABLE A-1. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

| Date | Company, Consultant, or agency/location | Nature of action |
|-------------------|---|---|
| 4/10/98 | U.S. Environmental Protection Agency | Chloralkali production listed as source of mercury emissions in section 112(c)(6) emission inventory |
| 4/14/98 | The Chlorine Institute | Meeting between the EPA and the Chlorine Institute to discuss plans for the development of a mercury standard for mercury cell chlor-alkali plants. |
| 5/4/98 - 5/7/98 | Olin Chemicals, Charleson, TN | Plant visit to gather information on mercury housekeeping procedures techniques, the mercury cell process, and mercury control techniques. |
| 5/26/98 - 5/29/98 | Occidental Chemical, Delaware City, DE | Plant visit to gather information on mercury housekeeping procedures techniques, the mercury cell process, and mercury control techniques. |
| 6/10/98 - 6/12/98 | Vulcan Materials, Port Edwards, WI | Plant visit to gather information on mercury housekeeping procedures techniques, the mercury cell process, and mercury control techniques. |

TABLE A-1. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT
(continued)

| Date | Company, Consultant, or agency/location | Nature of action |
|-------------------------|---|--|
| 6/22/98 - 6/25/98 | Pioneer Chlor-Alkali, St. Gabriel, LA | Plant visit to gather information on mercury housekeeping procedures techniques, the mercury cell process, and mercury control techniques. |
| 6/26/98 | PPG Industries, Lake Charles, LA | Plant visit to gather information on mercury housekeeping procedures techniques, the mercury cell process, and mercury control techniques. |
| 9/1/98 | ASHTA Chemicals (Astabula, OH), Holtrachem (Orrington, ME), Occidental Chemical (Delaware City, DE, Deer Park, TX, and Muscle Shoals, AL), Olin (Charleston, TN and August, GA), Pioneer Chlor-Alkali (St Gabriel, LA), PPG Industries (Lake Charles, LA and New Martinsville, WV), Vulcan Chemicals (Port Edwards, WI), Westlake (Calvert City, KY) | Section 114 information request. |
| 1/19/99 | EC/R Incorporated | Summary of Section 114 Responses from Mercury Cell Chlor-Alkali Facilities. |

TABLE A-1. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT
(continued)

| Date | Company, Consultant, or agency/location | Nature of action |
|----------------|---|--|
| 2/99 - 5/99 | ASHTA Chemicals (Astabula, OH), Holtrachem (Orrington, ME), Occidental Chemical (Delaware City, DE, Deer Park, TX, and Muscle Shoals, AL), Olin (Charleston, TN and August, GA), Pioneer Chlor-Alkali (St Gabriel, LA), PPG Industries (Lake Charles, LA and New Martinsville, WV), Vulcan Chemicals (Port Edwards, WI), Westlake (Calvert City, KY) | Follow-ups to section 114 responses. |
| 5/99 - 7/99 | Bacharach; Mine Safety Appliances; PerkinElmer; Arcadis, Geraghty & Miller; Emission Testing Services, Inc.; CHEMTEX | Requests for information related to mercury test methods and analytical equipment. |
| 7/29/99 | The Chlorine Institute | Meeting between the EPA and the Chlorine Institute to discuss XXX |
| 8/99 | Union Carbide, Linde | Requests for information on molecular sieves |
| 12/17/99 | The Chlorine Institute | Comments and information regarding MACT floor determination and thermal treatment units. |
| 5/4/00 | The Chlorine Institute | Information regarding RCRA rules applicable to mercury-cell facilities. |

TABLE A-1. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT
(continued)

| Date | Company, Consultant, or agency/location | Nature of action |
|--------------------|---|--|
| 6/8/00 | The Chlorine Institute | Documents regarding housekeeping and work practice standards. |
| 6/8/00 and 6/23/00 | The Chlorine Institute | Letters providing information related to mercury recovery thermal treatments units and emissions |
| 7/00 | Lake Shore, Process Control Systems, Sigma-Aldrich, Perkin-Elmer, Dwyer Instruments, Uehling Instrument Company, Princo Instruments, Davis Instruments, Universal Flow Monitors | Information requests for parametric monitoring cost data. |
| 7/00 | EcoChem Analytics, Aldora, ST ² | Requests for cost and other information on mercury continuous monitoring devices |
| 3/00 - | Occidental Chemical (Delaware City, DE, Deer Park, TX, and Muscle Shoals, AL), Olin (Charleston, TN), PPG Industries (Lake Charles, LA, Vulcan Chemicals (Port Edwards, WI) | Requests for additional testing, monitoring, and other information on mercury thermal recovery units |

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| 16. ABSTRACT This background information document (BID) provides information relevant to the proposal of national emission standards for hazardous air pollutants (NESHAP) for limiting mercury emissions from mercury cell chlor-alkali plants. The standards are being developed according to section 112(d) of Title III of the Clean Air Act (CAA) as amended in 1990. | | |
| 17. KEY WORDS AND DOCUMENT ANALYSIS | | |
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