Chapter 3
Manufacturing Processes Involving Mercury

3.1 Chlor-Alkali Manufacturing

3.1.1 Introduction

Facilities producing chlor-alkali are classified under the following business classifications:

SIC Code 2812: Alkalies and Chlorine

NAICS Code 325181: Alkalies and Chlorine Manufacturing

More mercury is used in chlorine and caustic soda manufacturing than in any other industrial sector in the United States. The SIC Code 2812 and NAICS Code 325181 describe all industries primarily engaged in manufacturing alkalies (e.g., NaOH) and chlorine (Cl_2). Chlorine and alkali manufacturing are linked because of a shared production process. Electrolysis separates the sodium and chlorine in salt brine (NaCl), producing 1.1 tons of caustic soda for every ton of chlorine. Since chlorine cannot be economically stored or moved over long distances, chlor-alkali facilities are often located near industries that require chlorine. The two largest industries for chlorine are vinyl chloride monomer manufacturing and pulp and paper manufacturing (Kirk-Othmer 1991).

There are three electrolytic methods used in chlor-alkali production: diaphragm cell, mercury cell, and membrane cell production. Although all new chlor-alkali facilities being built use either membrane cell or diaphragm cell technologies – processes that do not use mercury – several chlor-alkali facilities still use the mercury cell process. In the United States, mercury cell plants account for 10% of the chlorine production capacity; production takes place at 11 facilities using mercury cells (Chlorine Institute 2001 and ChemExpo 2000). One advantage of the mercury cell process is that it produces a low-salt caustic soda and it is much easier to scale production levels of chlorine and caustic soda based upon demand (Genna 1998).

Unlike the diaphragm cell and membrane cell processes, which are one-step processes, the mercury cell process is a two-step process: an electrolyzing stage produces the chlorine gas and a decomposing stage produces the caustic soda (USEPA 1997a). Flowing at the bottom of the cell, a few millimeters below the suspended metal anode, the mercury acts as the cathode in the electrolytic process. Each cell may contain three tons of mercury (USEPA 1997a), and through most of the 1990s there were a total of 762 mercury cells (Chlorine Institute 2001). An aqueous salt brine solution (NaCl) flows between the anode and the cathode, releasing chlorine gas at the anode. The remaining sodium and mercury amalgam flows from the electrolyzer cell to the decomposing cell, which separates the mercury from the sodium that produces sodium hydroxide (NaOH) and recycles the mercury back to the electrolyzer cell (Kirk-Othmer 1991).

3.1.2 Materials Flow

Exhibit 3-1 illustrates the consumption, release, and product content of mercury in chlor-alkali production. The environmental release estimates in Exhibit 3-1 are based on 1999 Toxic Release Inventory (TRI) mercury release data for 13 of the 14 plants operating in that year. Mercury use data are based on data from the Chlorine Institute (2001); mercury in products is estimated as described below.

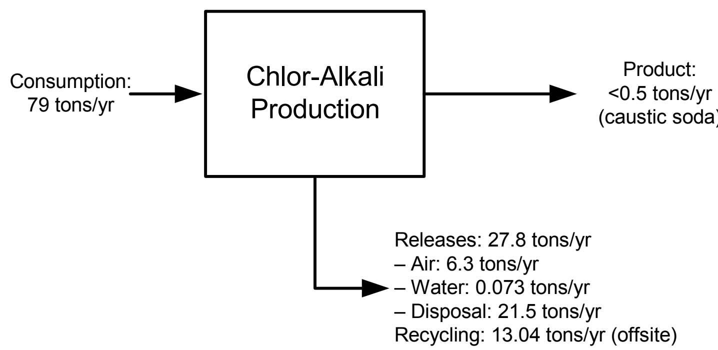
The calculation does not match the amount consumed with the total amount released. It is unknown why there is a discrepancy between consumption and release. Studies are being conducted by EPA to find out where the missing mercury goes. One explanation could be that the consumption is from the Chlorine Institute and the release data is from TRI.

Mercury Consumption

Exhibit 3-2 shows estimates of mercury consumption for several years along with mercury release data. The Chlorine Institute's (2001) estimate of mercury consumption from the domestic chlor-alkali facilities decreased from 222 tons in 1990 to 79 tons in 2000. The Chlorine Institute also provided estimates of mercury purchases by the chlor-alkali facilities. On a year-to-year basis, mercury purchases did not necessarily equal mercury use. However, over a multi-year period, mercury purchases were roughly equivalent to mercury use. Chlor-alkali facilities may purchase more mercury than they anticipate using, storing the excess mercury for later use (Dungan 1999). The 2000 consumption estimate is used in Exhibit 3-1.

Air Releases

Air releases of mercury from chlor-alkali production result from elevated process temperatures. The heat generated by the electrolysis process used to



Sources: Mercury Consumption: Chlorine Institute (2001).
Mercury Release and Recycling: 1999 TRI data.
Mercury in Product: Estimated from production capacity (Chlorine Institute 2001) and product concentration (WLSSD 1997).

Exhibit 3-1. Mercury in Chlor-Alkali Manufacturing

Exhibit 3-2. Chlor-Alkali Mercury Cell Process Mercury Used, Emitted, Recycled, and Disposed

Quantity (tons)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total Mercury Used[1]	222	175	148	104	146	165	137	118	104	88	79
Total Mercury Air Emissions[2]	-	-	-	-	-	-	-	-	7.3	6.3	-
Total Mercury Water Emissions[2]	-	-	-	-	-	-	-	-	0.1	0.07	-
Total Onsite Mercury Recycling[2]	-	-	-	-	-	-	-	-	469	374	-
Total Offsite Mercury Recycling[2]	-	-	-	-	-	-	-	-	8.2	13	-
Total Mercury Disposal[2]	-	-	-	-	-	-	-	-	7.2	21.5	-
Total Mercury in Caustic Soda[3]	-	-	-	-	-	-	-	-	0.6	0.6	-

[1] Source: Chlorine Institute (2001).
[2] Source: 1999 TRI data for 13 of 14 chlor-alkali facilities using the mercury cell process. These thirteen facilities represented 96 percent of the total production capacity, signifying that the reported releases are an excellent estimate of industry-wide releases.
[3] Source: Estimated; represents high estimate of mercury likely to be in product. See text.
This table does not summarize environmental release data from the TRI prior to 1998.

separate the chlorine from the salt brine contributes to mercury volatilization (Johnson 1999). There are three primary sources of mercury air emissions at a mercury cell chlor-alkali facility: (1) byproduct hydrogen steam, (2) end box ventilation air, and (3) cell room ventilation air (USEPA 1997a). Ventilation systems and scrubbers reduce the amount of mercury emitted to the atmosphere. The mercury is transferred to water or to solid waste, where it may be recycled or disposed. As shown in Exhibit 3-1, industry-wide air releases are estimated at 6.3 tons based on 1999 TRI data.

Water Releases

Releases of mercury-containing water result from the large quantities of water used in the electrolysis process. Mercury is also found in the wastewater and brine of the mercury cell process. Some mercury is found in the water collected from the periodic wash-down of floors and equipment. As shown in Exhibit 3-1, industry-wide water releases are estimated as 0.07 tons based on 1999 TRI data. The estimate represents the mercury content in waters discharged to a surface water or to a publicly owned treatment works (POTW).

Solid Waste Releases and Recycling

Wastewater treatment sludges from chlor-alkali facilities were routinely landfilled until 1992, when USEPA banned the landfilling of certain mercury-containing sludges (USEPA 1988b). Because of the restriction, many mercury cell facilities now use retort and hydrometallurgical processes to remove the mercury from their wastes prior to landfilling and recycle the recovered mercury back into the mercury cell process (USEPA 1998a). As shown in Exhibit 3-2, a large quantity of mercury is recycled onsite. (However, it is not possible to identify how each facility reported this quantity, and a portion of the quantity may represent mercury that is continuously re-inserted back into the process when using mercury as a catalyst.) This onsite recycling is not accounted for as recycled quantities in the summary of Exhibit 3-1 because it is internal to the industry, rather than being sent to a commercial recycling facility such as those discussed in Section 2. As shown in Exhibit 3-1, industry-wide land disposal releases are estimated as 21.5 tons based on 1999 TRI.

Product

Because mercury has a high vapor pressure at normal operating conditions, mercury is found in trace amounts in the reaction products (chlorine and caustic soda). No estimates of mercury content in chlorine gas were found. In 1987, a Wisconsin wastewater treatment district found that caustic soda (sodium hydroxide) can contain mercury ranging from 10 to 300 parts per billion (WLSSD 1997). The Chlorine Institute identified an average level of 100 parts per billion, based on 1995 survey data (Chlorine Institute 2000).

Using conservative assumptions, the industry-wide mercury content of caustic soda is estimated as no more than 0.5 tons per year. These assumptions include using the upper end of the mercury concentration range of 300 parts per billion, and estimating annual sodium hydroxide production of 1.7 million tons per year (which is equivalent to the capacities for mercury cell facilities reported in Chlorine Institute (2001)). This estimate assumes no mercury contributions from other processes. Such contributions are possible at facilities where the mercury cell process was replaced but where residual mercury may still be present.

Reservoir

A considerable quantity of mercury is present inside a chlor-alkali facility. This is partly due to the function of mercury as a catalyst; as discussed above, each cell may contain three tons of mercury (USEPA 1997a) and there were 762 cells operating for most of the 1990s prior to the most recent closures (Chlorine Institute 2001). An industry source estimates that a single plant holds between 75 and 750 tons of mercury, which would be available to the secondary market upon dismantling of the plant (Lawrence 2000). Additional mercury is also expected to be present within pipes, equipment, etc., as an amalgam, which may not be easily recoverable. Based on these data, this report estimates that at least 2,000 tons of mercury is present at operating and recently closed chlor-alkali production facilities.

3.1.3 Discussion

There is an apparent discrepancy between the mercury consumed by the chlor-alkali industry and the mercury emitted. Mercury consumed by the chlor-alkali industry is used to replenish production losses. However, mercury consumption is much larger than the reported mercury emissions (Johnson 1999), and the mercury contained in the product is not a significant fraction. Therefore, approximately 50 tons of mercury appear to be “missing” based on the 1999/2000 data. There is increasing concern among state and federal regulators regarding this “missing mercury” (Johnson 1999). Olin Corporation, a major chlor-alkali producer, is working with USEPA to eliminate mercury discharges from its two mercury cell chlor-alkali facilities (Johnson 1999). The head of Olin Corporation is urging the chlor-alkali industry to develop better methods to measure and control fugitive mercury emissions (Johnson 1999).

Data for 2000 mercury consumption were provided by the Chlorine Institute. USGS has not reported mercury usage statistics since 1997. Historically, USGS and Chlorine Institute data have differed. For example, the quantity of mercury consumption in 1995 as provided by the Chlorine Institute, 165 tons, is slightly lower than the quantity of mercury consumption in 1995 provided by USGS, 170 tons. This discrepancy is even more apparent when comparing 1997 data (118 tons Chlorine Institute vs. 176 tons USGS). The USGS data may include extrapolations for non-respondents. The Chlorine Institute is actively tracking mercury consumption at the plants using the mercury cell process.

3.2 Lamp Manufacturing, Use, and Disposal

3.2.1 Introduction

Facilities manufacturing lamps and lighting equipment may be classified under the following business classification:

> SIC Code 3641: Electric Lamp Bulbs and Tubes
>
> NAICS Code 33511: Electric Lamp Bulb and Part Manufacturing

SIC Code 3641 and NAICS Code 33511 are comprised of establishments primarily engaged in manufacturing electric bulbs, tubes, and related light sources. Mercury is a key component of fluorescent lamps and high intensity discharge (HID) lamps (including mercury vapor, metal halide, and high pressure sodium lamps). Fluorescent lamps are widely used for indoor lighting in businesses and increasingly in residences, while HID lamps are used for heat lamps, film projectors, dental exams, photochemistry, water purification, and street lighting. When an electrical current passes through mercury vapor, it emits ultraviolet light. In a fluorescent lamp, this ultraviolet light is converted into visible light when it excites the phosphorus coating inside the tube, causing it to fluoresce.

The mercury content in fluorescent bulbs in the United States has steadily decreased during the past two decades. In 1989, the average mercury content in a fluorescent bulb was 48.2 mg (USEPA 1999a), decreasing to 11.6 mg in 1999 for a typical four-foot lamp (NEMA 2000). In 1995, Philips Lighting introduced a low-mercury fluorescent lamp containing only 4.4 mg of mercury (USEPA 1999a). OSRAM Sylvania introduced a mercury-free high intensity discharge (HID) lamp in 1998 (Sylvania 1998).

3.2.2 Materials Flow

Exhibit 3-3 illustrates the consumption, release, and product content of mercury in electrical lighting, spanning manufacturing, use, and final disposal.

3.2.3 Manufacture

Mercury use in lamps depends on the quantity of lamps manufactured and the mercury content of the bulbs. Philips Lighting estimates that low-mercury lamps constitute 85% of its current lamp production and that they have reduced their mercury use by 13 tons per year (USEPA 1999a). Similar production information from other manufacturers was not available. OSRAM Sylvania estimates that introduction of their mercury-free HID lamp should reduce mercury consumption by 0.17 tons per year (Sylvania 1998).

<u>Mercury Consumption</u>

As shown in Exhibit 3-4, mercury consumption by domestic lighting manufacturers has declined from a peak of 61 tons per year in 1992 to about 32 tons per year in 1997, based on data from USGS. While these data are useful for identifying trends, the USGS estimate is not reflected in Exhibit 3-3. Instead, a lower estimate of 16 tons based on data from the Bureau of Census and the National Electrical Manufacturers Association (NEMA) was used. The NEMA estimate was used because it is based on more recent lamp composition data and, due to uncertainties with the USGS data identified in Section 3.1, the USGS data may overestimate actual use.

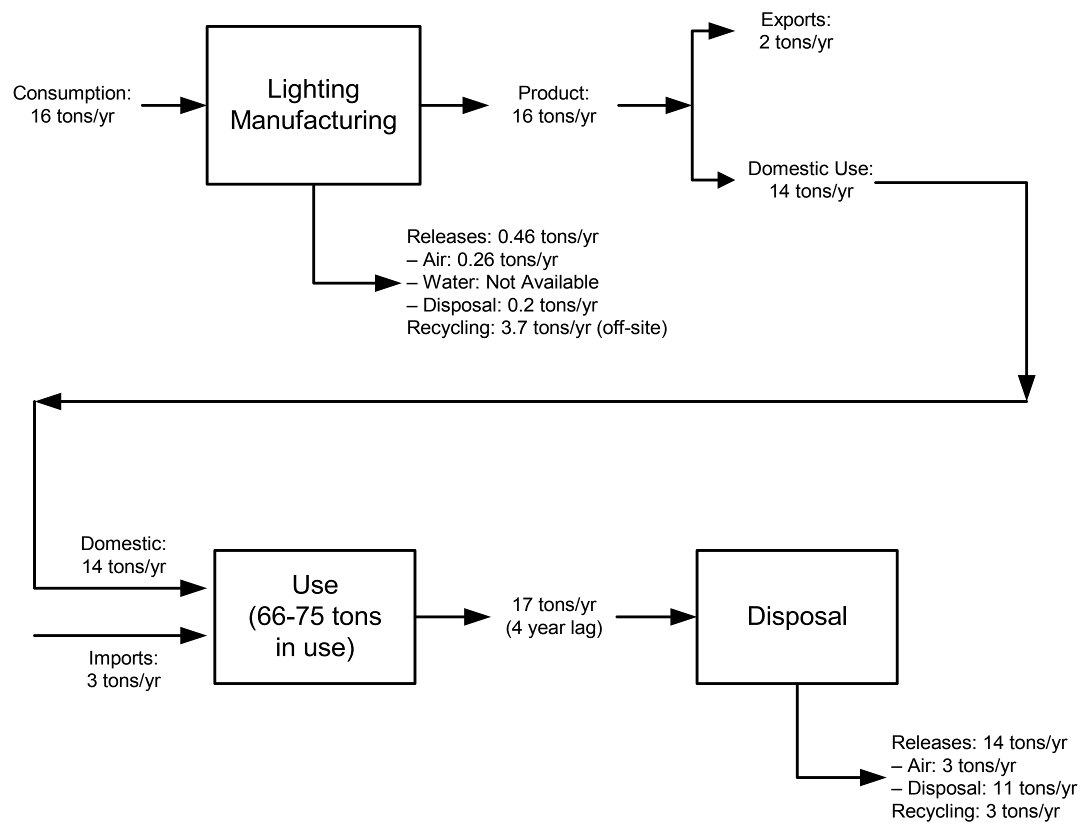
The U.S. Department of Commerce's Bureau of Census (USDOC 1995) estimates that 599 million fluorescent lamps and 28.5 million HID lamps were produced in the United States in 1994. Assuming an average mercury content of 11.6 mg of mercury per fluorescent lamp (NEMA 2000) and 25 mg per HID lamp (USEPA 1992b), lamp manufacturing consumed 16 tons of mercury in 1994. The quantity was used as an estimate for present day usage.

In 1994, the Census Bureau stopped collecting data on lamp production. Based on National Electrical

Manufacturers Association (NEMA) data, lighting system sales increased from $7.8 billion to $8.4 billion in 1997 (NEMA 1999), an increase of 8 percent. Therefore, the 1994 Bureau of Census estimate of 599 million fluorescent lamps manufactured in the United States appears to be a reasonable estimate for 1997.

Releases

Mercury can be released during transfer and parts repair, mercury handling, mercury injection into the lamps, accidents, and spills (USEPA 1997a). Two lamp manufacturing companies submitted TRI reports for 1999, reporting the release of 0.26 tons of mercury to the



Sources: Mercury Consumption: Extrapolated from the Bureau of Cencsus (DOC 1995), NEMA (2000), and EPA (1992b).
Mercury in Product: Extrapolated from lamps sold and exported (DOC 1995), lamps imported (EPA 1999b), and mercury content (NEMA 2000).
Mercury Release and Recycling: 1999 TRI data for manufacturing.
Exports and Imports: Bureau of Census (DOC 1995).
Emissions for Use: Recycling rate from NEMA (2000). Air and land disposal extrapolated using EPA (1997c).

Exhibit 3-3. Mercury in Electrical Lighting

Exhibit 3-4. Lighting Industry Mercury Consumed

	1990	1991	1992	1993	1994	1995	1996	1997
Total Mercury Consumed[1] (tons)	36	43	61	42	30	33	32	32

[1]Source: United States Geological Survey, Mineral Industry Surveys 1990-97

air and 3.7 tons recycled. Releases from these facilities are larger than the industry-wide estimate of 0.06 tons in the *Mercury Report to Congress* (USEPA 1997a). TRI data for these manufacturers are used in Exhibit 3-3. This estimate may be low due to the small number of facilities, but extrapolating to a larger population is difficult due to a lack of facility-specific information.

Exports

An estimated 68 million fluorescent lamps and 4 million HID lamps were exported in 1994 (USDOC 1995). This is approximately 1.8 tons of mercury (using the mercury content assumptions above). This number is used in Exhibit 3-3.

3.2.4 Use

Mercury Consumption

Of the nearly 600 million fluorescent lamps manufactured in the United States in 1994, 517 million lamps were sold domestically; the remainder were exported or stayed in inventory (USDOC 1995). An additional 100 million fluorescent lamps containing an estimated 2.5 tons of mercury were imported in 1995 (USEPA 1999b). Therefore, approximately 620 million fluorescent lights were sold in the United States containing 16 tons of mercury.

Of the 29 million HID lamps manufactured in 1994, 25 million were sold domestically; the remainder were exported or remained in inventory (USDOC 1995). An additional 3.5 million HID lamps containing an estimated 0.1 tons of mercury were imported in 1995 (USEPA 1999b). Therefore, approximately 29 million HID lamps (0.8 tons of mercury) were sold in the United States in 1994. The total quantity of mercury consumed from lighting (17 tons in Exhibit 3.3) reflects the combination of fluorescent lamps (16 tons) and HID lamps (1 ton).

Reservoir

Assuming a 20,000-hour lifespan for fluorescent lamps, these lamps should last about four years. Assuming the 620 million lamps sold each year are replacing one-fourth of the lamps in use, there were between 2.5 and 3 billion fluorescent bulbs in use in 1997, constituting 65 to 75 tons of mercury throughout the United States (assuming 11.6 mg of mercury per lamp).

Because HID lamps typically have a usable life of 10,000 hours and most are used 24 hours per day, USEPA (1992b) assumed that HID lamps are replaced annually. Therefore, all 29 million lamps are replacement lamps and they contained 0.8 tons of mercury (assuming 25 mg of mercury per lamp).

3.2.5 Disposal

Since fluorescent lamps have a lifespan of about four years, the quantity of mercury used in lamps today does not reflect the quantity of mercury being disposed. Instead, there is a four year lag from initial use to disposal. The estimated 620 million fluorescent lights purchased in 1994 probably entered the waste stream in 1997 - 1998. The 29 million HID lamps sold that year probably entered in 1995. Together, they equal about 17 tons of mercury removed from service in 1997.

Until 1995, most fluorescent lights were disposed of as municipal solid waste (MSW). USEPA (1992a) estimated in 1992 that 82 percent of mercury-containing lamps were landfilled, 16 percent were incinerated, and 2 percent were recycled. The number of companies collecting lamps for recycling has increased since the early 1990s to more than 60 companies. More recent estimates by the Association of Lighting and Mercury Recyclers state that the recycling rate in the late 1990s was 15 percent (NEMA 2000). Assuming rates of 15 percent recycled, 67 percent landfilled, and 18 percent incinerated (consistent with USEPA 1997c percentages of wastes that are landfilled and incinerated), this results in 11 tons that entered landfills, 3 tons incinerated, and 3 tons recycled.

The mercury lamp recycling rate is expected to continue to increase due to changes in USEPA's universal waste rule in June 1999. In this rule, USEPA streamlined recycling requirements for mercury-containing fluorescent, mercury vapor, sodium halide, and metal halide lamps that exceed mercury concentrations set by USEPA's Toxicity Characteristic Leaching Procedure (TCLP) test. A goal of this rule is to encourage recycling by making it easier for generators to collect, store, and transport bulbs destined for recycling (USEPA 1999c).

3.2.6 Discussion

The quantity of mercury consumed for production was assumed to equal the quantity estimated to be present in domestically manufactured products (16 tons). This estimate was used instead of the much greater Bureau of Mines (USGS 1997) estimate for mercury consumption of 32 tons in 1996. Therefore, this represents a source of uncertainty because additional methods to verify either of these estimates are not available.

The quantity of mercury in lamps is expected to decrease, but based on current research, elimination in fluorescent lamps is not expected. As a result, future releases of mercury will decrease slightly.

A second source of uncertainty is the extent to which mercury in post-consumer lamps is currently recycled. The recycling rates are expected to increase due to regulatory changes such as the 1999 regulatory changes by USEPA. Therefore, the quantities ultimately recycled and disposed by commercial, industrial, and consumer users are uncertain.

3.3 Thermometers and Other Instruments

3.3.1 Introduction

Facilities manufacturing thermometers and other instruments may be classified under the following business classifications:

> SIC Code 38295: Commercial, geophysical, meteorological, and general purpose instruments. Applicable SIC (Product) Codes are as follows :

Barometers:
- 20 - Barometers

Liquid in glass thermometers:
- 22 - Scientific thermometers
- 23 - Industrial thermometers (food, air conditioning, and refrigeration)
- 24 - Household and commercial thermometer
- 34 - Medical thermometer

NAICS Code 339112: Surgical and medical instrument manufacture.

NAICS Code 334519: Other measuring and controlling device manufacturing.

Mercury is often used in medical and scientific instruments because it is non-reactive, metallic, and liquid over a relatively wide range of temperatures. The most common use of mercury as a medical and scientific instrument is in the liquid-in-glass thermometer. Mercury is also used in instruments such as barometers and other pressure-sensing devices. Liquid-in-glass thermometers are commonly used for household, industrial, clinical, and scientific purposes. The U.S. Census Bureau provided estimates for each of these classes of thermometers bought and sold in the United States in 1997 (USDOC 1998). The Census Bureau did not distinguish between mercury-filled thermometers and those filled with other liquids, nor did they provide an estimate for thermometer imports and exports. Therefore, estimates for mercury use based on these Census quantities are likely to overestimate actual quantities of mercury consumed. USEPA (1997a) expects mercury use and emissions from thermometers to remain steady, with decreases resulting from digital thermometers to be offset by increased demand for thermometers by a growing population.

3.3.2 Materials Flow

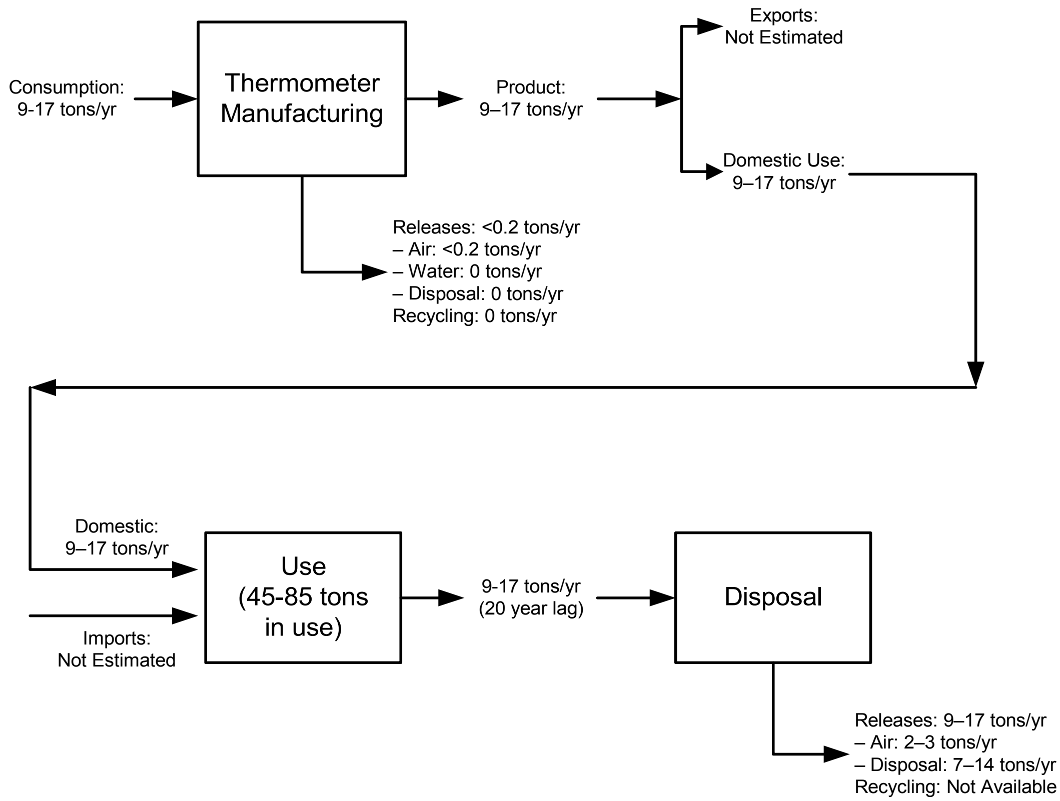
Exhibit 3-5 illustrates the consumption, release, and product content of mercury in thermometers and similar instruments in manufacturing, use, and final disposal.

3.3.3 Manufacturing

Mercury Consumption

USEPA (1992b) identified that oral/rectal/baby thermometers contained 0.61 grams mercury, and basal thermometers contained 2.25 grams mercury. They also estimated that 95 percent of clinical thermometers are oral/rectal/baby thermometers and basal thermometers comprised the remaining five percent. USEPA (1992b) did not provide an estimate of mercury content for scientific and industrial thermometers; therefore, the mercury content of these instruments were assumed to be equal to the quantity present in basal thermometers.

The U.S. Bureau of Census estimates that approximately 8.5 million medical and household thermometers (valued at $12.2 million, or $1.44 each) and 0.58 million industrial thermometers (valued at $10.2 million, or $17.60 each) were bought and sold in the United States in 1997 (USDOC 1998). The Bureau of Census did not provide an estimate for scientific thermometer production, but did provide an estimated value of $5.8 million. Assuming that each scientific thermometer costs between $1.44 and $17.60 (derived from the other thermometer types), an estimated 0.33 to 4.0 million scientific thermometers were bought and sold in the United States in 1997. The Bureau of Census also did not specify whether these thermometers were manufactured domestically or imported, although USEPA (1992b) states that thermometer imports have been increasing and assumes that exports are minimal.



Sources: Mercury Consumption: Calculated from USDOC (1998) and USEPA (1992b).
Mercury Releases: Air releases during manufacturing from USEPA (1997a). Other releases from general waste management data from USEPA (1997c).

Exhibit 3-5. Mercury in Thermometers

Exhibit 3-6. Mercury Used to Manufacture Thermometers in the U.S. in 1997

Thermometer Type	Quantity Manufactured[1]	Mercury Content per Thermometer (grams)[2]	Total Mercury (tons)
Medical and household thermometer - Basal	425,000	2.25	1.05
Medical and household thermometer - Oral/rectal/baby	8,100,000	0.61	5.45
Industrial thermometers	583,000	2.25	1.45
Scientific thermometers	330,000 to 4,000,000	2.25	0.74 to 9.0
Total	**8,300,000 to 11,900,000**	**-**	**8.7 to 17.0**

[1] U.S. Census (USDOC 1998), estimate for scientific thermometers is extrapolated from dollar value (see text).
[2] USEPA (1992b), mercury content for household thermometers is assumed to be same for oral/rectal/baby thermometers, mercury content for industrial and basal thermometer is assumed to be same as basal thermometers.

Product
For an upper-end estimate using Bureau of Census (USDOC 1998) data of liquid-in-glass thermometers bought and sold in the U.S. and USEPA (1992b) data for mercury content, Exhibit 3-6 shows that about 9 to 17 tons of mercury were contained in thermometers produced in the United States in 1997 (assuming no imports and that all liquid-in-glass thermometers are mercury-filled). This quantity is high because it assumes that all liquid-filled thermometers contain mercury.

Releases
Mercury thermometers are produced by creating a vacuum in the capillary glass tube to draw mercury into the bulb and glass tube. USEPA (1997a) cites a 1973 USEPA estimate of 18 pounds of mercury emitted for every ton of mercury used in instrument manufacture. However, USEPA (1997a) warns that this estimate is based on a survey of manufacturers during the 1960s and may be an overestimate of actual emissions. Using the 9 to 17 ton consumption estimate above, approximately 160 to 300 pounds (0.08 to 0.15 tons) of mercury are emitted to the air as a result of mercury thermometer manufacturing. Thermometer manufacturers reported no mercury releases to any media in the 1999 TRI.

3.3.4 Use
Using an estimated lifespan of 5 years (USEPA 1992b) and an annual production rate of 9 to 17 tons per year (as described in the manufacturing section), it is estimated that 45 to 85 tons of mercury are currently in use in thermometers in the United States. Because the mercury is completely contained in the thermometer, release and exposure to the mercury are unlikely under normal operating conditions.

3.3.5 Disposal
USEPA (1997a) reports that there is little data regarding mercury disposal. Most thermometers are discarded when they are cracked or broken and enter the waste stream from residential and clinical settings (USEPA 1997a). USEPA (1992b) estimates that five percent of the glass thermometers are broken each year. USEPA (1997a) cites a 1989 study that estimated that 16.3 tons of mercury were discarded in landfills from thermometers. It can be assumed that the quantity of mercury used in thermometer production (9 to 17 tons for 1997) requires eventual recycling or disposal. Assuming 80 percent is landfilled and 20 percent is combusted (based on typical municipal waste combustion rates), 7 to 14 tons are expected to be disposed to land and 2-3 tons are expected to be emitted to the air via combustion.

Increasing awareness regarding recycling of mercury thermometers has lead to programs such as Fisher Scientific's mercury thermometer trade-in program that offers to reclaim a mercury thermometer for every non-mercury thermometer ordered (Fisher Scientific 1999). Because of these recycling programs, disposal estimates may be high; there is no estimate available for the amount of mercury recycled from thermometers.

3.3.6 Discussion
The quantity of mercury in thermometers was estimated at 9 to 17 tons for 1997, based on Department of Commerce data addressing domestic sales of thermometers. Because all of the thermometers were assumed to be mercury-filled, this was intended to represent a high estimate for mercury consumption. The only other estimate is USGS data. As shown in Exhibit 3-7, 26 tons of mercury were used in 1997 for 'measuring and control instruments,' which is intended to include both mercury thermometers and thermostats (Reese 1999).

No estimates for other values could be found, so the remaining quantities on Exhibit 3-5 were calculated from this consumption quantity. Also, mercury recycling facilities are known to accept thermometers for recycling, but quantities are not available. Therefore, the quantities presented in Exhibit 3-5 as ultimately recycled and disposed are uncertain.

Exhibit 3-7. Mercury Consumption by SIC Code 382 – Measuring and Control Instruments (tons)

	1990	1991	1992	1993	1994	1995	1996	1997
Total Mercury Used[1]	119	99	88	72	58	47	45	26

[1]Source: USGS (1990-7)

3.4 Thermostats

3.4.1 Introduction

Facilities manufacturing thermostats may be classified under the following business classification:

> SIC Code 3822: Controls for Monitoring Residential and Commercial Environments and Appliance Regulating Controls.
>
> NAICS Code 334512: Automatic Environmental Control Manufacturing for Residential, Commercial, and Appliance Use.

A thermostat is a type of switch that turns on or off depending on the temperature. Thermostats are used to control the temperature in individual rooms, building spaces, appliances, and refrigerators. Mercury switch thermostats have been commonly used to control room temperatures in commercial and residential spaces for more than 50 years (USEPA 1994), although mercury-free alternatives are available. Typically, a mercury switch is mounted on a piece of bimetal. Bimetal is composed of a strip or coil of two thin layers of dissimilar metals that bend at different rates when heated or cooled. As the bimetal bends with the temperature change, a drop of mercury in a tube within the mercury switch moves under force of gravity to either complete or break an electrical circuit. Mercury thermostats have proven to be an accurate, reliable, and inexpensive means to control temperature (USEPA 1994).

3.4.2 Materials Flow

Exhibit 3-8 illustrates the consumption, release, and product content of mercury in thermostats during manufacturing, use, and final disposal.

3.4.3 Manufacturing

Mercury Consumption

Manufacturing of mercury switch thermostats consists of filling a short glass tube with a bead of mercury and sealing one end with wire contacts. There is little data available on mercury consumption in the manufacturing of thermostats. Using U.S. Bureau of Census data and consultations with thermostat manufacturers, USEPA (1994) estimates that 3 to 5 million mercury switch thermostats were manufactured in 1994. USEPA (1992b) estimates that each thermostat contains about 3 grams of mercury, therefore 11 to 17 tons of mercury are used to produce thermostats annually.

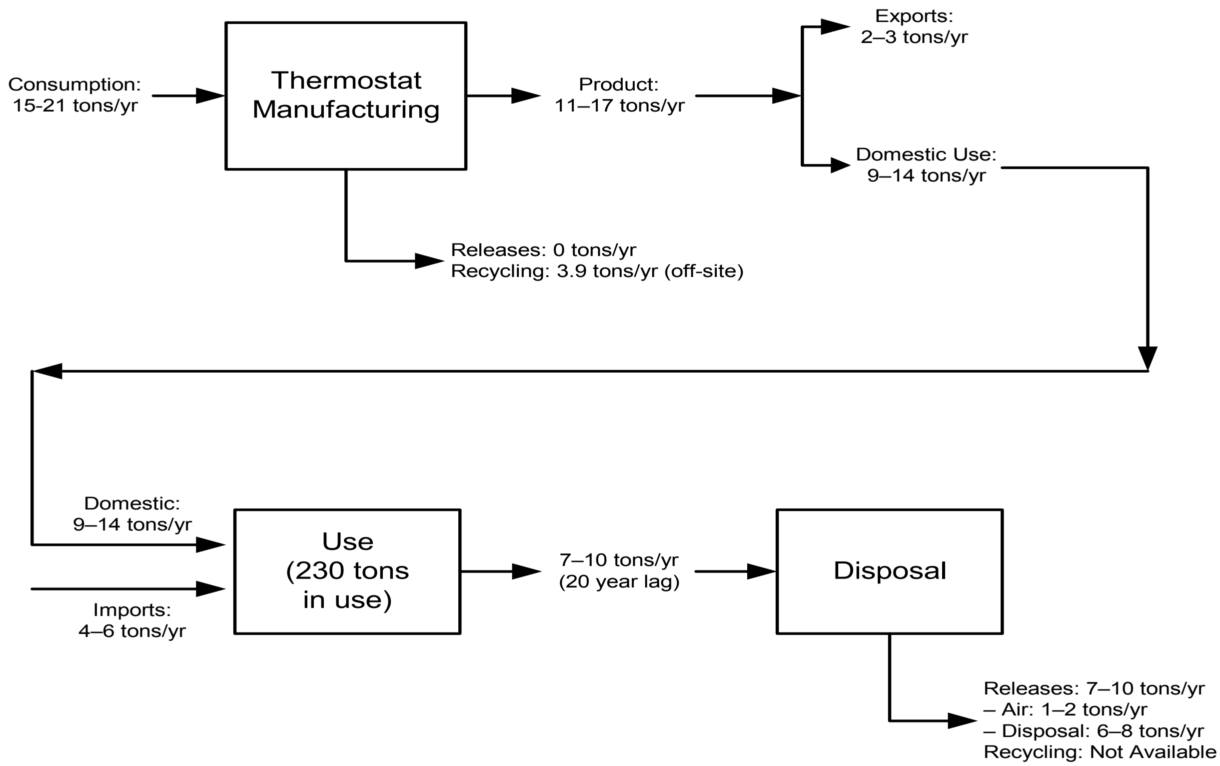
The U.S. Census Bureau (USDOC 1998) estimates that 45 million thermostats were manufactured in the United States in 1997, but some of these units may not contain mercury. Exhibit 3-7 shows the USGS estimates for domestic industrial consumption of mercury for SIC Code 382, which includes thermostat and thermometer manufacturing. Export data on mercury switch thermostats were not available.

Review of the 1999 TRI data shows four facilities involved in electronic component manufacturing (SIC Code 3679) reporting mercury releases; it is not known for certain whether these releases are a result of thermostat manufacturing (as opposed to switches or other products produced by the facility). Mercury may be emitted during the manufacturing process from spills and breakages, product testing, and product transfer (USEPA 1997a). Total emissions from these three facilities show negligible releases to air (0.002 tons), no releases to water, and 3.9 tons of mercury recycled off-site in 1999. This recycling quantity may be the result of off-spec product, spill collection, etc.

These quantities may not reflect other companies involved in thermostat production, and may be overestimates by including releases resulting from unrelated facility activities. Therefore, in Exhibit 3-8, it is assumed that the quantity present in products (11-17 tons), plus the quantity recycled (4 tons) equaled consumption (15-21 tons).

3.4.4 Use

Because mercury is contained in a sealed glass tube within the mercury switch thermostat, release and exposure to the mercury is unlikely under normal operating conditions. USEPA (1994) estimates that 70 million mercury switch thermostats were used in U.S. residences in 1994, which is associated with 230 tons of mercury (assuming 3 grams per thermostat as explained above). Since a mercury switch thermostat is a mechanical device with few moving parts, its lifespan is typically between 20 and 40 years, often exceeding that of the room or building within which it is housed (USEPA 1994). USEPA (1997a) cites a 1995 National Electrical Manufacturing Association finding that upgrading, remodeling, and building demolition are the principal causes of mercury switch thermostat removal.



Sources: Mercury Consumption: Sum of mercury in product and releases.
Mercury Release and Recycling: 1999 TRI for 3 facilities
Mercury in Product: Estimated from average mercury content (EPA 1992b) and number of thermostats produced (DOC 1998).

Exhibit 3-8. Mercury in Thermostats

Imports and exports may also affect the flow of mercury in thermostats. Bureau of Census data (USDOC 1998) indicate that the total value of thermostats produced was $718 million in 1997, the quantity imported was $259 million (36 percent of domestic production) and exports were $121 million (17 percent of domestic production). These data include mercury and non-mercury devices. Assuming an even distribution of mercury and non-mercury devices and a constant annual production rate, this indicates 11 to 17 tons of mercury are present in domestically produced devices, 4 to 6 tons of mercury are in imported products, and 2 to 3 tons are in exported products. The net result is that 13 to 20 tons of mercury annually enter the domestic consumer market in thermostats.

3.4.5 Disposal

USEPA (1994) estimates that 2 to 3 million thermostats were brought out of service in 1994. Assuming that all of the disposed thermostats contained mercury at 3 grams per unit, this corresponds to 7 to 10 tons of mercury per year. In the past, most thermostats have been disposed of as municipal solid waste. Assuming that 80 percent of solid wastes are landfilled and the remaining is sent to municipal waste combustors, 80 percent of the mercury (6 to 8 tons) is landfilled and the remainder emitted to the air.

Efforts to recycle mercury switch thermostats are increasing; however, it is unknown what proportion of the thermostat wastestream is being recycled. USEPA (1999b) cites Thermostat Recycling Corporation as recycling 120 pounds (0.06 tons) of mercury in the Great Lakes region in 1998.

3.4.6 Discussion

Since mercury switch thermostats have such long lives, they are expected to enter the waste stream for at least the next 30 to 40 years. USEPA (1992b) projects programmable (non-mercury) thermostats to steadily replace mercury switch thermostats, gaining an additional one percent of the market share annually.

The quantity of mercury in thermostats estimated to enter the consumer market (13 to 20 tons) is greater than the quantity of mercury estimated to be in thermostats removed from service (7 to 10 tons). This may represent an inaccuracy in one or both of these estimates. Alternatively, and perhaps more likely, it may be indicative of the large lag time between generation and disposal. For example, it may be the case that a larger number of thermostats are being sold today than 20 to 40 years ago (i.e., the thermostats just now being removed from service), or that new construction (rather than replacement) comprises a significant percentage of the new thermostat market and the number of thermostats in buildings in the United States increases every year.

The USGS consumption data were not used for consumption estimates because the data are combined with other product categories (i.e., thermometers). The estimate used here, however, is consistent with the USGS estimate from Exhibit 3-7.

Estimates are not available addressing the quantity of mercury in used thermostats sent for recycling. Potentially, this is a significant data gap, because numerous programs are in place to recycle mercury containing thermostats. Identifying an accurate estimate is difficult due to the varied methods by which the thermostats may enter the recycling market, not all of which are accountable. Therefore, the quantities ultimately recycled and disposed by commercial, industrial, and consumer use are uncertain.

3.5 Switches and Relays

3.5.1 Introduction

Facilities manufacturing switches and relays may be classified under the following business classifications:

> SIC Code 36251 66: Relays and Industrial Controls, General Purpose and Other Relays, Reed Relays; Mercury Wet Reed
>
> SIC Code 36433 69: Wiring Devices and Supplies, Current Carrying Wires, Switches for Electrical Circuitry, All Other Switches: Appliance and Fixture, Including Surface Mounted, Mercury, etc.

Mercury switches and relays are used in many household and automotive applications. Mercury switches are typically used to detect motion. A mercury switch consists of a glass or ceramic tube with electrical contacts at one end. When the tube is tilted or jolted, a bead of mercury flows over the electrical contact and completes the circuit. A mercury switch is often called a "silent switch" because electrical contact is established instantaneously due to the surface tension of the mercury. In a hard contact switch, the microscopic "bounce" that occurs as contact is established may cause electrical noise (USEPA 1994).

Tilt switches are mercury switches that are used to sense tilt. Mercury tilt switch applications include level controls, security alarm systems, vending machine alarms, washing machine covers, and automobile trunk light switches. Mercury tilt switches are also used as motion and vibration sensors in anti-theft devices, "smart appliances" that turn off when not in use, and automobile anti-lock brakes.

A relay is an electromechanical switch where the variation of current in one electrical circuit controls the current in another circuit. A relay consists of an electromagnet that is connected to a moveable contact. When the electromagnet is energized, the contact is moved to either complete or break a circuit. In a mercury reed relay, the electrical contacts are wetted with mercury to provide an instantaneous circuit (USEPA 1994).

3.5.2 Materials Flow

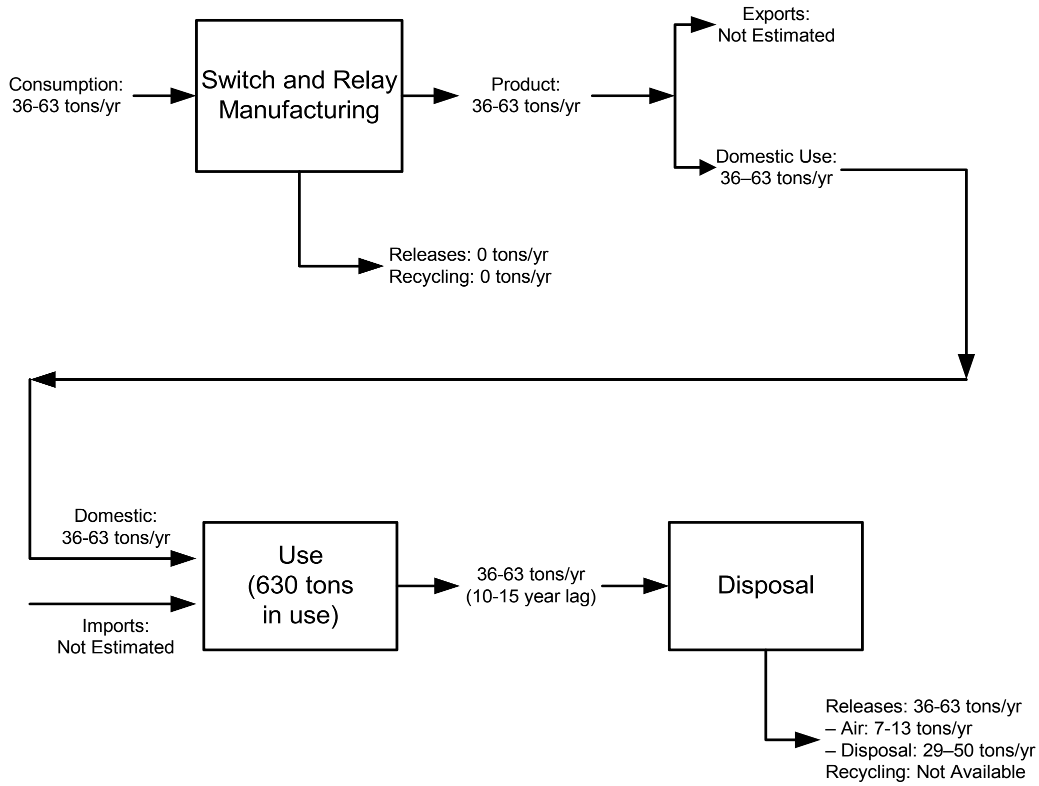
Exhibit 3-9 illustrates the consumption, release, and product content of mercury in switches and relays, in manufacturing, use, and final disposal.

3.5.3 Manufacturing

Mercury Consumption

USGS data in Exhibit 3-10 show that the total amount of mercury used to produce wiring devices and switches peaked in 1995 at 92 tons and dropped to 63 tons in 1997. The USGS estimate does not include mercury reed relays because relays are classified under SIC Code 3625. The mercury content of various switches and relays is shown in Exhibit 3-11.

Data from both the Department of Commerce's Bureau of Census and USGS (1997) were used for estimating mercury flow in this sector. The data are expressed as a range: 36-63 tons per year.



Sources: Mercury Consumption: Low end range from USDOC (1998) and M2P2 (1996). High end range from USGS (1997).
Mercury Releases: General waste management data from USEPA (1997c).

Exhibit 3-9. Mercury in Switches and Relays Manufacturing

The number of mercury switches manufactured in the United States is uncertain. Mercury switches could be included under various product codes within SIC code 36433 (Switches for Electrical Circuitry). Mercury switches are specified in product sub-code 69 (All other general use switches, including mercury). However, the quantities and values in the 1998 Current Industrial Report (USDOC 1998) combines product code 69 with other AC-DC switches (product code 51) to protect proprietary information. Moreover, mercury switches may be found within other product codes such as automotive switches and other special type of switches. Mercury reed relays are classified under SIC code 3625, however, specific production data were withheld in the 1997 Manufacturing Profiles report (USDOC 1998).

Assuming that all 16.5 million general use switches (SIC Code 36433-69) bought and sold in the United States (USDOC 1998) are mercury switches and each contains 2 grams of mercury results in approximately 36 tons of mercury. This estimate could be high because SIC Code 36433-69 includes non-mercury switches, but it could also be low because it does not include mercury reed relays and may not include automotive and other switches. In 1996, 11.2 tons of mercury was used in U.S.-made vehicles, primarily as lighting switches (GLU 2001).

Releases

Mercury may be released during the manufacturing process from spills and breakages, product testing, and product transfer (USEPA 1997a). The wastes associated with mercury switch manufacturing are uncertain. Mercury switch manufacturing consists of filling a glass or ceramic tube with 0.5 to 3 grams of mercury and sealing the end with electrical contacts. Although four facilities within SIC Code 3679 (Electric component manufacturing) reported mercury waste emissions to the Toxics Release Inventory in 1999, it is uncertain whether those releases result from manufacturing mercury switches or relays. Total emissions from these three facilities show negligible releases to air (0.0025 tons), no releases to water, and 3.9 tons of mercury recycled off-site in 1999. These estimates were previously accounted for in thermostat manufacturing, and are not repeated here. Applied to the industry as a whole, these quantities are not necessarily representative of other switch and relay manufacturers.

3.5.4 Use

Mercury switches are very reliable, and certain types of mercury switches can last up to 50 years (USEPA 1992b). Because the mercury is contained in a sealed glass or ceramic tube within the mercury switch, it is unlikely that it will be released under normal conditions. Because mercury switches are used in various applications, from lighting switches to anti-lock brakes, the number of switches currently in use is not easy to determine. Using the USGS mercury consumption data since 1990 (see Exhibit 3-10), and assuming that the mercury contained in those switches is still in use, there are at least 630 tons of mercury contained in switches in the United States. This estimate is probably low because of the long life span of mercury switches; most switches manufactured in the 1970s and 1980s are probably still in use. The amount of mercury imported into the U.S. contained in imported mercury switches is also unknown.

3.5.5 Disposal

USEPA (1992b) estimates that 1.9 tons of mercury are discarded from mercury electric light switches each year, assuming that 10 percent of the switches are disposed after 10 years of production, 40 percent discarded after 30 years of production, and the remaining 50 percent after 50 years. However, that estimate does not include other mercury switches such as those found in household appliances, automobiles, and mercury reed relays. Exhibit 3-10 assumes the amount used in switch and relay manufacturing (36-63 tons/year) must eventually be disposed, with 80 percent landfilled and 20 percent incinerated.

3.5.6 Discussion

Because mercury switches have such long life spans, they are expected to steadily enter the waste stream for at least the next 30 to 40 years. The automobile industry is working to reduce mercury consumption (CGLI 1999). Mercury reed relays are gradually being replaced by solid state relays (USEPA 1994).

Exhibit 3-10. Mercury Consumption by SIC Code 3643 – Wiring Device and Switches

	1990	1991	1992	1993	1994	1995	1996	1997
Total Mercury Used[1] (tons)	77	78	90	91	87	92	54	63

[1]Source: USGS (1990-7)

Exhibit 3-11. Mercury Content of Various Mercury Switches and Relays

Description	**Mercury Content (mg)**
Automobile trunk and hood light switch	500-1,000
Freezer light	2,000
Silent Switches	2,600
Mercury Reed Relay	140-3,000

Source: M2P2 1996

The wide variety of mercury switches and their applications in consumer and industrial products makes accounting extremely difficult. This variety results in different classifications of switches with some portion of each containing mercury. The most significant example is the classification of thermostats, which contain a mercury switch but is categorized separately (and discussed elsewhere in this report). Nevertheless, there may be difficulties with data interpretation, especially in cases where a manufacturer produces a wide variety of mercury-containing products that contain switches, but classifies its business activities according to a more limited set of SIC codes. Such a problem was apparent when interpreting TRI data for manufacturers of various electrical devices and attributing the data to different products (such as thermostats and switches).

The quantity of mercury used for switches is uncertain. The quantity provided by USGS (1997) is 63 tons. Bureau of Census data (36 tons) were also used to account for switches that are likely to contain mercury. Both values are included in Exhibit 3-10, as a range, to account for this uncertainty.

3.6 Organic Chemical Production

3.6.1 Introduction

Facilities producing organic chemicals may be classified under the following business classifications:

SIC Code 2869: Industrial Organic Chemicals

NAICS Code 325: Chemical Manufacturing

Mercury is used as a catalyst in the organic chemicals industry. One known use is in the production of vinyl chloride monomer using acetylene as a raw material. In this process, acetylene (C_2H_2) is combined with hydrogen chloride (HCl) and flows through a fixed bed of solid mercuric chloride catalyst. The product is vinyl chloride (C_2H_3Cl), which is subsequently purified. This process is used by a single facility, Borden Chemicals and Plastics in Geismar, Louisiana. In 1996, this facility had a capacity to produce 950 million pounds of vinyl chloride per year, but by 1998 was expected to increase this capacity by 250 million pounds per year (USEPA 2000a). As a result, the quantity of mercury used and subsequently released is expected to increase. In 1999, a total of three facilities (the Geismar facility was not one of them) reported releases of mercury; however, the releases were negligible (0.0005 tons).

3.6.2 Materials Flow

No estimates of mercury consumption data were available for this industry, therefore neither consumption nor release data can be presented due to insufficient data.

3.7 Dental Preparations

3.7.1 Introduction

Facilities manufacturing or using dental equipment may be classified under the following business classifications:

SIC Code 3843: Dental Equipment and Supplies
NAICS Code 339114: Dental Equipment and Supplies Manufacturing

SIC Code 8021: Offices and Clinics of Dentists
NAICS Codes 6212 and 62121: Offices of Dentists

This section focuses on use of mercury by the dental profession. Amalgam fillings, used to fill cavities in teeth, contain about 50 percent mercury. Not all of the mercury used by the dental profession ends up in the fillings. Some is lost as air emissions, some is discharged in wastewater, and some is disposed as hazardous waste or is recycled.

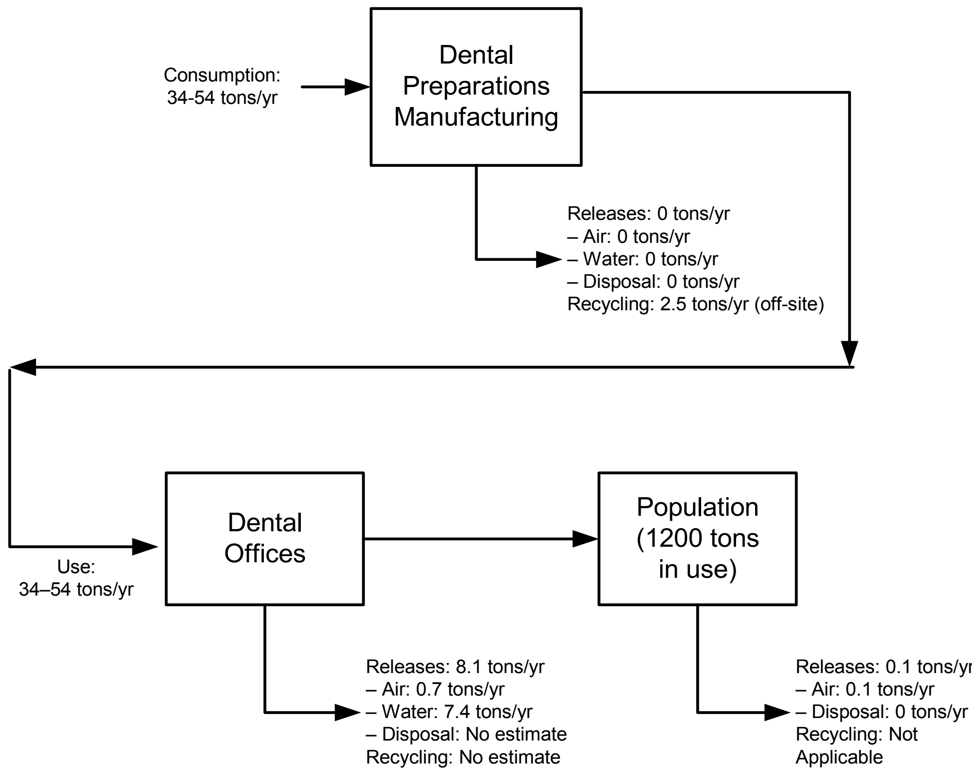
3.7.2 Material Flows

Exhibit 3-12 illustrates the flow of mercury in the dental profession.

<u>Mercury Consumption</u>

Mercury consumption is assumed equal to the amount of mercury used in amalgam fillings.

Mercury is a major component (50 percent) in amalgam fillings. Using data from USGS (1997), USEPA (1997a) assumed that 34 tons of mercury were used in the dental industry during 1996, including amounts found in equipment and supplies. However, another approach presented below results in a slightly higher estimate of 54 tons per year. To account for this uncertainty both estimates are given in Exhibit 3-12. In 1990, about 96 million of the more than 200 million restorative procedures that were performed used amalgam (USDHHS 1993). Amalgam use decreased by 12.5 percent among dentists from 1990 to 1995, and since the beginning of 1993 the trend has been steady (USDHHS 1997). Assuming that amalgam use continued to steadily decline results in 81.6 million amalgam fillings in 1996. According to a study by Yoshida (1994), an



Sources: Consumption and Use: USGS (1997) for low end, and Yoshida (1994) and USDHHS (1993, 1997) for high end.
Manufacturing Releases: 1999 TRI.
Dental Office and Popluation Releases: Air releases from EPA (1997a), water and population releases from DAMS (1999).

Exhibit 3-12. Mercury in Dental Preparations

amalgam filling contains 0.6 grams of mercury. Therefore, almost 49,000 kilograms (54 tons) of mercury were used in fillings during 1996.

Air Releases

Mercury in fillings can be released in various ways, including emissions from spills and scrap, air discharged by the dental office's vacuum pump system (Rubin 1996), and constant emissions from the fillings in people's mouths over time. USEPA (1997a) assumed that two percent (0.7 ton out of 34 tons) of the total amount of mercury used is emitted from spills and scrap, but admits that number is likely an underestimate of the total emissions. This estimate is reflected in Exhibit 3-12.

Studies have been conducted to determine the amount of mercury that is released from fillings once they are placed in people's mouths. As presented in USDHHS (1993), a study by Mackert found that, on average, a person's intake of mercury from fillings is 1.24 micrograms each day; results from other studies ranged from 1.7 to 27.0 micrograms per day. Using the U.S. Census Bureau estimate of 281 million people in the U.S. in 2000 (USDOC 2001) and 1.24 micrograms of daily release per person results in 0.35 kilograms (1 pound) of mercury released from fillings per year. This estimate is not presented in Exhibit 3-12 because it is not directed towards media releases to the environment but rather direct exposure.

Water Releases

Wastewater from a dental office may contain, on average, 270 milligrams per day (range 65 to 842) (based on data from Arenholt [1996] in DAMS [1999]). Using the mean daily level of 270 milligrams per day per office times 250 working days per year times 100,000 dental offices (conservative estimate, DAMS 1999) results in 6,750 kilograms or 7.4 tons of mercury entering wastewater each year.

Amalgam separators can reduce the mean mercury content in a dental office's wastewater from 270 to 35 milligrams per day (based on data from Arenholt [1996] in DAMS [1999]). However, few dental offices in the United States have amalgam separators (DAMS 1999).

Solid Waste Releases

No data are available to estimate quantities of mercury recycled or disposed.

Recycling

The quantity of mercury recycled by dental offices is unknown. 1999 TRI data showed one dental equipment manufacturing company reporting mercury emissions. Offsite recycling was reported as 2.5 tons, while releases to all other media were reported as zero.

Reservoir

The total quantity of mercury in the population is estimated based on the annual use rate of 34 to 54 tons. No data were available to estimate the lifetime of a filling. Assuming a 20 to 40 year span, this results in an estimated quantity of 1200 tons in use.

3.7.3 Discussion

The estimate used for the amount of mercury per filling was based upon a Japanese study. The mercury content of fillings in Japan may be higher than in the United States, which may help account for the discrepancy between this estimate of 54 tons of total mercury used and USEPA's estimate of 34 tons. Additionally, this is a single average value, where in reality the quantity used is a function of many factors such as the patient's needs and the technique of the dentist. Furthermore, non-amalgam fillings are being used for certain applications.

3.8 Pharmaceutical Use

3.8.1 Introduction

Mercury finds its way into a variety of pharmaceutical products, including opthalmics, vaccines, and topical products. Although use of mercury in these products has been scaled back in recent years both from voluntary actions by manufacturers due to increasing concerns over mercury toxicity and as the result of Food and Drug Administration (FDA) regulations, mercury is still found in many products.

To assess the presence of mercury in food and drugs, the FDA issued a request for data to identify food and drug products that contain intentionally introduced mercury compounds (63 FR 68775, December 14, 1998). FDA's analysis of these responses (USFDA 1999) indicate that three mercury compounds are intentionally introduced as a preservative into both prescription and over the counter (OTC) nonhomeopathic products such as nasal spray. These preservatives are thimerosal (TM), phenylmercuric acetate (PMA) and phenylmercuric nitrate (PMN). The responses also showed that more than twenty other mercury compounds are used in homeopathic drug products, usually as therapeutic ingredients.

3.8.2 Materials Flow

Exhibit 3-13 shows the consumption and release of mercury pharmaceutical product manufacturing.

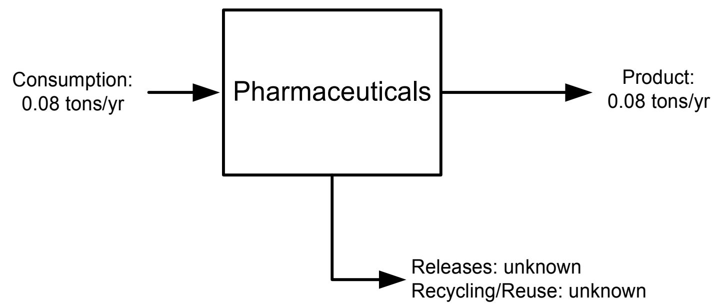
Mercury Consumption

USFDA (1999) calculated that approximately 75,000 grams (0.08 tons) of mercury compounds are used per year. The FDA calculated this amount by tallying the responses received from the request for data; categorizing the responses by compound used and product type; searching its databases for additional products that fall into these product type categories that were not reported in the responses to the request for data; applying the same average amounts of mercury compounds reported for that product type and category to the additional products found in the databases; then totaling the amounts of mercury compounds from each category to reach an estimated total amount of mercury compounds used in pharmaceutical products.

The 75,000 grams of mercury compounds estimated comes exclusively from the three common preservatives: TM, PMA, and PMN. While many homeopathic product uses were reported, the FDA concluded that the dilutions of mercury compounds in products were so low as to be negligible in comparison to pharmaceutical use. Thimerosal in products accounts for approximately 99% of the mercury compounds included in the FDA's estimate.

Releases

Releases may result from the manufacture or formulation of the mercury compounds themselves. No pharmaceutical manufacturers reported mercury releases in 1999 to the TRI.



Source: Mercury Consumption: FDA (1999).
Mercury Release and Product: Assumed equal to consumption.

Exhibit 3-13. Mercury in Pharmaceuticals

The potential release mechanisms for mercury in pharmaceutical products include excretion, exhalation, volatilization, spillage during administration, and the destruction or disposal of unused products. Because these products may be administered in any location, especially in the case of OTC products, there is no way to quantify the amounts that are spilled or discarded. Many studies have been conducted examining the output of mercury from the human body, but these are largely dependent on dose, method of exposure, and the specific mercury compound. Because mercury in pharmaceuticals can be introduced orally, nasally, dermally, ocularly, or through injection, it is also impossible to quantify the output of these compounds once introduced to the human body.

3.8.3 Discussion

While mercury preservatives in pharmaceuticals were reported to the FDA in a large array of products, their use is dwindling due to consumer and regulatory pressure. The few uses remaining are likely to be discontinued due to the requirements of the New Drug Approval process, which requires demonstration that a product is safe and effective. The estimated total amount of mercury compounds used annually, 0.08 tons, indicates that pharmaceutical use is negligible in comparison to other sources and uses of mercury.

3.9 Laboratory Use

3.9.1 Introduction

This section focuses on the use of mercury and mercury compounds in laboratory chemicals. Mercury compounds are used in laboratories in two ways: as chemical reagents in experiments and processes and in chemical products used for laboratory work. Mercury is also found in many laboratory instruments, such as thermometers and manometers, as discussed in other sections of this report; this section focuses specifically on non-equipment use.

Histology, the processing of body tissues for examination, comprises several types of steps. These steps include fixation and staining, both of which frequently use mercury-bearing compounds. It is important to note that these chemicals often contain mercury in concentrations less than 1 percent, so the mercury compound may not be listed on the product Material Safety Data Sheet (MSDS). A certification of analysis from the manufacturer will reveal the small amounts of mercury in these products.

3.9.2 Materials Flow

Mercury Consumption

Because there are a wide variety of mercury compounds used in laboratories, and these chemicals are made by many different manufacturers, it is not possible to determine the quantity of mercury annually being used in laboratory settings. One source notes a decline from 35 tons of mercury compounds used in 1990 to 11 tons of these compounds used in 1991 (NC DEHNR 1996). It can be assumed that the current total usage of the chemicals has continued to decline in the past nine years, in light of the recent revisions of standard analytical methods and growing concern over environmental hazards.

Releases

Releases may result from the manufacture or formulation of the mercury compounds themselves. No manufacturers of laboratory chemicals reported mercury releases in 1999 to the TRI.

Mercury can to be released in two additional ways: as unused product (e.g., expired or otherwise discarded reagent), and as a result of use (e.g., in samples at dilute concentrations). In general, laboratories prepare their own guidelines regarding handling procedures for these waste materials. Releases as solid waste and as water discharges are expected to be most prevalent. Solid wastes are expected to be the result of unused reagent that is sent offsite for recycling or disposal as a hazardous waste. Water releases would result from the disposal of analyzed samples which contain small concentrations of the reagent, which is rinsed down the sink. Water releases may also result from the disposal of unused reagent down the sink. The presence or absence of local regulations or permitting requirements regarding sewer discharges is expected to influence the laboratory practices used.

3.9.3 Discussion

Because data estimating the use of mercury-containing laboratory chemicals and equipment are not avaiable, it is impossible to determine the contribution of this sector to domestic mercury use and release. The only available estimate of use, 11 tons of mercury-bearing chemicals used in 1991 (NC DEHNR 1996), does not estimate the amount of mercury in these chemicals; because most of these chemicals contain only trace amounts of mercury (less than one percent), it can be assumed that the amount of mercury used and released from laboratory chemicals is negligible in comparison to other sources and uses of mercury.

3.10 Batteries

3.10.1 Introduction

Facilities manufacturing or storing batteries may be classified under the following business classification code:

SIC Code 3691: Storage battery manufacturing
SIC Code 3692: Primary battery manufacturing
NAICS Code 33591: Battery manufacturing

The use of mercury in electrical batteries has decreased significantly from more than 1,000 tons annually in the early 1980s to less than 1 ton in 1996 (USGS 2000e). The use of mercury in battery production was sharply reduced in the early 1990s. Mercury is presently used in two types of batteries: button cell batteries and mercuric oxide batteries. Button cell batteries are used in watches and other consumer electronics. Mercuric oxide batteries are larger cylindrical batteries used mostly for non-consumer use items such as medical or military applications (USEPA 1997a). The Mercury-Containing and Rechargeable Battery Management Act of 1996, in part, phased out the use of alkaline-manganese and zinc-carbon batteries containing intentionally added mercury and button cell mercuric-oxide batteries (USGS 2000e).

3.10.2 Materials Flow

At present, most batteries are expected to last no more than a few years either as a result of use or slow discharge over time. Therefore, little to no mercury is expected to be present as part of consumer use of batteries from applications prior to 1992. Furthermore, such a quantity from past use cannot be estimated.

Releases of mercury to air from battery manufacturing were estimated by USEPA (1997a). This estimate showed negligible mercury emissions (<0.001 tons) in 1995. Examination of the 1999 TRI data showed one battery manufacturer reporting mercury releases of 0.0125 tons. This facility corresponded to the only domestic mercuric oxide battery manufacturer (Maine 2000).

3.10.3 Discussion

In conclusion, mercury is consumed in very small amounts for battery production, relative to other sources. Quantities of mercury used and subsequently released are correspondingly small. For this reason, no exhibit illustrating mercury flow is presented.

3.11 Miscellaneous

TRI data for 1999 identified several facilities reporting releases of mercury that do not appear to be engaged in the manufacturing processes described above. The industries include electroplating (three facilities), explosives (one facility), food (one facility), transportation (one facility), jewelry and precious metals (one facility). The combined releases of all the industries is 0.21 tons of mercury.