Metallic Mercury Spill Response Guide

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1. Introduction

Metallic Mercury (Hg) occurs naturally in the environment as mercuric sulfide (cinnabar). Cinnabar has been refined for its mercury content since the 15th century. Mercury is a silvery white toxic metal, liquid at room temperature, easily breaks up into small droplets, and evaporates to form mercury vapor, a toxic colorless and odorless gas. This guide contains information on metallic (elemental) mercury only. Many of the documents cited here contain information on mercury compounds as well (Section 15). Mention of trade names or commercial products does not constitute endorsement or recommendation for their use.

This guide contains sections on:

- **Emergency Response and Protective Measures for Responders**
- **Physical Properties and Classification of Metallic Mercury**
- **Sources of Mercury**
- **Flammability and Reactivity**
- **Exposure to Metallic Mercury**
- **Sampling and Analysis**
- **Remediation and Disposal**
- **Prevention**
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- **Sampling and Analytical Methods**
- **Statistics for Mercury**

2. Emergency Response and Protective Measures for Responders

Under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulations, any release of greater than or equal to I pound (lb.) or 0.454 kilograms (kg) is a reportable quantity. The person in charge of the vessel or facility involved in the release must notify the National Response Center at (800) 424-8802. For the Washington DC metropolitan area, the National Response Center's number is (202) 426-2675. See Occupational Safety and Health Agency's (OSHA)'s 40 Code of Federal Register (CFR) 302.6 (section IV.D.3.b) for additional information.[1]

Contaminated clothing should not be worn off-site. Trained persons engaged in the mercury cleanup operation should make sure that their personal items, such as clothing and shoes are not contaminated before leaving the site. The cleanup personnel clothing and shoes must be scanned for mercury vapors using real-time instrumentation before leaving the site. If clothing or shoes are contaminated, the individual must follow the procedures outlined in this guide. Persons in the spill area should be advised not to remove any mercury from the spill site. Children and adults may be tempted to take some of the mercury home with them or to roll the beads around on desktops or tabletops. This behavior is not only dangerous for the persons directly involved, but it greatly increases the chance of spreading the contamination to hard-to-reach locations away from the area of the spill.

2.1. Assessment of Spill

The level of response to a reported mercury spill will depend on the size of the spill, the number and ages of the persons in the vicinity of the spill (small children are especially susceptible to harm), the amount of time elapsed since the spill occurred, and the speed and extent of contaminant dispersion. Site responders should advise residents and/or workers not to attempt clean up with a conventional vacuum cleaner or broom. These techniques can disperse liquid mercury and mercury vapors into previously uncontaminated areas.

Responders must assess whether the spill is in an open area or a confined space, and whether the release site is a workplace or a residence. Response measures will depend on whether a large amount of mercury was released suddenly, or if the mercury has been released slowly over a period of time. Inhaled mercury vapors pose the greatest threat to human health, with even small spills potentially producing enough volatile mercury to pose a serious health hazard. Intense heat and fire increase the hazard level because mercury may form toxic or explosive compounds when exposed to heat.[2]

Site responders should restrict entry to spill areas, evacuating all unauthorized persons at least 10 to 25 meters (m) (30 to 80 feet) in all directions, and moving them upwind of the spill.[3,4] For large spills, evacuate an area at least 100 m (300 feet) downwind. In case of fire, based on modeling data, evacuate the area recommended by the local health and safety personnel.

Site responders should wear chemical protective clothing (consult manufacturers specifications).[3,5] Respirators should be worn during emergencies and confined-space entries. Consult National Institute of Occupational Safety and Health (NIOSH) document #73-11024 or OSHA Safety and Health Standards, 29 CFR 1910.134 for lists of respirator specifications (Appendix A). Government regulations concerning exposure limits are discussed in Section 6.

Section 13 also provides a list of contact information for various government and private agencies that assist in mercury spill responses.

2.2. Size of Spill

2.2.1. Small Spill

If the Mercury spill is very small, (e.g., a broken thermometer), instruct an adult to follow the directions below to consolidate and contain the spill.[6] The use of protective gloves (nitrile rubber) is preferred.[7]

- Roll the mercury beads onto paper or suction them up with an eyedropper. Avoid bringing metal jewelry in contact with the mercury because mercury forms compounds with most metals, generating heat in the process.

- Place the mercury into a leak-proof, airtight container, such as a glass jar.
- Place the paper or eyedropper and the gloves in the container as well, and seal it tightly.
- Close off the room from the rest of the building.
- Open the doors and windows, and use fans for a minimum of four hour to ventilate the room.
- Consult the local health department on the proper procedure for disposal of the collected mercury.
- Do not dispose of mercury with other household or office-waste products.

2.2.2. Intermediate-Size Spill

Intermediate-sized spills in the workplace may be cleaned up by workers themselves if they have been trained to use spill kits and protective clothing. Gloves, eye protection, and laboratory coats are sufficient when cleaning up a spill of a few milliliters (mL) of mercury.[8] Contaminated clothing and shoes must not be worn off-site.

- Keep the area clear of all persons except those cleaning up the spill.
- Make sure the spill area is well ventilated.
- Do not walk through the spilled mercury nor touch it with bare hands.
- Contact the appropriate state or federal agency for disposal instructions.
- Do not dispose of mercury-containing waste with other workplace waste products.

2.2.3. Large Spill

For larger spills**,** especially those with exposure victims, professional help is essential.[2,3,4,5,8] Upon receiving a report of a large mercury spill responders should begin by exercising the following measures:

- Contact appropriate Agency (Section 13).
- Advise residents or workers not to disperse mercury or mercury vapors by attempting to sweep up the mercury spill or by attempting to clean up the spill by any means.
- Move all unauthorized persons, especially children, away from the spill area. If possible, isolate operations, using local exhaust ventilation at the site of the mercury release.
- Close windows and doors and seal off the area. Insure that the ventilation system to the contaminated area is isolated and sealed off as well.
- Vent the contaminated area to the outdoors to maintain negative pressure (when compared to other parts of the building) in the contaminated area.
- Cover large outdoor spills with earth, sand, or other non-combustible materials, followed by plastic sheeting for rain protection.

2.2.4. Contaminated Container

If a container of mercury is found in a home or other unauthorized location, contact the local health department or hazardous material team for instructions on proper disposal.[6] Any disposal container should be airtight or placed inside another container that can be sealed tightly. Wear protective (rubber) gloves when handling the container to guard against contact with any mercury that may be on the outside of the container. If the mercury has been spilled, leave the area and contact the local health or hazardous material team.

3. Physical Properties and Classification of Metallic Mercury[2]

Mercury (CAS# 7439-97-6, DOT# UN 2809, chemical symbol Hg) is a metallic element. It is also known as quicksilver, liquid silver, azogue, or hydrargyrum. Mercury is a dense [(13.59 grams per cubic centimeters (gms/cc)], silver-white liquid at room temperature. Mercury droplets will not tarnish upon exposure to air at ordinary temperatures, but may have a thin black oxide or sulfide coating on the surface if exposed to heat.[9] Unlike other metals, mercury has a significant vapor pressure under ambient conditions [(0.002 millimeters (mm).[9] It is this property that presents the greatest hazard because mercury enters the human bloodstream more readily through inhalation of the vapor than through ingestion or skin contact.

Mercury vapor is colorless and odorless. Small amounts of spilled mercury may produce enough vapors to reach hazardous levels in the immediate area of the spill. Mercury is insoluble in water. It is not flammable, but it may form toxic or explosive compounds at high temperatures.[2,3,10] Mercury forms alloys, known as amalgams, with most metals except iron,[9] often releasing large quantities of heat in the process.

Spilled mercury, whether classified as a commercial chemical product or manufacturing chemical intermediate (or as an off specification commercial chemical product or manufacturing chemical intermediate) must be managed as a hazardous waste according to federal or state regulations.[11] Any container or inner liner used to hold this waste, any residue, contaminated soil or water, or other debris resulting from cleaning up a mercury spill must be treated as hazardous waste as well. Generators of small quantities of this waste may qualify for partial exclusion from hazardous waste regulations {40 CFR 261.5(e)}. The EPA Hazardous Waste classification for mercury is U 151 (toxic waste).[12]

4. Sources of Mercury

Mercury is used in a variety of manufactured products and manufacturing processes.[2] Many applications have been discontinued in recent years because of the health hazards associated with using mercury. Metallic mercury is still used in household and workplace products including batteries, fluorescent bulbs, mercury arc lamps, and vapor lamps.[6,10] Mercury lighting is used in advertising signs.[6] It can be used as a reflective coating for mirrors.[2] Mercury is used for motion-sensitive electrical switches such as those used for car alarms and light-up sneakers.[6] Because these products are often discarded and disposed of as mixed waste, metallic mercury is also found in municipal incinerator ash, sludge, and landfill wastes.[2,4] Medical incinerator waste and uncontrolled emissions from medical facilities are a significant source of mercury in the atmosphere.[13] Section 14 contains statistics for mercury releases, transport, and chemical transformations.

4.1. Natural Sources

Natural sources of mercury include volcanoes, hot springs, and ore minerals.[4] Elemental mercury is rarely found in nature; most naturally occurring forms of mercury are organic or inorganic compounds.[14] Fish and seafood are a significant source of ingested mercury, but this mercury almost always occurs as organic compounds.

4.2. Industrial Sources

Mercury is present in industrial settings in the form of chemical intermediates and catalysts.[2,4,10,13,14,15] It is used in chlor-alkali plants (chlorine and caustic soda manufacturing) and in the cement, ink, paper, pharmaceutical, leather, and textile manufacturing industries. Mercury is used in various mining operations, including gold extraction. Coal-fired power plants and copper and zinc smelters are significant sources of mercury releases to the atmosphere.

4.3. Scientific and Medical Sources

Many scientific and medical measuring devices use mercury gauges.[2,6] These devices include thermometers, barometers, blood pressure measuring devices, hydrometers, and pyrometers. Mercury-containing instruments are found in hospitals and doctors' offices, industrial laboratories, and school laboratories. Some scientific instruments are equipped with mercury shutters. Mercury is also used in diffusion pumps[14] and as a lubricant for turbines.[11]

Although a variety of materials are now used for dental fillings, amalgam (mercury alloy) fillings are still common.[1,10,13] These fillings release a small amount of mercury vapor into the mouth over a long period of time. Dental workers bear a finite health risk because of their constant exposure to amalgam filling materials. This risk extends to the developing fetuses of pregnant dental workers because mercury can migrate across the placental barrier.

4.4. Religious Sources

Mercury is used in traditional religious practices and folk medicine, especially in certain areas of Mexico, the Caribbean, and in some Asian countries.[6,13] Mercury is referred to as "azogue" in regions with Spanish-speaking populations. Metallic mercury is worn in sealed pouches, sprinkled in homes or automobiles, mixed with bath water or perfume, or placed in devotional candles to ward off evil spirits and bring good luck.

5. Flammability and Reactivity[1,2,3,4,7,9,10]

Mercury is not flammable, but it generates toxic vapors when heated. Mercury corrodes copper and copper alloys. This may cause structural failure of copper plumbing or electrical wiring and contact materials. Mercury forms explosive compounds with acetylene and its compounds, chlorine, chlorine dioxide, methyl

azide, chlorates, nitrates, and ethylene oxide. Mercury dissolves in nitric acid (HNO_3) and hot concentrated sulfuric acid (H_2SO_4). It does not react with dilute hydrochloric acid (HCI), cold H_2SO_4 or alkalies. Mercury forms amalgams (alloys) with aluminum, calcium, potassium, sodium, and rubidium, with evolution of large amounts of heat. The heat released can present an additional hazard if there are heat-sensitive materials in the area. Prolonged contact of mercury with ammonia may yield an explosive solid. For this reason, mercury manometers should not be used with ammonia. Mercury also reacts violently with dry bromine.

If there is a fire in addition to the spill it is best to use a fire extinguisher suited to the type of fire encountered (e.g., paper, electrical, gasoline).[8,16] Water should not be sprayed directly at the heated mercury, however, water may be used to cool fire-exposed containers. Minimize the spread of the spill by preventing mercury from entering sewers, waterways, basements, or confined spaces. Do not use steel or aluminum tools or metal equipment, because mercury forms alloys with these metals on contact.

6. Exposure to Metallic Mercury

6.1. Means of Mercury Exposure [2,6,13,14,17]

Inhalation of mercury vapor poses the greatest risk to health and safety because mercury is absorbed more rapidly through the lungs than through the digestive tract or skin. Metallic mercury is highly lipophilic (has a high affinity for body fat) and is absorbed almost completely by the lungs upon inhalation. A few drops of mercury can raise the vapor concentration in surrounding indoor air to a dangerous level. Air saturated with mercury vapor at 20°C contains a concentration that greatly exceeds toxic limits for humans. Inhaled mercury enters the bloodstream, where it can accumulate and stay in the kidney and brain for weeks to months. One study of Japanese workers exposed to metallic mercury indicated high mercury levels in the brain ten years after their last exposure to metallic mercury.[17]

Dermal absorption is much slower than inhalation, but mercury exposure may produce skin irritations and allergic reactions. Absorption by ingestion is much slower than for inhalation. Ingested mercury does not enter the bloodstream easily, and is mostly expelled in the feces. Mercury is also expelled from the body via exhalation, saliva, bile, and sweat. The half-life of metallic mercury in the human body is approximately one to two months in the body as a whole. The half-life in blood ranges from two days to approximately one month.

6.2. Symptoms of Mercury Exposure

Acute mercury poisoning produces any of a wide variety of symptoms. These include irritation and burning of the skin and eyes and skin allergies, including a condition known as acrodynia.[2,5] The symptoms of acrodynia include flushing, itching, swelling, pink palms and soles of the feet, excess perspiration, and rashes.[6] Exposure to mercury may also produce symptoms of respiratory distress, including lung irritation with coughing, chest pain or chest tightness, shortness of breath, and pulmonary edema (lung swelling due to excess fluid buildup).[2,17] Mercury poisoning may lead to

chemical pneumonia, which can be fatal.[6] Acute mercury poisoning can also produce symptoms of neurological damage, including tremors, irritability, weakness, chills, headaches, and disturbances in vision. Victims may experience a metallic taste, abdominal pain, diarrhea, nausea, and vomiting.[2] If the damage is severe, death usually occurs within 10 days.[9] Both genders may experience reproductive problems, and there is some limited evidence for spontaneous abortions in women whose husbands were exposed to metallic mercury.[3,17]

Chronic mercury poisoning may develop gradually without conspicuous warning signs because mercury accumulates in body tissues.[15] Symptoms of repeated exposure include gray skin color, gum problems, tremors, memory and concentration problems, mood changes, and visual disturbances including clouding of the eyes.[2,6]

Rescuers are not directly at risk from individuals exposed to mercury vapor, although contaminated clothing can expose rescuers through direct contact or off gassing of mercury vapor.[2]

6.3. Exposure Procedures

Exposure victims may exhibit any of the symptoms discussed in this section. It is important to move the mercury-exposed victims to fresh air, and call emergency medical services; inform medical responders that mercury is involved.[8] A trained responder should wash the victim's exposed skin thoroughly with soap and water. If the victim's eyes have been in contact with the mercury, flush the eyes with water for at least 20 minutes. If the victim has ingested a large amount of mercury and is still conscious, give the victim a large amount of water to drink, then induce vomiting by having the victim touch the back of their throat with a finger.[12,16] Keep the victim warm and at rest. Get immediate medical attention.

Victims or suspected victims of mercury exposure should remain under medical observation for 24 to 48 hours.[3,4] Each victim should get a neurological exam (especially a handwriting test to detect tremors, an early sign of neurological damage). Kidney function and mercury levels in the urine should also be measured. The victims should get chest x-rays to detect signs of chemical pneumonia. An allergist should evaluate the victims' skin for reaction.

6.4. Physical Damage From Mercury Exposure[2,3,6,10]

Chronic and acute mercury poisoning can produce irreversible physical damage to the kidneys, lungs, spinal cord, and central nervous system. Developing fetuses may also be damaged if the mother is exposed to mercury. Mercury poisoning has not been shown to cause cancer in animals, but it produces a variety of other types of damage, often irreversible. Victims may experience digestive disturbances, skin irritation, eye damage, leg cramps, loss of sensation around the lips, ataxia (inability to control voluntary muscle movements), and/or tunnel vision.

6.5.Biological Exposure Ranges

Section 12 provides statistics for typical mercury exposure levels. The mean-whole-blood level of mercury in the general population is less than 8 micrograms per liter (µg/L). Memory disturbances, impaired eye-hand coordination, and altered electroencephalograms have been recorded at levels as low as 3 to 5 µg/L.

6.6.Exposure Limits

Several government agencies have established limits for various types of mercury exposure.[2,3,10,13] Many of these limits deal with the chronic exposure of workers in industries that use mercury or mercury-containing devices. Other limits deal with the effects of acute exposure, such as might result from a mercury spill (Table 1).

OSHA's legally enforceable ceiling limit for workplace exposure is set at 100 micrograms per cubic meter (µg/m^3). At no time should the mercury concentration exceed this level. The NIOSH Recommended Exposure Limit (REL) for mercury vapor is set at 50 µg/m^3 [as a time-weighted average (TWA)] with a skin designation.

The American Conference of Governmental Industrial Hygienists (ACGIH) set their Threshold Limit Value (TLV) at 25 µg/m^3 of mercury vapor (as averaged during and 8-hour workday).

The U.S Environmental Protection Agency (USEPA) has set a reference concentration of 0.3 µg/m^3 for inhalation exposure. The ATSDR's Minimal Risk Level (MRL) is 0.2 µg/m^3 with an action level of 1.0 µg/m^3 that triggers remediation if exceeded in air.

The EPA and Food and Drug Administration (FDA) limit for mercury in drinking water is 2 parts per billion (ppb). Ingesting 0.3 grams of mercury can be fatal to humans, and 75 milligrams per day (mg/day) in drinking water is fatal. The Resource Conservation and Recovery Act (RCRA) limit for mercury in leachate is 200 µg/L.[13] A summary of Environmental and Occupational health standards is presented in Table 1.

There is a significant potential contribution to the overall exposure from contact with the skin, eyes, and mucous membranes. Dermal exposure can result in over exposure even though air levels are less than the specified limits.

TABLE 1 Environmental and Occupational Health Standards for Inhalation Exposure to Mercury Vapor	
AGENCY	**MERCURY CONCENTRATION (µg/m^3)**
OSHA Ceiling Limit [2]	**100**
NIOSH REL [3]	**50**
ACGIH TLV [4]	**25**
ATSDR MRL [5]	**0.2**
ATSDR Action Level for clean up	**1**
EPA Rfc [6]	**0.3**

[1]micrograms per cubic meter (µg/m^3)
[2]Ceiling Limit = the concentration of mercury vapor cannot exceed this limit at any time
[3]REL = Recommended Exposure Limit, a time-weighted average for an 8-hour day
[4]TLV = Threshold Limit Value, a time-weighted average for an 8-hour day
[5]MRL = Minimal Risk Level
[6] Rfc = Reference Concentration

7. Sampling and Analysis

Section 11 provides a list of standard sampling and analytical procedures. Standard methods and field portable instrumentation will be discussed in this section.

7.1.Air

7.1.1. Air Monitoring

Field instruments are useful for providing real-time surveys of the affected areas and identifying "hot spots" that require immediate attention.

The Jerome™ Gold Film Mercury Vapor Analyzer (Arizona Instruments, Inc., Arizona, Model 411 or Model 431) is often used for this purpose.[13,18] The instrument's detection limit for approximately 3 µg/m^3 in air, is greater than the ATSDR long-term residential exposure limit of 0.2 µg/m^3 . However, the Jerome instrument is extremely useful for conducting an initial extent of contamination survey. Typically, three 10-second breathing-zone readings are averaged to produce the reported result. Jerome instruments may be used for indoor or ambient air. The instrument operates by drawing a precise volume of air over a gold film sensor. Mercury in the sample is adsorbed by the gold film, which results in an increase in electrical resistance. The change in resistance is compared to a reference gold film and is proportional to the mercury concentration. The Jerome is factory calibrated (from 0.01 to 0.1 mg/m^3) and mercury vapor results are reported in mg/m^3.

The Lumex RA-915$^+$ (Ohio-Lumex Co., Ohio) is a portable atomic absorption spectrometer designed to detect extremely low mercury vapor concentrations and perform fast and simple analyses both at a fixed laboratory and in the field. Two modes of operation

are available for ambient air analysis: (ON STREAM) and (MONITORING). At a sample rate of 15-20 liters per minute (L/min), the Lumex can detect mercury vapor in ambient air at concentrations as low as 2 nanograms per cubic meter (ng/m^3). The low mercury detection limit and the sensitivity of the instrument are achieved through a combination of a 10-meter multi-path optical cell and Zeeman Atomic Absorption Spectrometry using high frequency modulation of polarized light. The Lumex is factory calibrated (from 1,000 to 40,000 ng/m^3) and mercury vapor results are reported in ng/m^3. See Appendix C for instructions on the use of this instrumentation.

The Mercury Tracker 3000 is a portable instrument based on resonance absorption of mercury atoms at a wavelength of 253.7 nanometers (nm). The mercury sample is drawn through a 1-micron polytetrafluroethylene (PTFE) filter, at approximately 1.2 L/min, into the optical cell of the instrument by a membrane pump. Radiation from a mercury lamp passes through the cell and is measured by a solid-state ultraviolet (UV) detector. The attenuation of the UV light reaching the detector depends on the number of mercury atoms in the optical cell. The internal computer performs the quantitative evaluation of the mercury concentration in the sample in real-time. The Tracker is factory calibrated (from 60 to 300 $\mu g/m^3$) and mercury vapor concentration is reported in $\mu g/m^3$. See Appendix C for instructions on the use of this instrumentation.

A comparison of these three instruments is presented in Table 2. Other manufacturers of mercury vapor detectors are Cole-Parmer Instrument, and SpectroLab Analytical. Information on contacting these vendors may be found in the *Buyer's Guide* included in every August issue of *Physics Today*. Passive dosimeters and silver particulate filters may also be used to monitor mercury vapor concentrations.[19]

TABLE 2
Comparison of Real-Time Monitoring Instruments

	JEROME 431	MERCURY / EMP-1	VM-3000	LUMEX RA-915^{+}
Manufacturer	Arizona Instruments Corporation, AZ	Nippon Instruments Corporation, Japan	Mercury Instruments Gmbh, Germany	Lumex, Russia
Distributor	Arizona Instruments Corporation, AZ	Brandt Instruments Inc., LA	ST2 Service Technologies, Inc. CO	OhioLumex Co. OH
Units	mg/m^3	Mg/m^3	$\mu g/m^3$	ng/m^3
Range	Zero to 0.999	Zero to 0.999 1 to 5.00	Zero to 100 Zero to 1000 Zero to 2000	Zero to 25000
Methodology	Change in resistance of gold after mercury absorption	Ultraviolet absorption "cold vapor measuring technique"	Ultraviolet absorption "cold vapor measuring technique"	Zeeman Atomic Absorption Spectrometry-High Frequenc Modulation of Light Polarization
Accuracy (%)	5	5		20
Sensitivity	0.003	0.001 (low range) 0.01 (high range)	0.1	2
Response Time	10 seconds	Instantaneous and 5 minute averages	1 second	5 seconds
Wavelength	Not applicable	254 nm	253.7 nm	254 nm
UV source	Not applicable	Low pressure Hg discharge lamp	Electrodeless Hg low pressure lamp	Glow discharge mercury lamp
Stabilization	Not applicable	Reference beam	Reference beam and thermal	Info not available
Optical cell	Not applicable	Info not available	Fused silica, 25 cm long	Multi-path cell, 1 meter
Heating of cell	Not applicable	Info not available	70^{o}C	Info not available
Pump	0.75 L/min	1.5 L/min	Membrane, 2 L/min	20 L/min
Filter	Yes	Glass wool	PTFE, 1 µ, 47-50 mm diameter	Yes
Calibration	Manual	Automatic, using an absorber	Factory	Factory
Power	115 V or 230 V	None	230 V / 50/60 Hz or 110-120 V / 50/60 Hz optional	220 V, 50 Hz or 110V, 60 Hz
Battery	Internal Ni-Cd batteries, (5 hrs capacity)	Integrated rechargeable battery (11 hrs capacity)	Integrated 12 V batteries, (6 hrs capacity)	Built-in 6 V, 6-12 V dc (optional)
Weight	2.3 kg	4.2 kg	Approx. 7 kg	8.9 kg
Dimensions (W x H x D)	15.6 x 33.8 x 10.4 cm	11.3 x 23.8 x 25.6 cm	45 x 15 x 35 cm	46 x 21 x 11 cm
RS 232	None	None	Yes	Yes

7.1.2. Air Sampling and Monitoring

Analysis of low levels of mercury vapors can best be accomplished using laboratory analysis.[15,18,20] This is particularly important in the later stages of cleanup, where site responders are checking various areas for compliance with state and federal regulations; specifically health-based or risk-assessment values. Work is in progress at the EPA's Environmental Response Team Center (ERTC) Edison laboratory to determine if real-time monitoring instruments can be used to certify that the site meets state and federal action levels. This may be feasible because several of the field instruments are essentially portable variants of their laboratory counter parts.

Indoor air samples of volatilized elemental mercury are generally collected on solid sorbent materials (e.g., Hopcalite or silvered Chromosorb P) contained in glass collection tubes connected to personal sampling pumps. Pump flow rates are set to collect 0.25 to 0.50 L/min of air over a period of 6 to 8 hours. No preservatives or special storage conditions are required. However, filter samples should be stored with the filters upright and transported at or near ambient conditions to prevent significant deterioration. Impact and vibration should be avoided during transport because this can dislodge particulates from the filters. Before analyzing the samples, the sorbent material should be digested in acid to release the analyte.[21]

Indoor air samples can be collected under normal living conditions (air conditioning/ heating).[18] Samples should be collected from the centers of rooms that are occupied a significant number of hours per day, or where field instrument readings indicate potential problem areas. In homes, samples should be collected from living and sleeping areas, with particular attention paid to the sleeping areas of the youngest occupants of the residence. Duplicate samples and blanks should be used to monitor the repeatability of the data and to check for sample contamination.

Samples should be collected in common areas of multi-family dwellings (e.g., basements and common hallways), and ambient air samples taken for comparative purposes. Real-time mercury vapor monitoring before and after decontamination procedures provides useful information on the progress of the cleanup efforts and helps to identify problem areas that require further attention.

Ambient air samples at outdoor work sites help determine hazards to persons working in the area and to the surrounding community. Air monitoring should be performed using real time instrumentation such as Lumex or Tracker in the immediate work area, upwind, downwind, at the fence line or other perimeter, and in the surrounding neighborhood.

7.1.3. Laboratory Air Analysis Method

The most commonly used laboratory analysis method is NIOSH Method 6009: *Mercury*.[20]

This method uses cold vapor atomic absorption (CV-AA) to measure mercury concentrations in air samples at levels down to 0.1 $\mu g/m^3$. Neutron activation analysis is capable of detecting mercury levels down to 0.05 $\mu g/m^3$.[15]

7.2.Soil, Sludge, and Dust

7.2.1. Soil Sampling and Geophysical Detection

When it is suspected that mercury has penetrated the soil near a spill area, soil-core sampling may be necessary to determine the extent of contamination. Samples should be collected near the surface and at several depths, depending on the depth of fill material, the geological features of the site, and the suspected depth of penetration.

A geophysical survey may be necessary at the site of a spill if there is any indication that there may be buried metal containers such as drums or tanks. Magnetometers and ground-penetrating radar (GPR) can locate buried metal objects. Various instruments are available to measure terrain conductivity, ionization potential (IP), and electromagnetic (EM) properties of subsurface soil, rock, and groundwater. These instruments track variations in subsurface conductivity caused by porosity and permeability differences, rock fractures, buried objects, and migration of a plume of electrically conductive waste through the groundwater. A series of instrument readings may be used to construct a three-dimensional map to track the transport and fate of a mercury spill.

For large mercury spills a terrain conductivity meter may be appropriate for delineating the extent of gross contamination. However, its effectiveness will be dependant on other metals and interference in the area.

7.2.2. Soil, Sludge, and Dust Analysis

Solid and semisolid wastes should be analyzed for mercury using SW846-7471, *Mercury in Solid or Semisolid Wastes (Manual Cold Vapor Technique)*.[20] This technique uses CV-AA spectroscopy to measure total (elemental, inorganic and organic) mercury levels in extracts from soils, sludges, and dust samples. Alternately, when applicable USEPA 200 series CV-AA methods including Methods 245.1, 245.2, and 245.5 may be employed.

7.3. Water Analysis

Water samples (drinking water, groundwater) should be analyzed for mercury using SW846-7471, *Mercury in Solid, or Semisolid Wastes (Manual Cold Vapor Technique)*.[24] The ASTM method (D3223-80, Standard Test Method for Total Mercury in Water) may also be used. When applicable, USEPA 200 series CV-AA methods including Methods 245.1 and 245.2 may also be employed.

8. Remediation and Disposal

Remediation alternatives should be evaluated for timeliness, cost-effectiveness, reliability, duration of useful life, and health and safety considerations. The remediation process and the resulting remediated site should meet regulatory requirements for contaminant removal and disposal, and the removal process should not entail undue noise, dust, odors, or traffic in the surrounding neighborhoods.

8.1. Indoor Spills

Visible, indoor mercury spills can be covered with epsom salts, chelating resins, alum (potassium aluminum sulfate), calcium sulfide, sodium thiosulfate, or sulfur and lime to reduce the mercury exposure to the air. This will lower the mercury vapor concentration of the indoor air. This must be done before any attempt is made to remove the mercury.[8,10] The spilled material should be consolidated into an airtight container, and disposed of in accordance with federal, state, and local regulations. Contact your local health department for disposal assistance.

A variety of commercial products are available for cleaning up indoor mercury spills. These include:

- HgX (Acton Technologies, Pittstown, PA) for floors;
- Mercosorb and Merconwipes (EPS, Inc. Delta, BC) for bulk spill cleanup;
- Mercongel (EPS) for drains;
- Merconvap (EPS) for walls, floors, baseboards; and
- Merconspray (EPS) for air.
- Flower of sulfur

Mercury spill kits may be obtained from:

- Aldrich Chemical Company
- Atomergic Chemicals
- Bel-Art Products
- Cole-Parmer Instrument
- Thomas Scientific
- U.V. Process Supply

Information on contacting these vendors may be found in the *Buyer's Guide* included in every August issue of *Physics Today*.

Mercury can be collected and removed using a specially equipped vacuum cleaner (NILFISK or MINUTEMAN™, Lab Safety) with a trap to catch and contain the mercury vapor generated during the cleanup process. Mercury spills in residences are difficult to clean up because mercury tends to accumulate in low spots and cracks.[6] It may not be possible to decontaminate carpet,

furniture, and bedding. Items that cannot be decontaminated must be disposed of properly.

8.2. Contaminated Air

Mercury vapors inside buildings can be dispersed to the outside atmosphere, where the concentrations quickly fall to acceptable levels, set by ATSDR for the specific site. Closing off the affected room and heating it to 80-90^{o}F can accelerate the vapor release and dispersal process. (The temperature is determined by what heat-sensitive items are present in the affected room.) Windows should then be opened and fans turned on in the room to drive the released mercury outside. Mercury vapor levels should be re-checked, and the procedure repeated until the mercury levels drop below the action level, as set by local health agency/ EPA in consultation with ATSDR.[22]

Appendix B provides the ATSDR's suggested action levels for indoor concentration of mercury vapors in homes and business as associated with indoor gas regulators were developed in December 2000. In practice, during a mercury spill emergency response, ATSDR recommendation is made based on the site-specific circumstances, the nature of the exposures, and the results of a risk-benefit analysis.

Activated charcoal absorbs mercury vapors from air, but it is not particularly efficient. Charcoal treated with sulfur compounds is more efficient, but this adsorbent cannot be regenerated once it is saturated, and it must be disposed of properly. Systems have been designed using gold or silver to remove mercury from air streams. Mercury forms amalgams with these metals, and it can be recovered by heating the adsorption unit. The regenerated unit may be reused. Copper and zinc are also used for mercury adsorption units. Aqueous scrubbers are used to remove organic mercury from the atmosphere.[15]

8.3. Contaminated Personal Belongings

Depending on level of contamination, personal belongings may be decontaminated using heat. Items may be put into plastic bags, labeled to identify the owners, and collected in a central area. Initial mercury levels inside the bag headspace should be measured and recorded. The bag contents may be heated from approximately 90^{o}F to 140^{o}F for 24 hours, and then vented. Mercury vapor levels should then be measured, and if necessary, the process is repeated until the mercury levels drop below the action level.[23]

8.4. Contaminated Water

Several techniques are available for cleaning contaminated water.[1,4,11,24] In the Bristol-Myers Squibb (BMS) process; chlorine is added to wastewater, followed by BMS adsorbent (activated carbon/sulfur). Clarification and sedimentation have been proven effective in removing mercury from water. Surface waters with a pH of 4-9 can be treated with sulfide to form a precipitate, which can then be removed by sedimentation or filtration. Duolite^{TM} GT-73 ion-exchange resin can routinely

reduce the mercury content of wastewater from 0.2 to 70 parts per million (ppm) to between 1 and 5 ppb. In the Trace Mercury Removal - Immobilized Metal Affinity Chromatography (TMR IMAC™) process, chlorine is used to oxidize the mercury, and the solution is passed through TMR IMAC ion-exchange resin. Peat absorbs mercury from wastewater with pH from 5 to 5.5 and an approximate efficiency of 70%. Peanut hull charcoal can be used as a sorbent material. Bioremediation using *Pseudomonas putida* FB1 has achieved 99% mercury removal efficiency in laboratory studies, but this is not yet been proven an accepted field remediation method.

Mercury-containing brine produced by electrolytic processes in the chlor-alkali manufacturing industry can be decontaminated using a bed of activated carbon impregnated with silver. This brine may also be passed through a strong anion-exchange resin. Mercury salts can be precipitated from alkaline solutions using soluble alkali sulfides. Flocculating agents such as ferric salts, starch, or gum arabic facilitate the removal of the mercury precipitates from the aqueous medium.[15]

8.5. Soils and Sediments[25,26]

Large-scale cleanup efforts may be necessary when industrial or mining operations have spilled significant amounts of mercury in surface and subsurface soils, or when several years' worth of accumulation endangers surrounding land areas and waterways. Evaluation operations should establish the sources of the mercury contamination and delineate the pathways by which the mercury is dispersed to the surrounding environment. Dispersal pathways may include erosion and weathering of mine tailing piles, windblown soil and debris, leaching and runoff from affected areas, and mercury volatilization.

Remediation efforts can include source-control measures such as slope reduction and re-vegetation of mine tailing piles and management of water flow to and from the affected site. Pollution abatement measures include dredging or excavation, capping or covering the affected site, immobilization procedures, extraction and concentration, and off-site disposal. As with all large-scale remediation efforts, the cleanup process itself should not increase the hazard to public health and wildlife safety.

8.6. Disposal

Metallic mercury and mercury containing product should be recycled or disposed of properly. A list of mercury disposal and recycling companies can be found at the following websites. Section 14 provides a list of mercury manufacturers. Note that some manufacturers can also dispose of mercury.

Updates and additions can be found in:
Chemical Week Buyer's Guide, published by McGraw-Hill, Inc., New York, NY.
http://www.orcbs.msu.edu/AWARE/pamphlets/hazwaste/table2mercury.html
Going Green: A Resource Kit for Pollution Prevention in Health Care
EPA's Safe Mercury Management page

9. Prevention

Education is perhaps the most effective measure for the prevention of mercury spills and the resulting hazards to health and safety. Persons who deal with mercury-containing products and instruments in the workplace should be trained in safe handling procedures and how to respond in the event of a spill. Emergency procedures placards or signs should be posted in the workplace, including factories, school laboratories, and medical facilities. ATSDR has published an informational document on mercury hazards, intended for the general public.[6] A short video (approximately two minutes run time) suitable for school children is available from the ERTC.[27] There is no charge for this video, and it can be ordered directly from the ERTC's Web site.

Because of the hazards associated with mercury and its compounds, many household, medical, and industrial products that contain mercury have been removed from the marketplace.[4,15] Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) regulations have canceled all approved uses of mercury and mercury compounds, except as a fungicide for the treatment of textiles and fabrics intended for continuous outdoor use, to control brown mold on freshly sawn lumber, to treat Dutch Elm disease, as an in-can preservative for water-based paints and coatings, for water-based paints and coatings used for exterior application, and to control "winter turf diseases" (with certain restrictions).[11]

When it is necessary to work in the vicinity of mercury, adhering to safety precautions will minimize the chances of accidental exposure. Do not eat, drink, or smoke in areas that might be contaminated. In case of large spill install eye wash equipment and emergency showers in the workplace near potential spill areas if necessary. Wear safety goggles or face shields when working with mercury.[3] Keep work surfaces free of cracks, crevices, and indentations where mercury could accumulate. Workplace floors should be constructed of a nonporous material. Mercury should be stored in sealed containers inside locked cabinets.[15]

Small children are at risk from spilled mercury in the home because their breathing zones are closer to the floor, where mercury is likely to accumulate.[6] Children are especially susceptible to permanent damage from mercury exposure because their central nervous systems are not fully developed. Evacuate children immediately from the area of a spill or suspected spill.

10. Post-Decontamination

At the conclusion of the decontamination procedures the following steps should be taken:

- Facility should be warmed up to 80°F to 85°F for a minimum of eight hours.
- Vent the facility for a minimum of two hours-open door and windows and circulate air with fans.
- Thermostat should be set for normal living conditions -doors and windows closed for four hours.
- Perform air sampling for mercury vapor, and analyze collected air samples by NIOSH 6009 method.

When the results of the air sampling study confirm that the mercury vapor concentration is below the action level set by local health officials/EPA/ATSDR, the OSC or the local public health agency will indicate that the facility is ready for reoccupation and the cleanup has been completed.

11. Sampling and Analytical Methods[22]

ASTM

D3223-95 Standard Test Method for Total Mercury in Water *(Annual Book of ASTM Standards, Vol.* I 1.0 1, Water, 1997)

NIOSH

6009 Mercury (atomic absorption, air samples)

SW-846

0060 Determination of Metals in Stack Emissions
3051 Microwave-Assisted Acid Digestion of Sediments, Sludges, Soils, and Oils
3052 Microwave-Assisted Acid Digestion of Siliceous and Organically Based Matrices
6010B Inductively Coupled Plasma-Atomic Emission Spectroscopy
7000 Atomic Absorption Methods
7470 Mercury in Liquid Waste (Manual Cold Vapor Technique)
7471 Mercury in Solid or Semisolid Waste (Manual Cold Vapor Technique)
7472 Mercury in Aqueous Samples and Extracts by Anodic Stripping Voltammetry

EPA 200 Module

200.1 Determination of Metals and Trace Elements in Water by Ultrasonic Nebulization ICP-AES
200.2 Sample Preparation Procedure for Spectrochemical determination of Total Recoverable Elements
200.3 Sample Preparation Procedure for Spectrochemical Determination of Total Recoverable Elements in Biological Tissues
200.7 Determination of Metals and Trace Elements by Inductively Coupled Plasma-Atomic Emission Spectroscopy
200.8 Determination of Trace Elements by Inductively Coupled Plasma-Mass Spectroscopy
245.1 Determination of Mercury in Water by Cold Vapor Atomic Absorption Spectrometry (Manual)
245.2 Determination of Mercury in Water by Cold Vapor Atomic Absorption Spectrometry (Automated)
245.3 Determination of Inorganic Mercury (II) and Selected Organomercurials in Drinking and Groundwater by High Performance Liquid Chromatography with Electrochemical Detection
245.5 Determination of Mercury in Sediments by Cold Vapor Atomic Absorption Spectrometry
245.6 Determination of Mercury in Tissues by Cold Vapor Atomic Absorption Spectrometry

DOE

Method MB 100(a) Immunoassay of Inorganic Mercury as Mercury $^{2+}$

OSHA

ID-140 Mercury Vapor in Workplace Atmospheres
ID-145 Particulate Mercury in Workplace Atmospheres

12. Statistics for Mercury Releases, Transport, and Transformation[13, 17]

12.1. Air

Concentrations of mercury in ambient air averaged 10 to 20 ng/m^3 in 1980, with higher concentrations observed in industrialized areas. Over the last 140 years, the level of atmospheric mercury has increased approximately 2% per year. However, mercury levels appear to be declining in recent years, with gas-phase levels observed at 2 to 16 ng/m^3 in Sweden, Wisconsin, Tennessee, the St. Louis River, and Ontario in 1990. Higher levels have been observed near point sources including mines and agricultural fields treated with fungicides. Recent reductions in atmospheric mercury concentrations appear to be largely the result of a reduction in use of coal as a source of power generation. Aerosol mercury concentrations are generally lower than gas-phase concentrations by a factor of 10 to100. Particulate mercury concentrations are greater in precipitation than in ambient air.

Inhalation of mercury in workplace atmospheres is the main route of occupational exposure. In the United States, approximately 70,000 people are potentially exposed to mercury in workplace environments. The general population is exposed to mercury mostly through ingestion of contaminated foodstuffs, primarily fish. Mercury has been identified in 600 of the 1,300 hazardous waste sites on the National Priorities List (NPL).[28]

A major source of atmospheric mercury is out gassing of mineral mercury from the lithosphere (2,700-6,000 metric tons/year). Anthropogenic releases to atmosphere are responsible for approximately 2,000 metric tons/year.

Medical waste incineration can generate 12.3 milligrams per cubic meter (mg/m^3) of mercury in air. Uncontrolled emissions from medical facilities generate 110 mg/kg compared to 25.5 mg/kg for general medical waste, indicating that medical equipment may be a significant source of atmospheric mercury.

Scrubbers can remove 51% of the mercury from incinerator gases.

Over 95% of the mercury in the atmosphere is elemental mercury. Mercury's residence time in the atmosphere is 6 days to 2 years. Approximately 5% of atmospheric mercury is associated with particulates, which may be removed by dry or wet deposition (sedimentation or rain). Mercury in rain may originate from sources up to 2,500 kilometers (km) away.

Atmospheric mercury can be oxidized to mercuric (Hg^{2+}) by ozone, peroxides, hypochlorites, organoperoxy compounds, or organoperoxy radicals. Some mercury compounds, such as mercuric sulfide, may be quite stable in the atmosphere as a result of binding to aerosol particles. Divalent mercury may be reduced to monovalent mercury by sunlight.

12.2. Water

The baseline concentration of mercury in unpolluted marine waters is estimated at less than 2 ng/L. Fresh aerobic surface waters without known sources of mercury contamination generally contain less than 5 ng/L total mercury, although levels between 0.07 and 500 ng/L have been observed at specific sites. Concentrations in rainwater and fresh snow are generally below 200 ng/L. The background level of mercury in precipitation is approximately 3.2 to 15 ng/m^3. Drinking water is generally assumed to contain less than 25 ng/L of mercury.

Weathering of mercury-bearing minerals in igneous rocks releases approximately 800 metric tons of mercury per year to surface waters on a global basis.

Anaerobic conditions favor the demethylation of methyl mercury, producing volatile elemental mercury in the process. Inorganic mercury compounds may also be reduced to elemental mercury under anaerobic conditions. Abiotic reduction can occur in acidic waters containing humic and fulvic acids. Abiotic reduction is enhanced by light, and it occurs under both aerobic and anaerobic conditions. Abiotic reduction is inhibited by competition from chloride ions.

12.3. Soil and Solid Waste

The normal concentration of mercury in rocks and minerals is 10 to 50 ng/g (ppb), but the mineral cinnabar (HgS) contains 86.2% by weight of mercury.

Anthropogenic sources of mercury in the soil include organic and inorganic fertilizers (sewage sludge, compost), lime, and fungicides. Typically, sewage sludge contains 2.90 ppm mercury, yard compost contains 0.15 ppm mercury, and municipal solid waste contains 3.95 ppm mercury. Thermometers, batteries, and electrical switches are common sources of mercury in domestic solid waste. Municipal incinerator ash typically contains 0.03 ppm to 25 ppm mercury, depending on the season of the year. Mercury levels in municipal incinerator ash rise significantly after Christmas. One reason may be the large number of toys and small electrical appliances that use mercury-containing batteries.

Volatilization and leaching studies show that mercury levels in headspace and leachate increase as the levels in the soil increase, but the elemental mercury concentrations never exceeded the RCRA limit of 200 µg/L. This indicates that elemental mercury is relatively unleachable.

12.4. Human Exposure

The mean whole-blood level of mercury in the general population is less than 8 micrograms per liter (µg/L). Memory disturbances, impaired eye-hand coordination, and altered electroencephalograms have been recorded at levels as low as 3 to 5 µg/L. Mercury levels of less than 20.0 µg/L. are considered normal in the urine.

Dietary intake is the most important non-occupational source of human exposure to mercury. Mercury in food products is present mainly as organic compounds, which are not covered in the scope of this report.

Data from the National Occupational Exposure Survey (NOES), conducted by NIOSH from 1980 to 1983, estimated that approximately 68,000 workers in 2,900 workplaces (70 of the workers were male) were potentially exposed to mercury or mercury compounds in the workplace. Most of the potentially exposed workers were employed in the health services, business services, special trade contractors, chemical technicians in the chemical and allied products industries, science technicians, registered nurses, and machine operators. It is unknown how many of the potentially exposed workers were actually exposed.

Children of workers who are occupationally exposed to mercury are at an increased risk of mercury exposure, especially if their parents do not use protective uniforms and footwear, or if the parents wear contaminated clothing at home.

Latex paint manufactured prior to 1991 may contain phenylmercury. Paint produced after 1990 containing phenylmercury must be so labeled. Exterior latex paints may have contained phenylmercury concentrations of up to 1,500 ppm, putting house painters at risk.

13. Contact information[3,13]

U.S. EPA/ERTC:
2890 Woodbridge Avenue, Building 18,
Edison NJ 08837

Emergency Response during business hours	(732) 321-6740
24-hour Emergency Response	(732) 321-6660

Other Agencies:

ATSDR Emergency Response Hotline	(404) 498-0120
USCG National Response Center & Terrorist Hotline	(800) 424-8802

Washington DC metropolitan area:	(202) 426-2675

ATSDR Division of Toxicology	(404) 498-0160
1600 Clifton Road NE, Mailstop E-29	(888) 422-8737
Atlanta GA 30333	

New Jersey Department of Health & Senior Services	(609) 984-1863
New Jersey Department of Environmental Protection Hotline	(877) 927-6337
CHEMTREC	(800) 424-9300

For Long-Term Response Efforts:

The Association of American Railroads Bureau of Explosives	(719) 584-0610
U. S. Department of Transportation (DOT) Hotline	(202) 267-5190
CHEMTREC	(800) 424-9300

14. Additional Sources of Information

Materials Safety Data Sheet (MSDS) for Mercury (Metal),
http://msds.pdc.cornell.edu/msds/msdsdod/a228/m113798.htm

Mercury Frequently Asked Questions (FAQ),
http://atsdrl.atsdr.cdc.gov:8080/tfacts46.html

Companies that recycle mercury.
http://www.yahoo.com/categories
Society and Culture: Environment and Nature: Companies@: Environment: Waste Management: Hazardous Waste
Society and Culture: Environment and Nature: Companies@: Environment: Waste Management: Recycling: Hazardous Waste
Society and Culture: Environment and Nature: Companies@: Environment: Waste Management: Recycling: Metals

Vendors of mercury vapor detectors and mercury spill kits.
Physics Today Buyer's Guide, published every August by the American Institute of Physics, Woodbury, New York. *Buyer's Guide* is also available at http://www.aip.org/pt/guide

Mercury: A Fact Sheet for Health Professionals.
http://www.orcbs.msu.edu/AWARE/pamphlets/hazwaste/mercuryfacts.html
This fact sheet includes a list of companies that dispose of and recycle mercury. The link is
http://www.orcbs.msu.edu/AWARE/pamphlets/hazwaste/table2mercury.html

Mercury Thermometers
http://www.ase.org.uk/therms.html
This is a brief safety article intended for schoolteachers.

Federal Hazardous Waste Regulations: 40 CFR 261.5(e)

Occupational Safety and Health Administration's Safety and Health Standard for protective gear: 29 CFR 1910.134

National Institute for Occupational Safety's information on protective gear: NIOSH Document #73-11024

Comprehensive Environmental Response, Compensation Act's Reportable Quantities, Mercury Releases: 40 CFR 302.6 (section IV.D.3.b)

Mercury Manufacturers:

Primary Producers:
None

Secondary Producers:

Bethlehem Apparatus, 935 Bethlehem drive, Bethlehem, PA 18017	(610) 882-2611
D. F. Goldsmith Chemical & Metal Corp. 909 Pitner Ave., Evanston, IL 60202	(312) 869-7800
Mercury Refining, 1218 Central Ave., Albany, NY 12205	(518) 459-0846

Mercury as a by-product Producers

Homestake Mining Co., 650 California Street, San Francisco, CA 94108	(415) 981-8150
Newmont Gold Co., 1700 Lincoln Street, Denver, CO 80203	(303) 863-7414

Mercury can be purchased from the following:

Centerchem, Inc. 475 Park Ave. S., New York, NY 10016	(212) 725-5665
D. F. Goldsmith Chemical & Metal Corp. 909 Pitner Ave., Evanston, IL 60202	(312) 869-7800
Spectrum Chemical MFG Corp., 14422 S. San Pedro St., Gardena, CA 90248	(213) 516-8000
SST Corporation, 1373 Broad St., Clifton, NJ 07015	(516) 466-8440

See also: *Chemical Week Buyer's Guide,* published by McGraw-Hill, Inc., New York, NY.

15. References

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2. *Cooper's Toxic Exposures Desk Reference with CD-ROM.* Cooper, A.R.; Sr., Ed., Lewis Publishers Inc., (CRC Press): Boca Raton, FL, 1997, 1396-1407.

3. NJFS: Right to Know Program (*New Jersey Hazardous Substance Fact Sheets*). New Jersey Department of Health, Trenton, New Jersey (electronic version). Thomson MICROMEDEX, Greenwood Village, Colorado, USA. Available at: http://csi.micromedex.com (02/24/04).

4. *HAZARDTEXT*® Hazard Managements. Klasco, R. K. (Ed): TOMES® System (electronic version). Thomson MICROMEDEX, Greenwood Village, Colorado, USA. Available at: http://csi.micromedex.com (02/24/04).

5. NIOSH: *Pocket Guide to Chemical Hazards*. National Institute for Occupational Safety and Health, Cincinnati, Ohio (electronic version). Thomson MICROMEDEX, Greenwood Village, Colorado, USA. Available at: http://csi.micromedex.com (02/24/04).

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11. Prager, J. C.; *Environmental Contaminant Reference Databook Vol.* 11; Van Nostrand Reinhold: New York, 1996, 549-554.

12. *Mercury* Materials Safety Data Sheet (MSDS), http://msds.pdc.cornell.edu/msds/msdsdod/a228/m113924.htm

13. *ATSDR Toxicological Profiles*, on CD ROM, Version 5.1 (2003), CRC Press: Boca Raton, Fl. or visit http://www.atsdr.cdc.gov/toxprofiles/tp46.html

14. *CRC Handbook of Chemistry and Physics,* 76th ed., D. R. Lide, Ed., CRC Press: Boca Raton, FL, 1995, **4**-18.

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20. Chemsoft® *Chemical Methods Database*. Network Version 3.11, Chemsoft Inc., 2975 Bowers Ave., Suite 300, Santa Clara, CA 95051

21. Environmental Response Team SOP #2119, "*Air Sampling for Metals (NIOSH 7300, Elements)"*, available for downloading from http://www.ertresponse.com/sops/2119.pdf

22. USEPA / Environmental Response Team "*Quality Assurance Work Plan for the Belle Glade Mercury Site*", 1994. Internal ERT document.

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27. "*Mercury Video News Release*" can be ordered directly from the ERTC's Website, http://www.ert.org/media_resrcs/media_resrcs.asp

28. ATSDR, HAZDAT DATABASE, *Hazardous Substance Release and Health Effects Database*, http://www.atsdr.cdc.gov/hazdat.html

16. Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BMS	Bristol-Myers Squibb
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Register
cm	centimeter
CV-AA	Cold Vapor Atomic Absorption
DOE	Department of Energy
DOT	Department of Transportation
ELSI	End of Service Life Indicator
EM	electromagnetic
EPA	Environmental Protection Agency
ERTC	Emergency Response Team Center
FDA	Food and Drug Administration
g/cc	grams per cubic centimeter
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GPR	Ground-Penetrating Radar
HAZDAT	ATSDR's Hazardous Substance Release and Health Effects Database
HCI	Hydrochloric acid
HEPA	High Efficiency Particulate Arresting
Hg	Metallic Mercury
Hg^{2+}	Mercuric
HgS	Cinnabar
HNO_3	Nitric acid
H_2SO_4	Sulfuric acid
IDLH	Immediately Dangerous to Life and Health
IP	Ionization Potential
kg	kilogram
km	kilometer
lb	pound
L/min	Liters per minute
m	meter
mL	milliliter
mm	millimeter
MCE	Mixed Cellulose Ester
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
µg /L	micrograms per liter

µg	micrograms
µg/m^3	micrograms per cubic meter
MRL	Minimal Risk Level
NIOSH	National Institute for Occupational Health
ng/m^3	nanograms per cubic meter
ng/g	nanograms per gram
ng/L	nanograms per liter
nm	nanometers
nm/m^3	nanometers per cubic meter
NOES	National Occupational Exposure Survey
NPL	National Priorities List
OSC	On-Scene Coordinator
OSHA	Occupational Safety and Health Administration
ppm	parts per million
ppb	parts per billion
PTFE	polytetrafluroethylene
RCRA	Response Conservation and Recovery Act
REL	Recommended Exposure Limit
Rfc	Reference Concentration
TLV	Threshold Limit Value
TMR/IMAC™	Trace Mercury Removal Immobilized Metal Affinity Chromatography
TWA	Time-Weighted Average
V	volt

APPENDIX A

Specifications for Respirators and Protective Gear

Respirator Specifications:[3,5]

Potential Exposure to Mercury (mg/m^3)	Assigned Protection Factor	Respirator Specifications
0.05 - 0.5	10	8-hour average, airborne exposure, use NIOSH/MSHA-approved half-mask respirator with cartridges providing protection against mercury (ELSI required), or any supplied-air respirator
1.25	25	Any supplied-air respirator operated in continuous-flow mode. Any powered, air-purifying respirator with cartridges providing protection against mercury, ELSI required
2.5	50	Any chemical cartridge respirator with a full facepiece, with cartridges providing protection against mercury, ELSI required. Any air-purifying, full facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against mercury, ELSI required. Any supplied-air respirator that has a tight-fitting facepiece and cartridges providing protection against mercury. Any self-contained breathing apparatus with a full facepiece. Any supplied-air respirator with a full facepiece
Escape	50	Any air purifying, facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against mercury appropriate self-contained breathing apparatus
10	2000	Any supplied-air respirator operated in a pressure-demand or other positive-pressure mode. NIOSH defines this level as immediately dangerous to life and health (IDLH)
High Exposure		MSHA/NIOSH-approved supplied-air respirator with a full facepiece operated in positive pressure mode or with a full facepiece, hood, or helmet in continuous flow mode. Or use an MSHA/NIOSH-approved self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode
28 mg/m^3 or entry and escape from unknown or IDLH conditions	10,000	Immediately dangerous to life and health (IDLH). If the possibility of this level of exposure exists, use a MSHA/NIOSH-approved self-contained breathing apparatus with a full facepiece, operated in pressure-demand or other positive-pressure mode, or a combination respirator that includes type-C supplied-air respirator with a full facepiece, operated in pressure-demand or other positive-pressure or continuous flow mode, in combination with an auxiliary self-contained breathing apparatus, operated in pressure-demand or other positive-pressure mode

Be sure to consider all potential sources of exposure. You may need a combination of prefilters, cartridges, or canisters to protect against different forms of mercury (e.g., vapor and mist) or against mercury mixed with other chemicals.
ELSI = End of service life indicator

Materials for Protective Clothing:[4,8]

Butyl Rubber (IIR, Butyl)	compatible, recommended
Butyl Rubber/Neoprene (butyl rubber laminated with neoprene)	good resistance, based on a small amount of qualitative data or inconsistent data
Chlorinated Polyethylene (CPE)	recommended
Fluorocarbon Rubber (Viton®, FPM, VIT)	recommended
Viton/Neoprene (Viton laminated with neoprene)	good resistance, based on a small amount of qualitative or inconsistent data
Neoprene (chloroprene rubber, CR, NEO)	limited to good resistance, based on a small amount of qualitative data or inconsistent data; recommended, no effect to garment
Nitrile Rubber (NBR, Nitrile)	recommended
Polycarbonate (PC)	compatible
Polyvinyl Chloride (PVC)	good resistant recommended
Small spills:	nitrile rubber gloves, laboratory coat, eye protection
Spill No Fire / Rescue:	Sealed chemical suit (structural protective suit is inadequate), self-contained (polycarbonate, butyl rubber, viton, nitrile, PVC, chlorinated polyethylene, neoprene)
DuPont Barricade™ Suits (Level A/hooded/totally-encapsulating)	Greater than 480 minutes breakthrough time under conditions of continuous contact, 0 mg/m^3/min permeation rate, Performance Index Number 0 (scale of 0 to 5, with 0 being highest resistance), this material is designated as toxic, and is believed to present significant risk of skin absorption
Saranex ™	Greater than 4 hours breakthrough time, this material is designated as toxic, and is believed to present a significant risk of skin absorption
DuPont Tyvek™ suits (Sarane –23)-	Greater than 210 minutes breakthrough time, less than 0.01 mg/m^3 /min permeation rate, Performance Index Number 1 (scale of 0 to 5, with 0 being highest resistance)
DuPont Tyvek suits (Sarane –23, 2-ply)-	Greater than 480 minutes breakthrough time, less than 0 mg/m^3/min permeation rate, Performance Index Number 0 (scale of 0 to 5, with 0 being highest resistance)
For more information:	
OSHA 1910.134 necessary for proper respirator use	workplace conditions, worker training, respirator fit testing, medical exams
OSHA Pub. 3077	Personal Protective Equipment
OSHA Safety and Health Standards	29 CFR 1910.134

NIOSH Pocket Guide[5]

APPENDIX B

ATSDR
December 12, 2000

Suggested Action Levels for Indoor Mercury Vapors in Homes or Businesses with Indoor Gas Regulators

Purpose: This document is intended solely as a quick reference guide for use by public health and environmental officials in evaluating data collected from structures in which mercury pressure regulating devices for natural gas meters were moved from inside to outside the structures as part of a modernization process. It does not provide detailed justifications for environmental sampling requirements, as health consultations or environmental sampling plans may do.

In the past, ATSDR has been reluctant to provide a list of suggested action levels such as this because of the site-specific nature of exposures. ATSDR has recognized that action levels can differ according to differing populations, exposure durations, concentrations, and specific hazards. However, the immediacy and extent of the potential health risk associated with mercury contamination in the present situation require publication of this guide. Many parts of the country may be affected by the possible exposure to mercury resulting from re-positioning of mercury-containing gas pressure regulators and the subsequent response efforts of gas utilities, public health, and environmental officials. Moreover, the involvement of multiple health and environmental jurisdictions creates a need for consistency in presenting health risk information. Therefore, ATSDR, at the request of a state health department and an U.S. EPA regional office, is attempting to provide suggested action levels for various response activities under different exposure scenarios.

Background: In this context, an *action level* is an indoor air concentration of mercury vapor, which should prompt consideration of the need to implement a recommended response by public health and environmental officials. The various suggested action levels provided in this document are intended as recommendations, not as regulatory values or cleanup values, although some may correspond to present or future values adopted by regulatory authorities.

The suggested action levels presented in this document recognize that an individual must be exposed to a sufficient concentration over some specific period of time in order for mercury vapor to cause adverse health effects. The suggested action levels also recognize that while individual susceptibility may vary, developing fetuses and young children under six years old are generally at higher risk than others of incurring adverse health effects from exposure to mercury vapor. If the indoor air concentration corresponding to any suggested action level is exceeded, then a potential health risk may be present, and responders should evaluate the exposures at that location and consider implementing appropriate protective measures to reduce or eliminate the risk.

The suggested action levels presented here are based on data available in ATSDR's Toxicological Profile for Mercury (1999) or in the Hazardous Substance Databank of the Toxicology Data Network at the National Library of Medicine. ATSDR has also made use of additional data collected by the US Environmental Protection Agency (EPA) and of specific experiences of ATSDR at other sites. Other factors considered in the development include available information on normal background levels and analytical detection limits of various techniques for evaluating air borne contamination. Any information specific to the exposures at any given location as described below should also be considered before implementing a response action.

These suggested action levels are extrapolated from health guidance values (HGVs) independently developed by two federal agencies, ATSDR and EPA. These HGVs are based on both animal studies and human epidemiology studies that detail the health effects of inhalation of mercury-contaminated air. ATSDR has developed a chronic Minimal Risk Level (MRL) of 0.2 ug/m^3 that is based on a 1983 study of workers exposed to an average Lowest Observed Adverse Effect Level (LOAEL) of 26 ug/m^3 over an average of 15 years. This workplace average exposure was adjusted from a 40 hour per week exposure to a 168 hour per week exposure (i.e., 24 hours/day, 7 days/week) and then divided by an uncertainty factor of 30 to account for the use of the LOAEL and the different sensitivities of individuals. In addition, EPA has used the same study to develop a Reference Concentration (RfC) of 0.3 ug/m^3, using different assumptions and uncertainty factors. ATSDR considers the RfC and the Chronic MRL to be the same value for all practical purposes. An MRL, then, is defined as an estimate of the daily exposure level to a hazardous substance (in this case, metallic mercury) that is likely to be without appreciable risk of adverse, non-cancer health effects (metallic mercury is not considered to be a carcinogenic substance) over a specific exposure route and duration of exposure. For further information, see Section 2.5, Chapter 7, and Appendix A of the ATSDR Tox. Profile and the EPA's Integrated Risk Information System (IRIS) on the Internet at www.epa.gov/ngispgm3/iris/index.html.

The suggested action levels in the tables below were designed for a group of structures where pressure regulators using approximately 2 teaspoons (and perhaps more) of mercury (~10 ml or 135 g) and the accompanying gas meters were re-positioned from the interior of buildings (including homes) to the exterior. During this adjustment of regulator location that may have taken place some time ago, mercury was spilled in some instances. However, spills of mercury may not have occurred indoors. Therefore, the categories of exposure include (a) buildings that may have had no spills; (b) buildings that had spills and needed cleanup but had air mercury levels that constitute no immediate health risk; and (c) buildings that had spills resulting in indoor air concentrations sufficient to warrant isolating humans from the exposure. In general, the screening for these homes or businesses consists of: (1) confirming that a natural gas meter had been in the building and moved outside; (2) observing the area where the gas meter had been originally for metallic mercury; (3) asking the resident if they had ever noticed metallic mercury in the vicinity of the gas meter; and, (4) evaluating the area with a Jerome™ meter or the equivalent. If there is any positive indicator of mercury on the Jerome Mercury Vapor Analyzer (a real-time air monitoring instrument) that cannot be explained by interferences, then the building is placed on the list for further characterization. Visible mercury is not only a source of vapors but also a tracking hazard and an attractive nuisance. No matter what the airborne concentration is, free liquid mercury may pose a

problem in the general population. Generally, a condition that no visible mercury be present is stipulated only at stages when cleanup is completed. This condition may be considered as much a check on the data quality as anything else. It is rare that liquid mercury exists at concentrations as low as would be considered safe in most exposure scenarios other than a workplace where mercury is used in the production process.

General Exposure Assessment Considerations: The primary route of entry for metallic mercury is by inhalation; ingestion and skin absorption of this form of mercury is usually not biologically significant. Sensitive populations to mercury exposure are those with developing central nervous systems, including young children and the fetuses of women who are pregnant. Other individuals of potential concern are those with pre-existing kidney conditions, usually at exposures to much higher concentrations than the first group. The specific exposure of these groups in any given situation should be considered when assessing the need for any given response action. Specific concerns are mentioned in the tables below. If there is any doubt, responders should consult with state or local public health officials before deciding on a course of action. Responders may also contact ATSDR at 404-639-0615, 24 hours a day.

Exposure Assumptions for Different Settings: For the purposes of this document, the residentially exposed population includes infants, small children, and pregnant women presumed to have inhaled mercury for a period up to 24 hours per day, 7 days per week potentially for months or even years. Occupational or commercial settings include those individuals that are primarily healthy adults exposed up to 8-10 hours per day, 40 hours per week, with transient exposures by sensitive populations (e.g., a retail establishment or schools). The concentrations provided as suggested action levels are for comparison to the environmental data collected in affected residences and workplaces.

Suggested Action Levels for Mercury (CAS # 7439-97-6) - Residential Settings †

Indoor Air Concentration (ug/m^3)	Use of the Action Level	Rationale for Action Level	Method of Analysis *	Reference
<1.0	Level acceptable for occupancy of any structure after a spill (also called the residential occupancy level.)	A spill occurred in this building, and the risk manager needs to know if the building is safe for occupancy. ATSDR would prefer no one ever be chronically exposed to concentrations above the MRLs; however, experience has shown cleanup operations in a response to concentrations below 1 ug/m 3 can be extremely disruptive to individual and family quality of life. While this concentration is slightly above HGVs, this level is still 25 times lower than the human LOAEL on which the MRL is based. An indoor air concentration of 1 ug/m^3, as measured by the highest quality data (e.g., NIOSH 6009 or equivalent), is considered safe and acceptable by ATSDR, provided no visible metallic mercury is present.	NIOSH 6009 or equivalent	Based on HGVs above. ATSDR, 1999. EPA/IRIS
No qualitative detection on an Arizona Instrument's Jerome™ Meter.	Screening level for homes that had indoor gas meters with no evidence of a spill	Mercury was present in the regulator inside the home, but no evidence of a spill is found. The qualitative detection limit of the most commonly available air monitoring instruments approximates 1 order of magnitude below levels of known human health effects. As there was no spill, no visible metallic mercury should be present. Natural ventilation (e.g., windows, HVAC air changes, etc.) should reduce any concentration even lower with no disruption of family life or costs.	Real-time Air monitoring instrument (i.e., Jerome™ meter or equivalent)	
10	Isolate residents from the exposure	When adjusted from an intermediate to chronic exposures to a continuous exposure scenario (i.e., 24 hrs/day, 7days/week), this concentration approaches levels reported in the literature to cause subtle human health effects. Applied to acute exposures with good accuracy by real-time instruments, this value allows for interventions before health effects would be expected. Whenever possible, the mercury vapors should be prevented from reaching living spaces rather than temporarily relocating individuals. See the building evaluation protocol developed for these situations in your area and Section 2.1 of ATSDR's Toxicological Profile.	Real-time Air monitoring instrument (i.e., Jerome™ meter or equivalent)	ATSDR, 1999.
10	Acceptable level in a modified test procedure to allow personal effects to remain in the owner's possession	For personal effects, such as clothing, warmed in a discrete plastic container much smaller than a typical room (e.g., a garbage bag), this concentration in the air trapped inside the container is considered safe by ATSDR based on a number of factors.	Real-time Air monitoring instrument (i.e., Jerome™ meter or equivalent)	

*** - Environmental analysis should be in accordance with the requirements specified by environmental authorities. When real-time air monitoring instruments are specified in this table, laboratory analysis may be substituted at the discretion of the risk managers involved in the event. Operation of real-time**

instruments should be in accordance with manufacturer's instructions.
† - Structures where mercury pressure regulating devices for natural gas meters were moved from inside the structure to outside the structure.

Suggested Action Levels for Mercury (CAS # 7439-97-6) - Occupational and Commercial Settings †

Indoor Air Concentration (ug/m^3)	Use of the Action Level	Rationale for Action Level	Method of Analysis *	Reference
3.0	Re-occupancy after a spill of an occupational or commercial setting where mercury is not usually handled.	Based on residential occupancy level but adjusted for the shorter duration exposures typical of most workplaces. This concentration approximates one order of magnitude below levels of known human health effects, provided no visible metallic mercury is present to act as an attractive nuisance or a source for more vapors. Those exposed in this instance would not expect hazards associated with mercury as part of their normal work and may include transient exposures by more sensitive individuals (e.g., retail facilities).	NIOSH 6009 or equivalent	HGVs. ATSDR, 1999. EPA/IRIS
25	Occupational settings where mercury is handled.•	Based on the 1996 ACGIH TLV. Assumes hazards communications programs as required by OSHA; engineering controls as recommended by NIOSH; and medical monitoring programs as recommended by the ILO, NIOSH, and ACGIH are in place. This concentration is ½ the peer-reviewed 1973 NIOSH REL and 1/4 the regulatory1972 OSHA PEL. See HSDB at toxnet.nlm.nih.gov/sis on the Internet.	Real-time Air monitoring instrument (i.e., Jerome™ meter or equivalent)	HSDB, 1999
25	Response Worker Protective Equipment Upgrade. •	Response workers subject to HAZWOPER should evaluate need to upgrade protective equipment. Based on the 1996 ACGIH TLV. Assumes hazards communications programs as required by OSHA; engineering controls as recommended by NIOSH; and medical monitoring programs as recommended by the ILO, NIOSH, AND ACGIH are in place. This concentration is half the peer-reviewed NIOSH REL and a quarter of the regulatory OSHA PEL. See HSDB at toxnet.nlm.nih.gov/sis on the Internet. For these workers, engineering controls are not typically in place, and it is not possible to control the exposure by other safety techniques.	Real-time Air monitoring instrument (i.e., Jerome™ meter or equivalent)	29 CFR 1910.120; 40 CFR 311; NIOSH, 1987
10,000	IDLH. Response Workers Protective Equipment upgrade.	Response workers subject to HAZWOPER should upgrade protective equipment. See http://www.cdc.gov/niosh/idlh/ on the Internet.	Real-time Air monitoring instrument (i.e., Jerome™ meter or equivalent)	29 CFR 1910.120; 40 CFR 311; NIOSH 1987

*** - Environmental analysis should be in accordance with the requirements specified by environmental authorities. When real-time air monitoring instruments are specified in this table, laboratory analysis may be substituted at the discretion of the risk managers involved in the event. Operation of real-time instruments should be in accordance with**

manufacturer's instructions.
† - Structures where mercury pressure regulating devices for natural gas meters were moved from inside the structure to outside the structure.
• - Women workers in these settings who are pregnant or attempting to become pregnant should consult their physicians regarding their mercury expo

http://www.ertresponse.com/Response_Resrcs/mercury_response_guide_index.asp

APPENDIX C

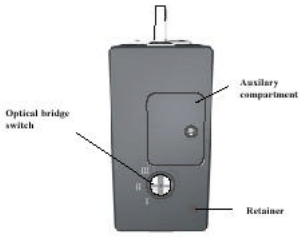
INSTRUCTIONS FOR THE USE IOF LUMEX RA-915^{+}

PRE-OPERATIONAL PROCEDURES

Instrument can be used in two modes:

- Self Contained Operation, no preparation required.
- Operation with a stand alone PC, connect the PC to the instrument with the necessary RS-232 cable. Make sure that the instrument and the PC are turned off before making the RS-232 connection

FRONT PANEL



BACK PANEL

LEFT PANEL

Instrument can be run either with the built-in battery or with the use of a low voltage power adaptor.

1. Set the handle of the test cell on the left panel in the **OFF** position and the optical bridge handle on the back panel to position **III**.
2. Switch on the analyzer on with the power button located in the front panel.
3. Press the **Ent** button on the display monitor to go from the Lumex logo to the **MAIN MENU**. An asterisk sign * will appear in the upper left corner of the main menu.
4. Press and hold for several seconds the **LAMP IGNITION** button (front panel). When the spectral lamp turns on, the * sign will go out. (If * `is showing then the lamp is not on or is too weak for use)
5. Warm up the instrument for at least 20 minutes before use.
6. Set the operational parameters by using the SETTINGS command from the main menu by using the cursor control buttons and **Ent** button.
7. Select Language and press **Ent** button.
8. Select the **PARAMETERS** command and change the measurement parameters as necessary. In most cases the default values are used.

PARAMETER	RANGE	DEFAULT
Bas. Corr. Time, sec.	10-255	10
Frame time, sec.	1-255	10
Integr. Time, sec.	1-255	150
Low limit, ng/m^3	1-255	20
High limit, ng/m^3	1-10,0000	100

INSTRUMENT CALIBRATION

1. **TEST** handle in the **OFF** position (left panel).
2. Select **TEST** command from the MAIN MENU.
3. Set the **OPTICAL BRIDGE** to position III (Back Panel) as instructed on the screen and press **Ent** button. Instrument being zeroed.
4. Set the **TEST** handle (left panel) to the **TEST CELL** position (after rotating it back and forth several times) as instructed on the screen. Press **Ent** button.

5. If the **TEST** screen shows Deviation (**R, %**) of equal to or less than 25% then the instrument is functional.
6. Press the **ESC** button.
7. **TEST CELL** handle back to the **OFF** position and press **Ent** button. Main menu will appear.

ON STREAM ANALYSIS (Measurement of Mercury Vapor Concentrations in Air)

1. **TEST** handle in the **OFF** position.
2. Set default parameters using the **PARAMETERS** command.
3. Select **ON STREAM** from the **MAIN MENU** screen and press **Ent** button.
4. **SET OPTICAL BRIDGE TO POSITION III** as instructed on the display screen and press the **Ent** button.
5. The ON STREAM mode screen will appear on the display.

Mercury vapor concentration is measured in terms of ng/m^3.

$1\ ng/m^3 = 0.001\ mg/m^3 = 0.000001\ mg/m^3$

$1\ mg/m^3 = 1000\ mg/m^3 = 1{,}000{,}000\ ng/m^3$

INSTRUCTIONS FOR THE USE OF MERCURY TRACKER 3000

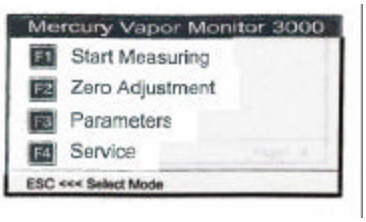
1. Turning on the instrument ignites the mercury lamp and the instrument is stabilized within 15 to 25 minutes.
2. The LCD monitor will indicate that the lamp is ignited and is stabilizing.
3. After stabilization an Auto Zero is performed. The Auto Zero Mode screen reads:

   Absorbance: 0.0001
   Concentration: 0 µg/m^3
   Time left: 17

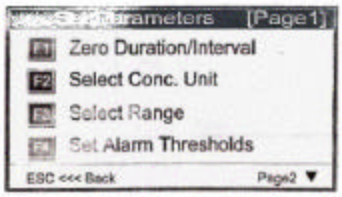
4. After auto-zeroing the instrument automatically goes into the measuring mode. The screen displays:

   Absorbance: 0.0000
   Next Auto-Zero in 15 min
   Concentration: 0 µg/m^3

5. Press the ESC key twice to return to the main menu.



6. Pressing the F2 key manually performs the zero point adjustment.
7. Press F3 to set the parameters, typical values are:



   Zero Duration: 30 seconds
   Zero Interval: 30 minute
   Concentration Unit: µg/m^3
   Range: 0.100

8. Data logger can be used for logging in data and up to 15000 measurements can be stored.