August 19, 2002

MERCURY STORAGE WORKSHOP

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Chemical Accident Prevention Program (CAPP) Introduction and Overview

Part 1

Bill Hermes

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Chemical Accident Prevention Program (CAPP)

March 17, 2010

Part 1 Introduction (8:00 a.m.)
Part 2 CAPP Elements
Part 3 Test (10:00-10:30 a.m.)
Part 4 Selected ORNL Research Results
Adjourn Noon

Chemical Accident Prevention Program (CAPP)

Associated with Defense National Stockpile Center (DNSC) Mercury Stockpile and CO_2 Fire Protection

A Mercury Storage Program training module has been developed that provides a Program overview. This module addresses the health, safety, environmental aspects, and overall operations involved with receipt, inspection, off-loading, and ongoing inspection of containerized mercury and the CO_2 fire suppression system. This training will be provided to all personnel involved with the Program. The training module will be available at HWAD for review by employees and CAPP inspectors. This training will be offered via classroom instruction and/or web-based instruction

March 17, 2010

1. An overview of the process and CAPP requirements/elements
2. An overview of relevant CAPP – specific operating procedures
3. Mercury storage concept of operations/layout
4. The location of equipment and instrumentation
5. Specific health and safety aspects involving mercury
6. Emergency operations and emergency shutdown
7. Relevant safe work practices
8. Management of change process
9. ORNL summary of mercury stockpile and research focused on flasks drums and storage

Mercury Storage Process

- Mercury is transported to HWAD in dry cargo vans – 14 pallets per shipment, 5 drums per pallet, 6 flasks per drum, 76 lb mercury per flask
- Vans/pallets are inspected for high mercury vapor concentrations
- Pallets from acceptable vans are unloaded into specified mercury storage warehouses
- Unacceptable vans/pallets are remediated and then unloaded
- Conditions of drums/pallets are inspected according to contract requirements
- During the inspections, mercury vapor concentrations in the warehouse are recorded
- Visible mercury or mercury vapor concentrations above 25,000 ng/m^3 (the HWAD action level) requires evacuation and action by FES

Chemical Accident Prevention Program Elements

Management Plan, including

I. Facility and Substance Information
II. Process Safety Information
III. Process Hazard Analysis
IV. Standard Operating Procedures
V. Training Program
VI. Mechanical Integrity Program
VII. Management of Change
VIII. Pre-Startup Safety Review
IX. Verification of Audit Compliance
X. Incident Investigation Program
XI. Employee Participation Program
XII. Contractor Program
XIII. Emergency Response Plan

CAPP-Specific Standard Operating Procedures

Receiving and Storage of the Mercury in the Warehouses	DZHC-0000-M-010
Mercury Monitoring & Response	DPD.IOP.FES.0019
Inspection of Mercury Storage Sites	SOC.QP.QAD.0002
Testing, Inspection & Maintenance of CO_2 Fire Suppression System 110 Hg Storage	DPD.IOP.FES.0015
110 Hg Storage Warehouse with CO_2 Fire Suppression Response and Manual Activation of System	DPD.IOP.FES.0017
Refrigeration and Maintenance Plan	BOP.IOP.EMB.1300
Base Operations Start Up/Shut Down and CO_2 Tank Fill/Refill Procedure	QP.BOP.EMD.1301
LockOut/Tag Out Procedure	QP.HSE.SAF.021
Inspection of Incoming/Outgoing Shipments of Material by Truck, Rail and Container	QAD.IOP.0006
Safety Hot Work Permit	QP.HSE.SAF.010

Mercury Storage Concept of Operations

- Receive delivery of shipment
- Conduct inspection and acceptance
- Store material in warehouse
- Perform routine inspections

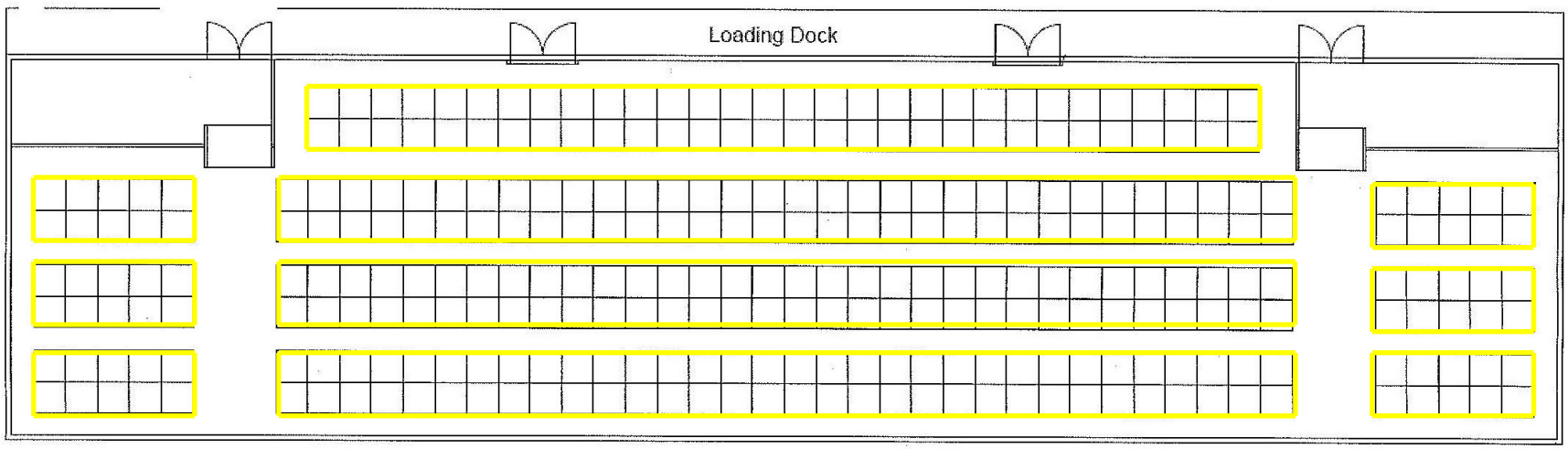
Typical 110 Building

- Length – 200 Feet
- Width – 50 Feet
- Area – 10,000 Square Feet

WN - 0061
WN - 0068
CORROSIVE
8
RQ Mercury, UN

Mercury Storage

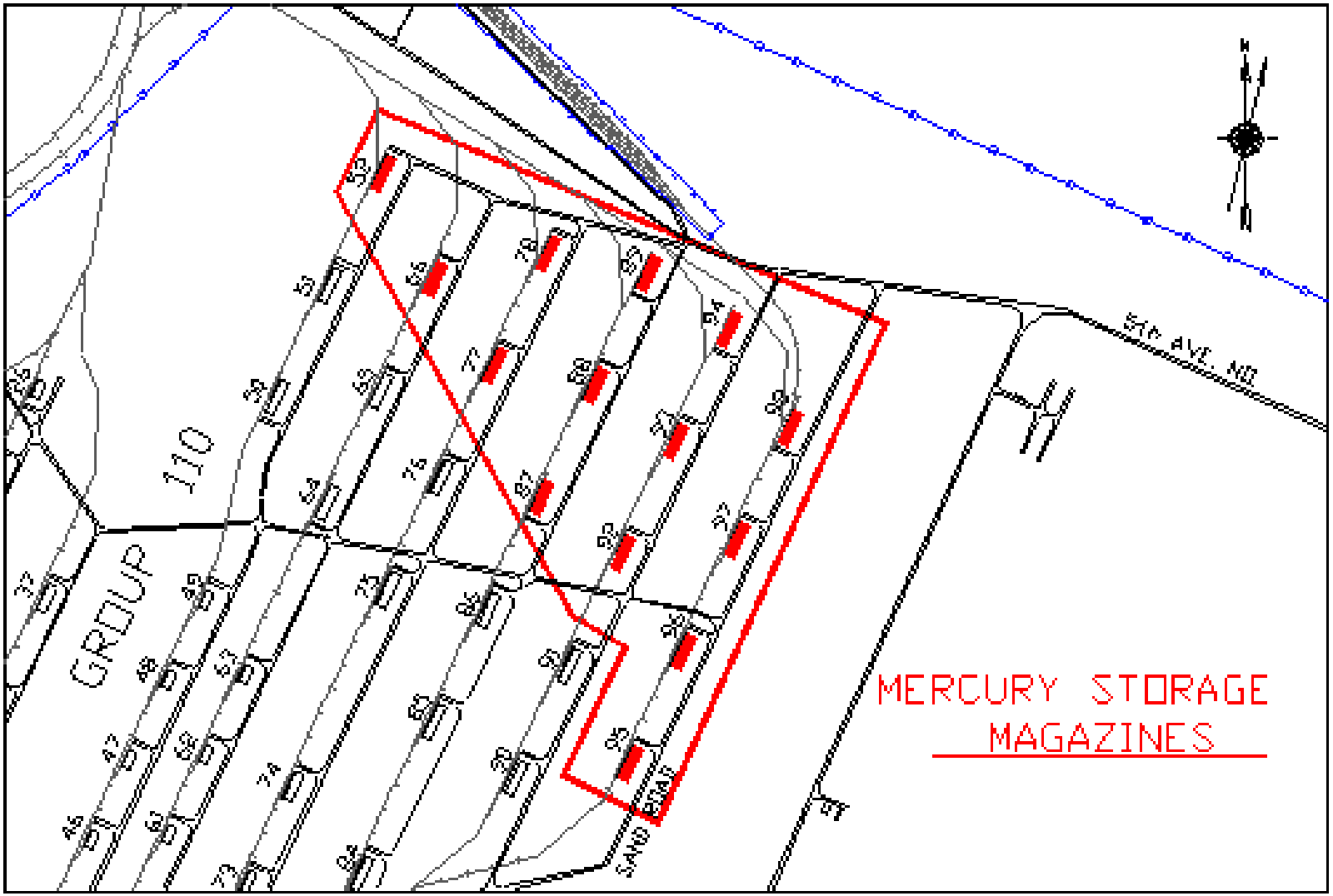
Mercury Storage Layout



Current Mercury Locations – 3-17-2010

- Somerville, New Jersey ~ 76,000 flasks
- New Haven, Indiana ~ 16,000 flasks
- Warren, Ohio ~ 37,000 flasks

Mercury Will Be Stored in the 110 Group



Protection Features

- Lighting
- Door contacts
- Intrusion detection
- Warning signs
- Illuminated exits
- Floor lined with a geomembrane
- Diking to prevent spread of release
- Fire alarm pull stations
- CO_2 release override
- Smoke detectors
- Heat detectors
- IR detectors
- Fire extinguishers
- Alert horn and strobes
- CO_2 fire suppression system

Lighting

Door Contacts

Management of Change

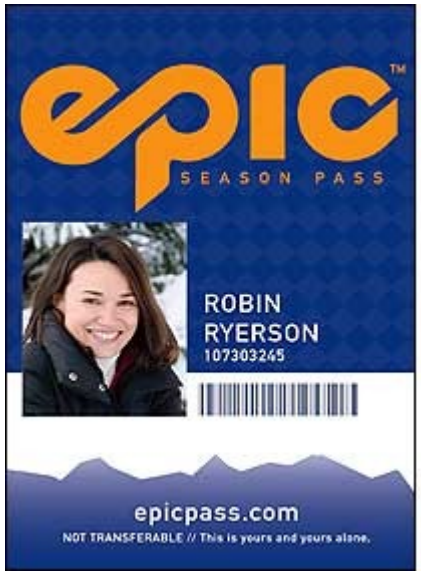
DZHC has prepared a document entitled:
Management of Change - Standard Procedure for the Mercury Storage Program to comply with the NDEP – CAPP and ISO 14001:2004

- **Procedures are written to evaluate and document the impacts on safety of proposed changes to**
  - **processes**
  - **organizational structure or staffing levels**
- **Replacements in kind are also subject to review under the management of change process**
- **Changes may be implemented only after formally documented evaluation, approval, and training are completed**
- **All workers potentially impacted by the change must be trained**

Management of Change (MOC) Process
Tier 1 document

Examples:

- **Improving procedures/lessons learned**
- **Flask integrity checks post-transport such as X-ray (radiography) of some drums**
- **Addition of radio frequency identifiers**



Vail's season passes, such as the Epic Pass, contain an embedded RFID tag providing unlimited lift access at the company's ski resorts. Source: RFID Journal

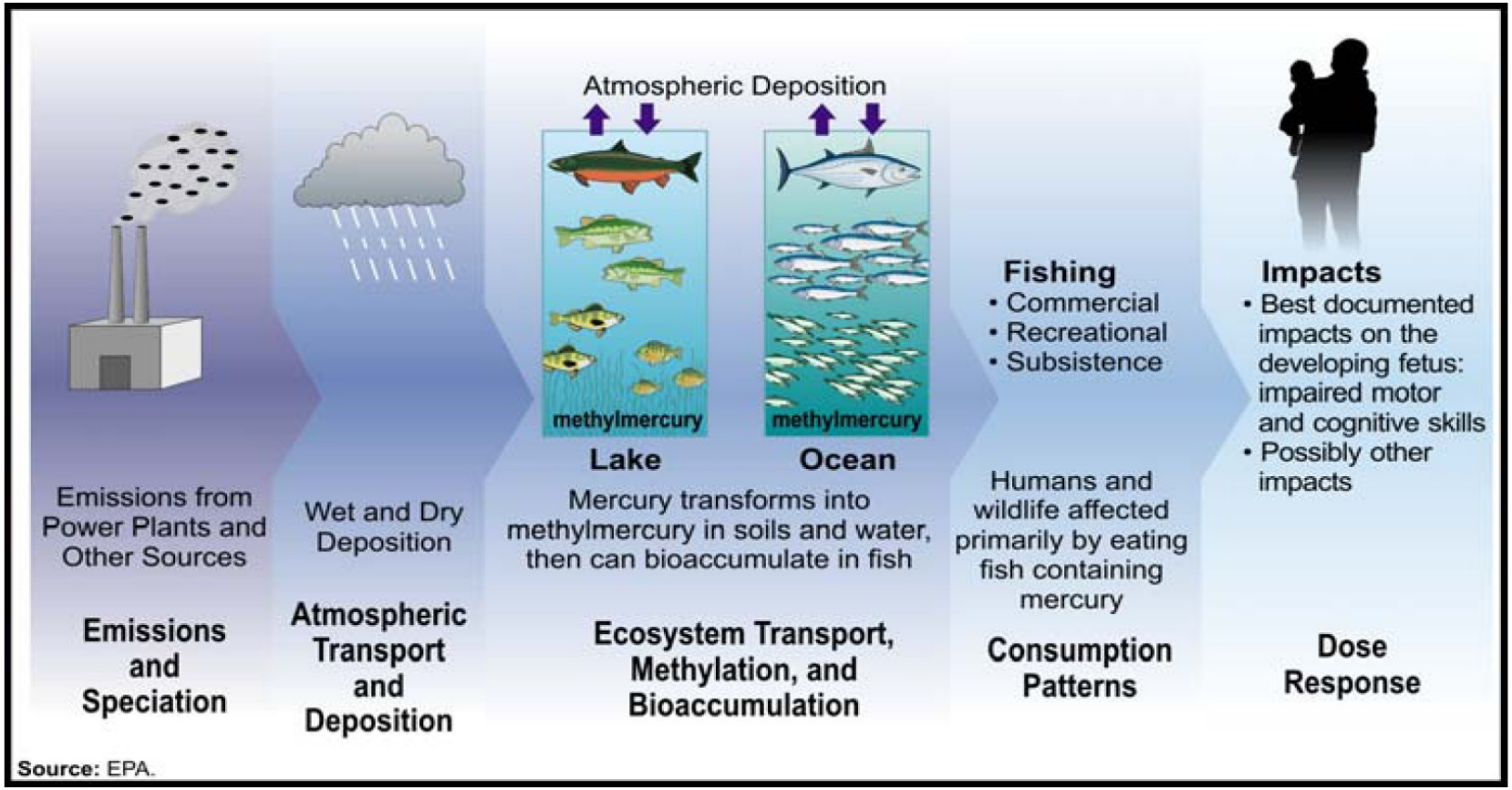
Four Points Below Covered in Body of Training Slides

- The location of equipment and instrumentation – see descriptions and photos
- Specific health and safety aspects involving mercury – reference Material Safety Data Sheets (MSDS)
- Emergency operations and emergency shutdown – reference Emergency Operations
- Relevant safe work practices – reference Process Safety Information and Process Hazards Analysis
  - Lockout/Tagout
  - Hot Work Permit

Mercury Was Once Used Extensively in Manufacturing
(DOE/EIS-0423D January 2010)

Source: VA DEQ Website.

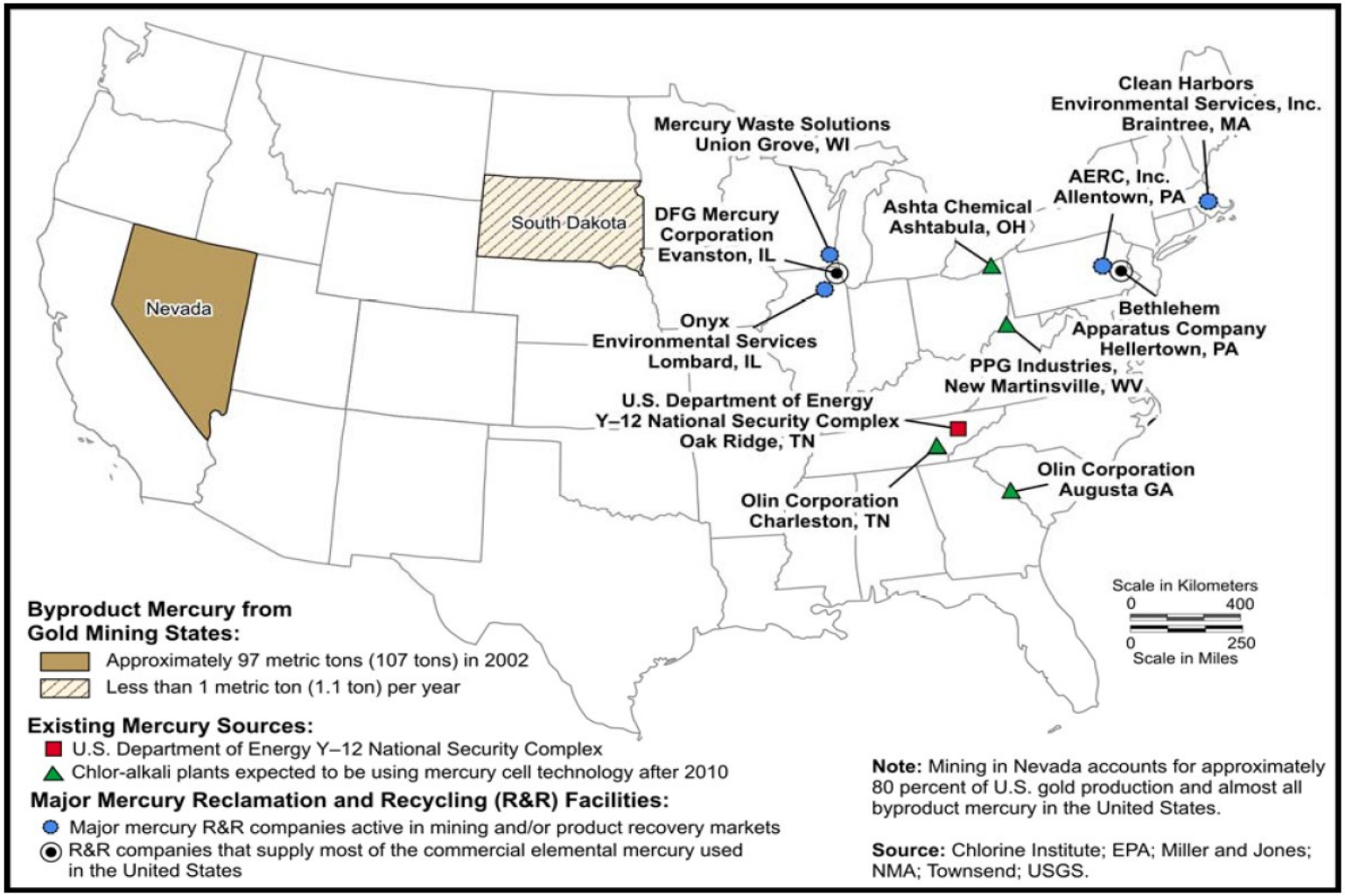
The Mercury Cycle
(DOE/EIS-0423D January 2010)



Estimated U.S. Mercury Inventory That DOE Could Manage and Store
(DOE/EIS-0423D January 2010)

Source	Years Sent to Storage [a]	Quantity in Metric Tons (tons)
DOE Y–12 National Security Complex in Oak Ridge, Tennessee	2013–2014	1,200 (1,300)
Closure of four chlor-alkali plants or conversion to non-mercury-cell technology	2013–2019	1,100 (1,200)
Waste reclamation and recycling facilities	2013–2052	2,500 (2,800)
Byproduct of gold mining	2013–2052	3,700–4,900 (4,100–5,400)
Total		**8,500–9,700 (9,400–10,700)**

Potential Sources of Mercury in the United States
(DOE/EIS-0423D January 2010)



Typical Mercury Storage Flasks
(DOE/EIS-0423D January 2010)

Existing Storage Buildings in the Central Magazine Area at the Hawthorne Army Depot (DOE/EIS-0423D January 2010)

Mercury Storage Program Overview
(Nancy Dailey)

ORNL Summary of Mercury Stockpile and Research Focused on Flasks, Drums, Storage, and Monitoring
(Jim Terry)

Mercury Storage Program Overview
Part 2

Nancy Dailey

For compliance with
Chemical Accident Prevention Program (CAPP)
(per Nevada Administrative Code 459.95418)

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Training Objectives/Scope

- Chemical Accident Prevention Program Overview
- Overview of Mercury Storage Program
- Overview of Mercury Storage Program procedures*
- Test: Verify that employees understand training (75% = minimum passing test score)
- Summarize results of studies conducted by Oak Ridge National Laboratory in support of Chemical Accident Prevention Program

*Operations-specific training not covered in this module

Chemical Accident Prevention Program Purpose

- Protect the health, safety and general welfare of the residents of Nevada from the effects of the improper handling of hazardous chemicals
- Ensure that employees in Nevada who are required to work with hazardous chemicals are guaranteed a safe and healthful working environment
- Protect Nevada natural resources by preventing and mitigating releases of hazardous chemicals
- Ensure the safe and adequate handling of hazardous chemicals in Nevada

Chemical Accident Prevention Program

- Stresses hazard identification and accident prevention
- Facilities subject to approval (of Mercury Storage Program documents prior to receipt of mercury) and periodic inspections by Nevada Division of Environmental Protection
  - Noncompliances found by regulators can result in fines and/or penalties

Chemical Accident Prevention Program Regulations

- Senate Bill 641, the Chemical Catastrophe Prevention Act (July 1991)
  - Chlorine release in Henderson, NV, in May 1991
- Enacted Nevada Administrative Code – Chapter 459.380 through 459.3874 in 1992
  - Nevada Division of Environmental Protection administers the program
  - Regulations amended several times
  - Mercury amendment enacted 2007
    - Threshold quantity: 200,000 lbs of elemental mercury

Chemical Accident Prevention Program Intent

- Facility documents how each requirement is implemented at site
- Documents answer
  - Who?
  - What?
  - When?
  - Where?
  - How?
  - Records?

Mercury Health & Safety Topics

- The most severe health effects associated with chronic mercury exposure are related to long-term exposures to vapors at levels above the OSHA permissible exposure limit (100,000 ng/m^3)
- The level of mercury vapor in the storage warehouses is expected to stay well below the level to create a health concern to employees
- Employees handling mercury should perform the following actions: use PPE appropriate for the work task; wash thoroughly after handling mercury; avoid breathing mercury vapors at concentrations above the HWAD action level (25,000 ng/m^3); do not eat or drink while handling mercury; remove contaminated clothing immediately; report all mercury releases promptly
- Copy of MSDS for Mercury in handouts

Carbon Dioxide Health and Safety Concerns

- Exposure to carbon dioxide (CO_2) vapor at high concentrations has the following effects:
  - light headedness and dizziness
  - difficulty breathing
  - drowsiness
  - nausea
  - mental confusion
  - loss of consciousness which may prove fatal due to suffocation as it displaces oxygen
- See MSDS for CO_2 in handouts

Material Safety Data Sheets

- MSDS are available through your supervisor and the HWAD intranet
- Copies of MSDSs for mercury (Hg), carbon dioxide (CO_2), methyl salicylate, and methyl alcohol are in the class handout
- Methyl salicylate (oil of wintergreen) and methyl alcohol are odorants added in trace quantities to the CO_2 that enable you to smell the CO_2 if discharged
  - If ingested in their pure form, methyl salicylate and methyl alcohol are toxic
- If you smell the wintergreen odor, you should evacuate the warehouse and radio or call the GOC (7911)

Key Safe Work Practices

- The Lockout/Tagout Safe Work Practice defines the process for ensuring that no employees or contractors are exposed to hazards associated with a release of hazardous energy or deficiencies with, or inadequacies of control of hazardous energy in buildings and grounds at HWAD
- The Hot Work Permit process at HWAD has been updated to include hot work at the Mercury Storage Warehouses

Overview of Mercury Storage Program Procedures

- Mercury Storage Program (MSP) affects many DZHC organizations/staff
- DZHC General Manager and HWAD Commander administer and implement the CAPP including the integration of CAPP across HWAD
- DZHC Environmental Services Manager is the technical contact for CAPP issues

Mercury Storage Program Administrative Level Documents

- Management System and Implementation Plan
- Process Safety Information Program Plan
- Process Hazard Analysis Procedure
- Mechanical Integrity Procedure
- Management of Change Standard Procedure
- Employee Participation Program

Mercury Storage Program Administrative Level Documents (cont.)

- Standard Operating Procedure Program
- Training Program Plan for Mercury Storage Program
- Pre-Startup Safety Review Procedure
- Emergency Operations Plan
- Incident Investigation Standard Procedure
- Compliance Audit Program

Mercury Storage Program Administrative Level Documents – General

- Current versions available on HWAD intranet under Environmental Management System and from your management
  - Administrative (programmatic) level documents
  - Operating procedures
- Subject to annual review and certification of accuracy and completeness

Management System and Implementation Plan

- Defines HWAD system to implement Chemical Accident Prevention Program requirements
- Assigns key roles and responsibilities
- Defines key records that must be maintained and retention schedules
- Defines specific facility information and regulated chemical information: Hg amount and Hg operations (storage only)
- Appendix 1 (see handout) identifies the Mercury Storage Program administrative documents and the supporting documents, including relevant operating procedures

Process Safety Information Program Plan

- Program plan defines HWAD system to compile and evaluate design/operating information
  - Resource for developing the process hazard analysis (PHA)
  - Sets initial basis by which proposed changes would be evaluated via Management of Change (MOC)
  - Sets basis for implementing the Mechanical Integrity Program (inspection, maintenance, testing)
  - This training module includes a summary of the Process Safety Information (PSI)
  - PSI report on HWAD intranet

Process Hazard Analysis Procedure

- Defines HWAD system to evaluate process hazards and mitigate those hazards
- Covers Hg storage (process)
- Covers utilities and auxiliary systems
- Evaluates potential failures to ensure adequate safeguards are implemented
- Ensures recommendations are tracked to completion
- PHA reports available on HWAD intranet

Mechanical Integrity Procedure

- Defines HWAD system to ensure proper maintenance of MSP equipment and instruments
  - Hg storage: building, grounding, electrical, dikes, geomembrane (Teranap), drums, pallets, etc.
  - CO_2 fire suppression system: tanks, piping, valves, refrigeration, vents, alarms, etc.
  - Instrumentation and forklifts
- Ensures equipment and instruments are maintained in a manner to prevent failure

Mechanical Integrity Procedure (cont.)

- Ensures maintenance personnel are trained to perform maintenance tasks in a safe and adequate manner
- Ensure deficiencies in equipment are corrected before using equipment again
- Ensure required inspection, testing, maintenance records are maintained
- MSP procedures that address mechanical integrity are listed in Appendix 1 of the Management System and Implementation Plan and are available on the HWAD intranet

Management of Change – Standard Procedure

- Defines HWAD system to ensure proposed changes to MSP procedures, PSI or staffing does not introduce hazard
- Defines steps to evaluate proposed changes and the steps for implementing a change
  - See MOC flowchart in procedure
- Important for MSP staff to identify "change" in order to implement the MOC evaluation
- HWAD system begins with staff proposing a change

Management of Change – Key Definitions

- "Change" – includes temporary or permanent modifications to technology, process equipment, procedures, chemicals, or processing conditions; modifications to buildings, structures, or equipment; and modifications to organizational structure or staffing that impact the prevention program and the emergency response program
- "Equipment" – includes changes in materials of construction, equipment specifications, piping arrangements, computer programs, alarms or interlocks
- "Replacement in kind" – means replacing something with the exact same thing (based on review of design specifications) or a replacement that is equivalent to or that satisfies the design specification of the item to be replaced or performs the same role of that part or procedure. [Minor changes to procedures that are editorial, administrative or nontechnical (do not affect the way staff perform their work) are not subject to the Management of Change Procedure, but are still subject to tracking per the applicable document control process.]

Management of Change – Step by Step

- Step 1: Staff member proposes change
- Step 2: Staff member/supervisor documents proposed change (see Management of Change checklist) including replacements in kind
  - Contact Environmental Services Manager to obtain tracking number
  - Note: Time limits are set for temporary changes; extensions must be reapproved or go through the full Management of Change process
- Step 3: Identify affected managers and initiate review and approval of proposed change by affected managers
- Step 4: Managers review and document impacts, if any, to Mercury Storage Program documents (plans, procedures, training, Process Safety Information, Process Hazard Analysis, etc.)
  - Safety Manager must review and approve changes to safe work practices, Process Safety Information and Process Hazard Analysis

Management of Change – Step by Step (cont.)

- Step 5: Managers make necessary modifications to Mercury Storage Program documents; training implemented (if necessary) and documented
- Step 6: Environmental Services Manager verifies Management of Change process complete
- Step 7: Change approved for implementation

Employee Participation Program

- Defines HWAD system to consult with Mercury Storage Program employees on the development and implementation of the Chemical Accident Prevention Program accident prevention and emergency response program
  - Employee input is voluntary and welcomed; includes review of or pilot testing of draft procedures or other program documents
  - Contact your management and the Environmental Services Manager if you wish to volunteer
- Intent is to ensure employees have access to the Process Hazard Analysis and other information developed (procedures, Process Safety Information, Incident Investigations, etc.)
- Records of employee participation (input) must be retained

Procedure for the Development, Maintenance and Control of Documents

- Defines HWAD system for the development, maintenance and control of documents issued to comply with Chemical Accident Prevention Program
- Goals:
  - Provide clear instructions for safe operations
  - Provide opportunity for employee participation
  - Ensure employee's can readily access to procedures
  - Cover all operating scenarios, safety and health considerations, and Safe Work Practices
  - Ensure consistency with the Process Safety Information
- Requires annual review of accuracy and completeness and certification of Chemical Accident Prevention Program procedures by DZHC management and HWAD Commander

Mercury Storage Program Training

- Purpose is to ensure that Mercury Storage Program personnel are trained to the:
  - hazards associated and tasks involving receipt, storage, inspection, operations and maintenance of containerized mercury (Hg) and the carbon dioxide (CO_2) fire suppression system;
  - standard operating procedures and safe work practices for the Mercury Storage Program; and
  - process by which changes are managed/evaluated (e.g., management of change procedure)
- Training responsibilities assigned under Human Resources (overview) and affected managers (operations specific)
  - Initial training and refresher training (every 3 years)
- Positional training needs are defined in Mercury Storage Program training matrix
- Records: Employee understanding of oral or written tests; names, dates, training content

Pre-Startup Safety Review Procedure

Defines HWAD system to:

- **Ensure the completeness, operability and safety of the Mercury Storage Program**
  - **Operating procedures, emergency response systems, etc. in place**
- **Ensure Process Hazard Analysis is complete and recommendations have been implemented**
- **Ensure Management of Change (procedure/process) is implemented and training is complete**

Emergency Operations Plan*

- Defines HWAD system for emergency preparedness, including roles of HWAD staff and outside agencies, response procedures and the recovery process
- Includes description of means to notify emergency responders, notify outside agencies, and issue required reports
- Refers to Safety System Description for Mercury Storage Program for concise description of Emergency Response systems at the mercury warehouses and instructions for staff
  - For suspected fire: pull fire alarm, close doors, evacuate upwind to a safe distance; (Fire and Emergency Services staff will respond)
  - For spill of mercury, exit building, radio or phone Guard Operations Center who will notify Fire and Emergency Services

*Operates in concert with the HWAD Hazardous Materials and Resource Conservation and Recovery Act Contingency Plan

Incident Investigation Standard Procedure

- Defines HWAD system to investigate incidents involving the Mercury Storage Program that resulted in a catastrophic release (or could have resulted in such a release)
  - Includes near misses (incident where no damage/unplanned release occurred, but might easily have occurred given a slight change)
  - Identify root cause and contributing factors
  - Develop recommendations to prevent recurrence
- Investigation must be initiated within 48 hours following the incident
  - Starts with employee filling out an incident report
- After the investigation is complete and recommendations made, the incident report is circulated for employee input. Comments are then resolved and then the report is issued in final form

Contractor Program

HWAD has not issued an administrative level procedure addressing Contractor Program requirements under Chemical Accident Prevention Program. Those requirements

- Ensure contractors are provided with the necessary information to enable them to perform their jobs in a safe manner
- Contractors are obligated to ensure their employees are trained to enable them to perform their jobs in a safe manner
- Apply to contractors who perform maintenance, repair, turnaround, major renovation or specialty work on, or adjacent to the Mercury Storage Program

Compliance Audit Program

- Defines HWAD system to evaluate compliance with Chemical Accident Prevention Program
  - Prevention Programs
  - Emergency Response Program
- Audit/self-assessment must be conducted at least every three years
- HWAD must document the evaluation
- HWAD must correct deficiencies identified during audit

Summary

- The Chemical Accident Prevention Program regulations stress hazard identification and accident prevention
- HWAD, through issuance of procedures, plans, etc., has implemented an integrated system to comply with Chemical Accident Prevention Program for the Mercury Storage Program
  - Important for all staff to understand and comply with Mercury Storage Program procedures, plans, etc.
  - Also important for all Mercury Storage Program staff to understand how Chemical Accident Prevention Program regulations affect their work
  - Contact DZHC Environmental Services Manager for questions or comments on this training or the Mercury Storage Program
- This training serves as the main (overview) training for the Mercury Storage Program. You may also be required to take additional operating procedure training (required readings, on-the-job, etc.) based on work assignments

Part 3: Written TEST

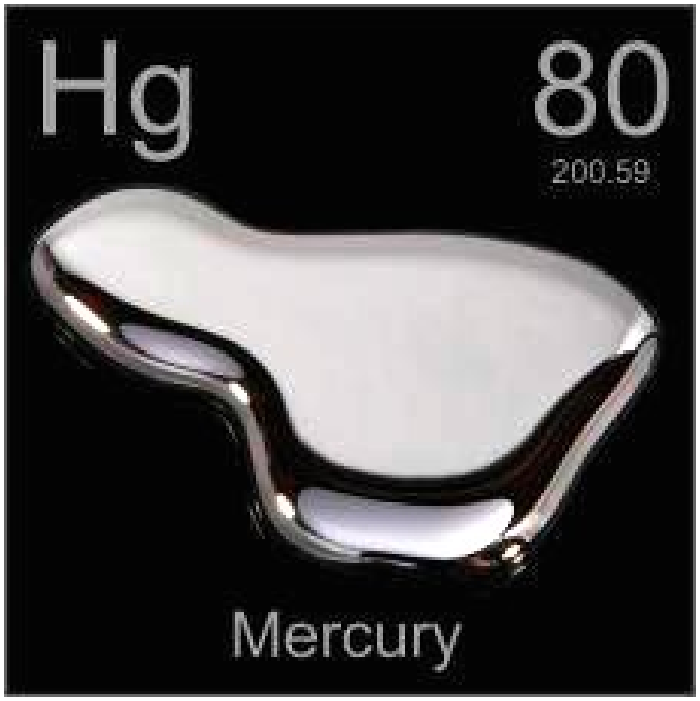
- 75 % = minimum passing test score
  - Open book and notes
- Be sure to put your name on your answer sheet
- We also welcome your feedback on course content

ORNL Summary of Mercury Stockpile and Research Focused on Flasks, Drums, Storage, and Monitoring

Part 4

Jim Terry

What is Mercury?
How to Work Safely Around it.



Chemical and Physical Properties

Elemental mercury

- Chemical symbol: Hg
- Atomic weight: 200.59
- Density: 13.6 g/cm^3 (iron: 7.9 g/cm^3, lead: 11.3 g/cm^3, gold: 19.3 g/cm^3)
- One of the rare elements to be liquid at room temperature
- Emits mercury vapor
- Vaporization increases with temperature, surface area, and agitation
- Metallic form is insoluble in water
- Forms alloys with metals (except iron, steel, and platinum)

Elemental mercury vapor

- Toxic
- Invisible, odorless, and tasteless
- Biologically harmful
- Soluble in fat

Inorganic and Organic Mercury Compounds are not Expected to Occur Under the Storage Conditions at Hawthorne

Inorganic mercury compounds (mercury salts)

- Two different types (Hg^{+} or Hg^{++})
- Emit vapor
- Biologically harmful

Organic mercury compounds

- Emit vapor
- Biologically harmful
- Mercury attached to a short chain of carbon molecules
- Contains some organic forms such as methyl or alkyl mercury, which are particularly toxic, more readily absorbed into the body and more difficult to excrete

NIOSH Pocket Guide to Chemical Hazards

Mercury compounds [except (organo) alkyls] (as Hg)

CAS

7439-97-6 (metal)

Hg (metal)

RTECS

OV4550000 (metal)

Synonyms & Trade Names

Mercury metal: Colloidal mercury, Metallic mercury, Quicksilver
Synonyms of "other" Hg compounds vary depending upon the specific compound.

DOT ID & Guide

2809 172 (metal)

Exposure Limits

NIOSH REL:
Hg Vapor: TWA 0.05 mg/m^3 [skin]
Other: C 0.1 mg/m^3 [skin]

OSHA PEL†:
TWA 0.1 mg/m^3

IDLH

10 mg/m^3 (as Hg) See: 7439976

Conversion

Physical Description

Metal: Silver-white, heavy, odorless liquid. [Note: "Other" Hg compounds include all inorganic & aryl Hg compounds except (organo) alkyls.]

MW: 200.6	BP: 674°F	FRZ: -38°F	Sol: Insoluble
VP: 0.0012 mmHg	IP: ?		Sp.Gr: 13.6 (metal)
Fl.P: NA	UEL: NA	LEL: NA	
Metal: Noncombustible Liquid			

Incompatibilities & Reactivities

Acetylene, ammonia, chlorine dioxide, azides, calcium (amalgam formation), sodium carbide, lithium, rubidium, copper

Measurement Methods

NIOSH 6009; OSHA ID140
See: NMAM or OSHA Methods

Personal Protection & Sanitation

(See protection codes)
Skin: Prevent skin contact
Eyes: No recommendation

First Aid

(See procedures)
Eye: Irrigate immediately
Skin: Soap wash promptly

International Chemical Safety Cards

MERCURY

ICSC: 0056

Quicksilver
Liquid silver
Hg

ICSC # 0056
CAS # 7439-97-6
RTECS # OV4550000
UN # 2809
EC # 080-001-00-0
April 22, 2004 Validated

TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/ SYMPTOMS	PREVENTION	FIRST AID/ FIRE FIGHTING
FIRE	Not combustible. Gives off irritating or toxic fumes (or gases) in a fire.		In case of fire in the surroundings: use appropriate extinguishing media.
EXPLOSION	Risk of fire and explosion.		In case of fire: keep drums, etc., cool by spraying with water.
EXPOSURE		STRICT HYGIENE! AVOID EXPOSURE OF (PREGNANT) WOMEN! AVOID EXPOSURE OF ADOLESCENTS AND CHILDREN!	IN ALL CASES CONSULT A DOCTOR!
•INHALATION	Abdominal pain. Cough. Diarrhoea. Shortness of breath. Vomiting. Fever or elevated body temperature.	Local exhaust or breathing protection.	Fresh air, rest. Artificial respiration if indicated. Refer for medical attention.
•SKIN	MAY BE ABSORBED! Redness.	Protective gloves. Protective clothing.	Remove contaminated clothes. Rinse and then wash skin with water and soap. Refer for medical attention.
•EYES		Face shield, or eye protection in combination with breathing protection.	First rinse with plenty of water for several minutes (remove contact lenses if easily

International Chemical Safety Cards

MERCURY

ICSC: 0056

IMPORTANT DATA

PHYSICAL STATE; APPEARANCE:
ODOURLESS, HEAVY AND MOBILE SILVERY LIQUID METAL.

PHYSICAL DANGERS:

CHEMICAL DANGERS:
Upon heating, toxic fumes are formed. Reacts violently with ammonia and halogens causing fire and explosion hazard. Attacks aluminium and many other metals forming amalgams.

OCCUPATIONAL EXPOSURE LIMITS:
TLV: 0.025 mg/m³ as TWA; (skin); A4; BEI issued; (ACGIH 2004).
MAK: 0.1 mg/m³; Sh;
Peak limitation category: II(8);
Carcinogen category: 3B;
(DFG 2003).
OSHA PEL†: C 0.1 mg/m^3
NIOSH REL: Hg Vapor: TWA 0.05 mg/m^3 skin
Other: C 0.1 mg/m^3 skin
NIOSH IDLH: 10 mg/m^3 (as Hg) See: 7439976

ROUTES OF EXPOSURE:
The substance can be absorbed into the body by inhalation of its vapour and through the skin , also as a vapour!

INHALATION RISK:
A harmful contamination of the air can be reached very quickly on evaporation of this substance at 20°C.

EFFECTS OF SHORT-TERM EXPOSURE:
The substance is irritating to the skin. Inhalation of the vapours may cause pneumonitis. The substance may cause effects on the central nervous systemandkidneys. The effects may be delayed. Medical observation is indicated.

EFFECTS OF LONG-TERM OR REPEATED EXPOSURE:
The substance may have effects on the central nervous system and kidneys , resulting in irritability, emotional instability, tremor, mental and memory disturbances, speech disorders. May cause inflammation and discoloration of the gums. Danger of cumulative effects. Animal tests show that this substance possibly causes toxic effects upon human reproduction.

PHYSICAL PROPERTIES

Boiling point: 357°C
Melting point: -39°C
Relative density (water = 1): 13.5
Solubility in water:
none

Vapour pressure, Pa at 20°C: 0.26
Relative vapour density (air = 1): 6.93
Relative density of the vapour/air-mixture at 20°C (air = 1): 1.009
Electrical conductivity (NOT on card): 1.04 x 10(+18)pS/m

ENVIRONMENTAL DATA

The substance is very toxic to aquatic organisms. In the food chain important to humans, bioaccumulation takes place, specifically in fish.

NOTES

Depending on the degree of exposure, periodic medical examination is indicated. No odour warning if toxic concentrations are present. Do NOT take working clothes home.

Transport Emergency Card: TEC (R)-80GC9-II+III

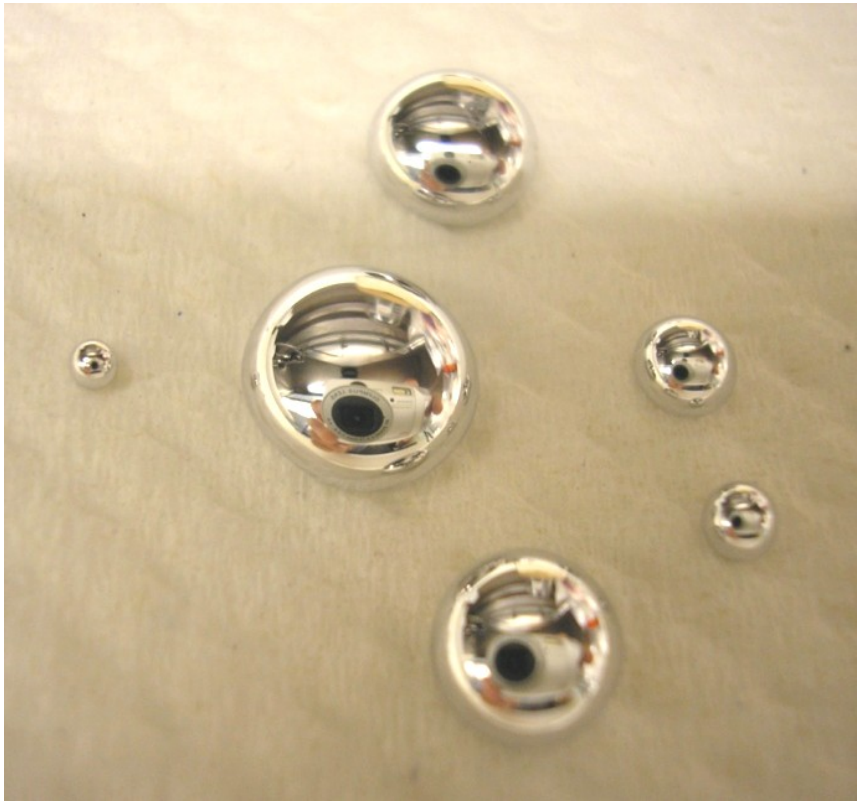
Mercury – Important Details

- When elemental mercury is dropped, it breaks into many small droplets and the droplets divide again producing a larger total surface area
- Mercury droplets roll and break into smaller droplets if touched
- Fewer vapors are emitted from a large droplet of mercury than if the droplet is broken into many smaller ones (more surface area is more dangerous)

Movie of a Drop of Water Falling

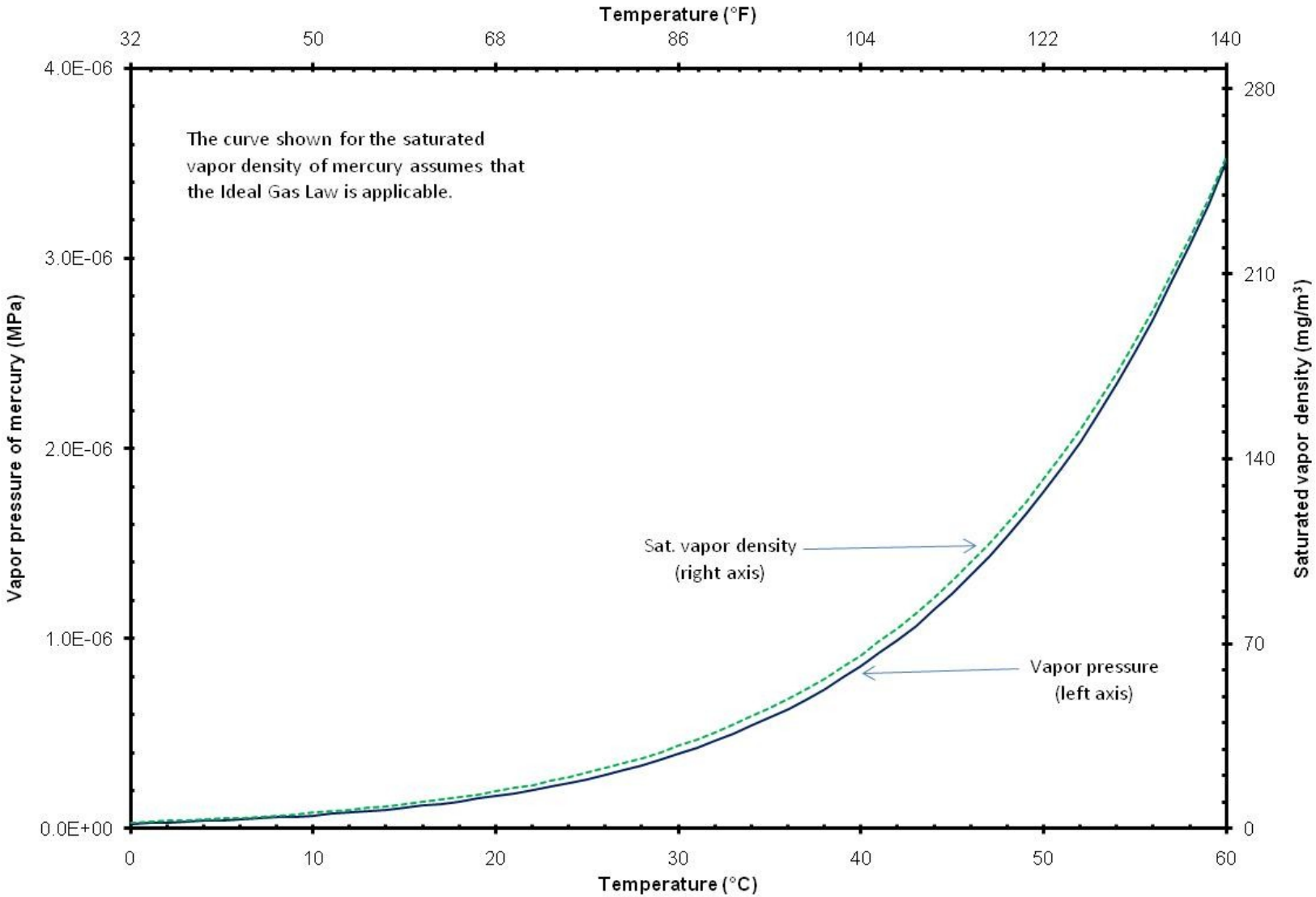
Movie of a Drop of Mercury Falling

Movie of a Drop of Mercury Falling



Pure elemental mercury forms circular drops and moves without leaving a visible path on the support media

Mercury with impurities loses its round shape and leaves some microdroplets attached to the support material


Temperature (°F)
32
50
68
86
104
122
140
4.0E-06
3.0E-06
2.0E-06
1.0E-06
0.0E+00
Vapor pressure of mercury (MPa)
280
210
140
70
0
Saturated vapor density (mg/m³)
The curve shown for the saturated vapor density of mercury assumes that the Ideal Gas Law is applicable.
Sat. vapor density (right axis)
Vapor pressure (left axis)
0
10
20
30
40
50
60
Temperature (°C)

Mercury's Toxicity was not Known Several Decades Ago, so Mercury was Used in Many Common Applications

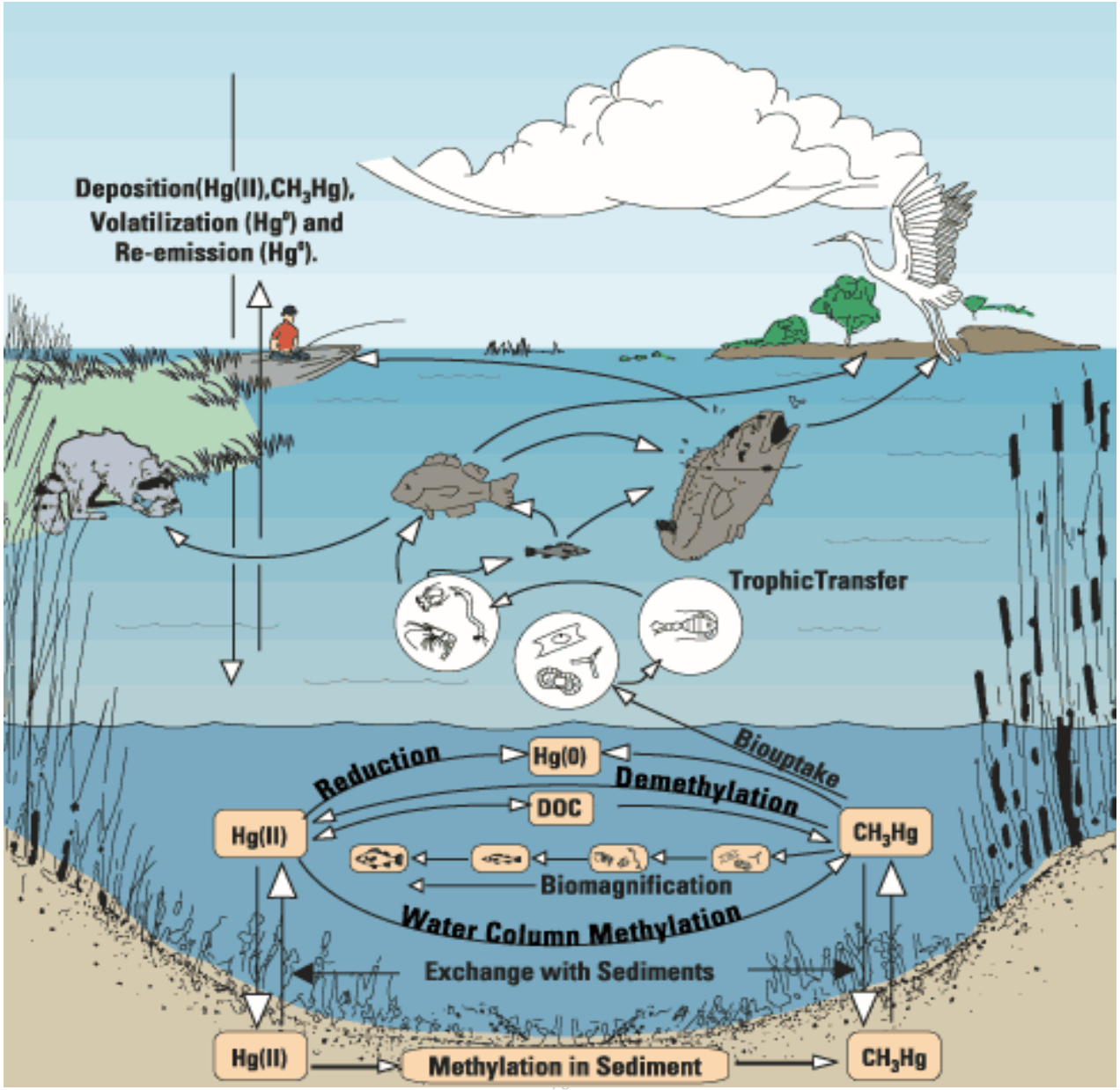
- Dentistry – fillings made of mercury amalgams
- Medicine – vaccine fabrication
- Automotive – relays, switches
- Metrology – thermometers

One famous application of mercury is a modern sculpture designed by the American artist Alexander Calder and presented by the Spanish Republican government for the 1937 World Exhibition in Paris. Calder's mercury fountain, now at the Fundació Joan Miró in Barcelona, is displayed behind glass for safety reasons.

This gold miner is sitting on mercury contained in a tank

Mercury and the Environment

Mercury in the Food Chain



Ban on Mercury

- To reduce the extent of mercury pollution, measures are being taken worldwide to eliminate the commerce in mercury. For example the United States and the European Community have created laws to prevent the sale of mercury outside their borders
- All U.S. chlor-alkali plants will operate without using mercury in a few years
- Industries are replacing mercury containing devices with ones that perform the function without mercury. A notable exception is fluorescent lighting which the U.S. is encouraging because it is more energy efficient than incandescent lighting

Mercury's Toxicity

Mercury in the Body

Cumulative Nature

- Mercury has a half-life in the body of 70 days
- Mercury can be slowly excreted from the body, but its effects (and damage) are not easily repaired. Therefore, the effects of mercury exposure tend to be cumulative

Biological Symptoms of Mercury Exposure

- Headaches, vertigo, nausea, diarrhea
- Restlessness, irritability
- Tremors, loss of fine motor control
- Psychological disturbances such as mood and personality changes
- Blurring of vision
- Lesions on skin with prolonged contact
- Increased perinatal mortality

Basis for Breathing Zone Exposure Limits

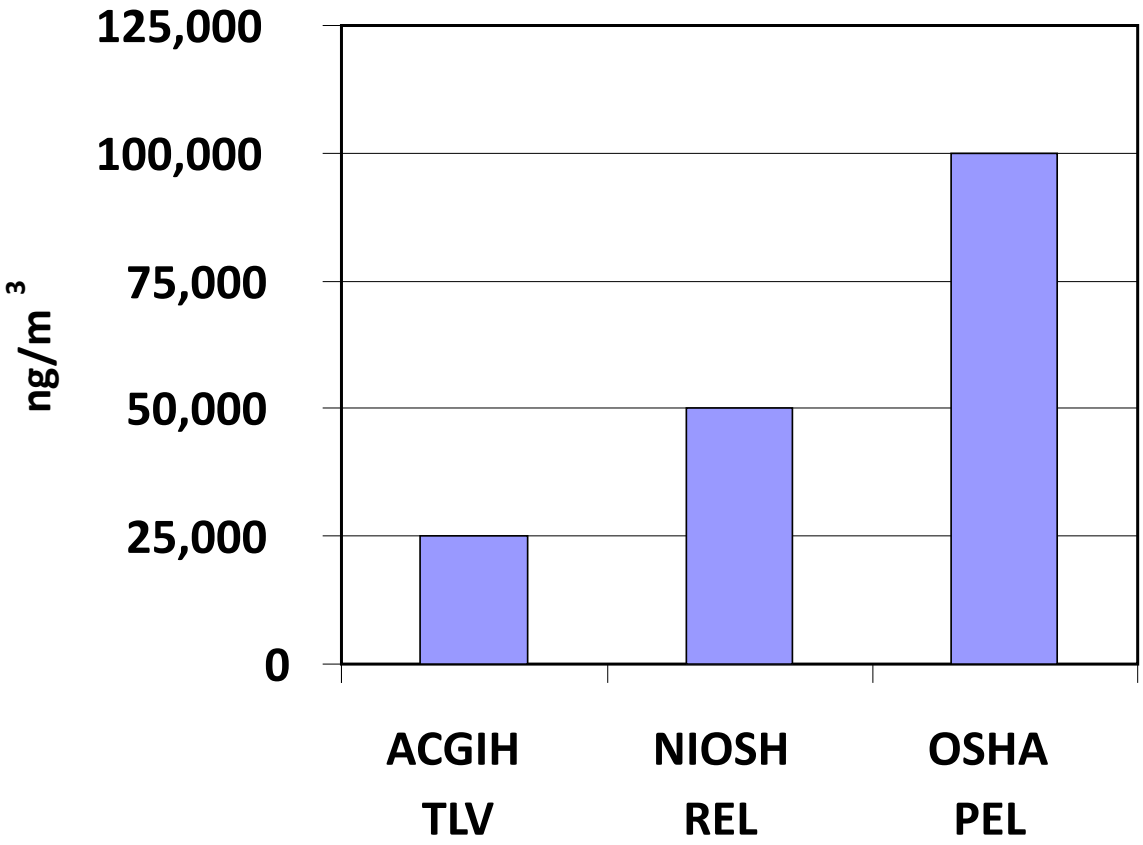
ACGIH TLV-8hr TWA is 0.025 mg/m^3

The time weighted average is set low enough to prevent symptoms of mercurialism (mercury poisoning), including:

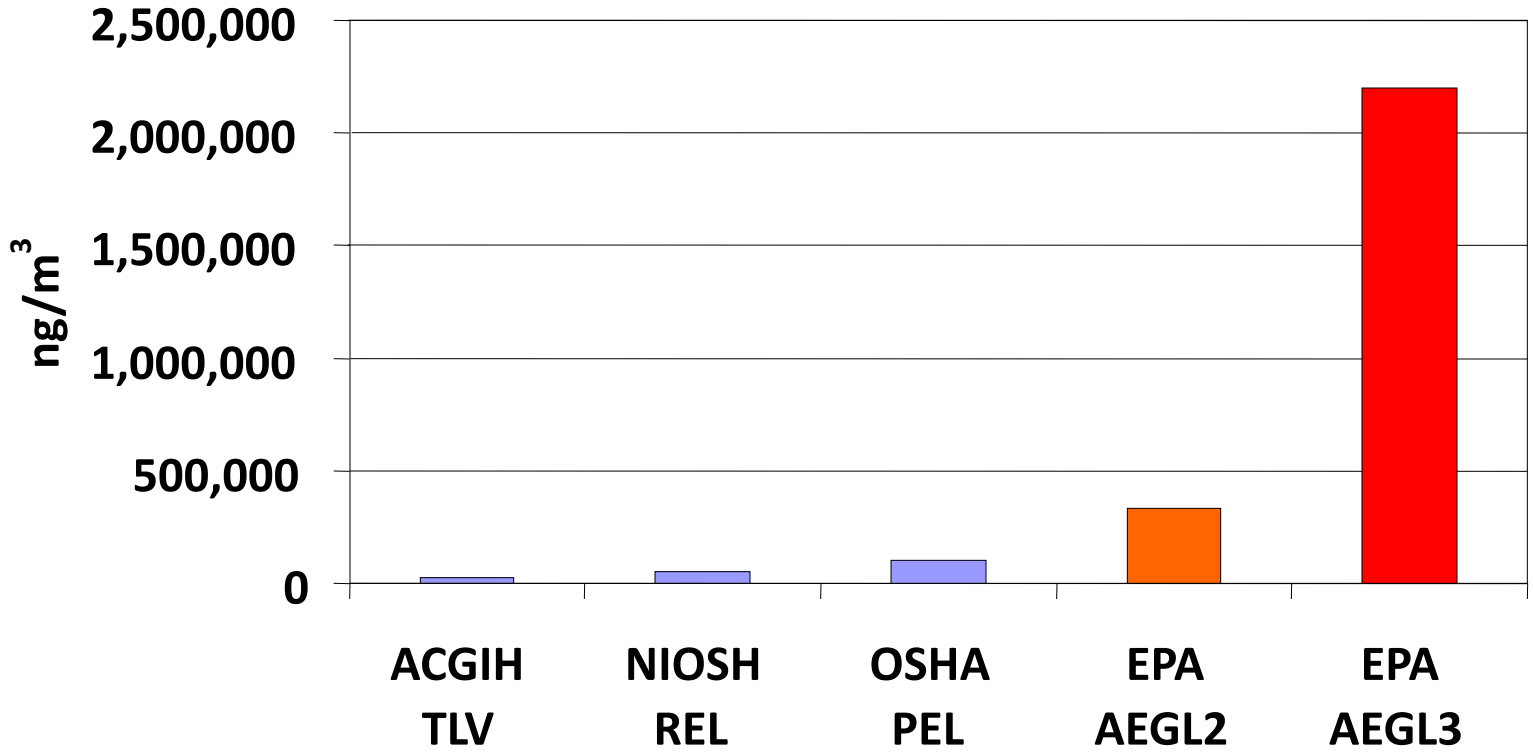
- **gingivitis (inflammation of gums),**
- **tremor (unintentional muscle movement),**
- **erethism (abnormal state of excitement/irritation), and**
- **nephrotoxicity (poisonous effect on kidneys)**

Exposure occurs primarily through inhalation, and to a much lesser extent through skin absorption or ingestion

Breathing Zone Limits (8-hr exposure)



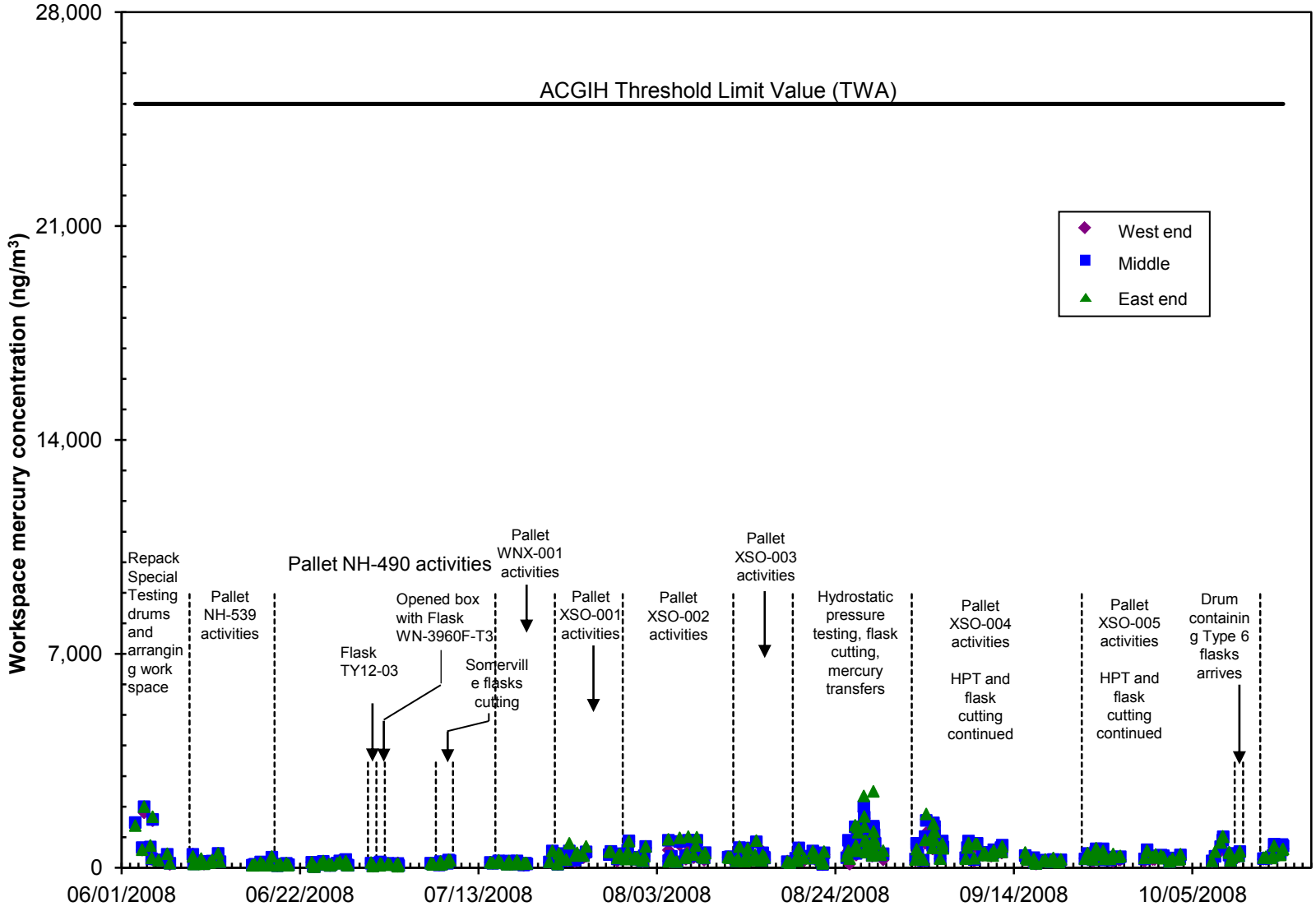
Breathing Zone Limits (8-hr exposure)



DON’T PANIC

- Even though mercury is harmful, with correct protective measures, personnel exposure is minimal. For example ORNL worked with flasks contaminated externally with small droplets of mercury and levels were kept well below action levels
- The following chart shows the level measured in the laboratory

Building 7604 Workspace Mercury Concentration



Minimum Requirements for Handling Mercury

- Monitor the vapor concentration in the breathing zone
- Employ good aeration – open doors to let the air circulate
- Wear protective clothing – gloves, safety glasses, safety shoes, and coveralls
- Wear respirators with mercury cartridges if the mercury level is above the HWAD action level: (25,000 ng/m^3)
- Capture mercury vapors when working in an area where the mercury vapor concentration is consistently above the HWAD action level – use snorkels equipped with carbon sulfur filters

Instruments for Mercury Vapor Measurements

Units of Measurement for Mercury Vapor in Air

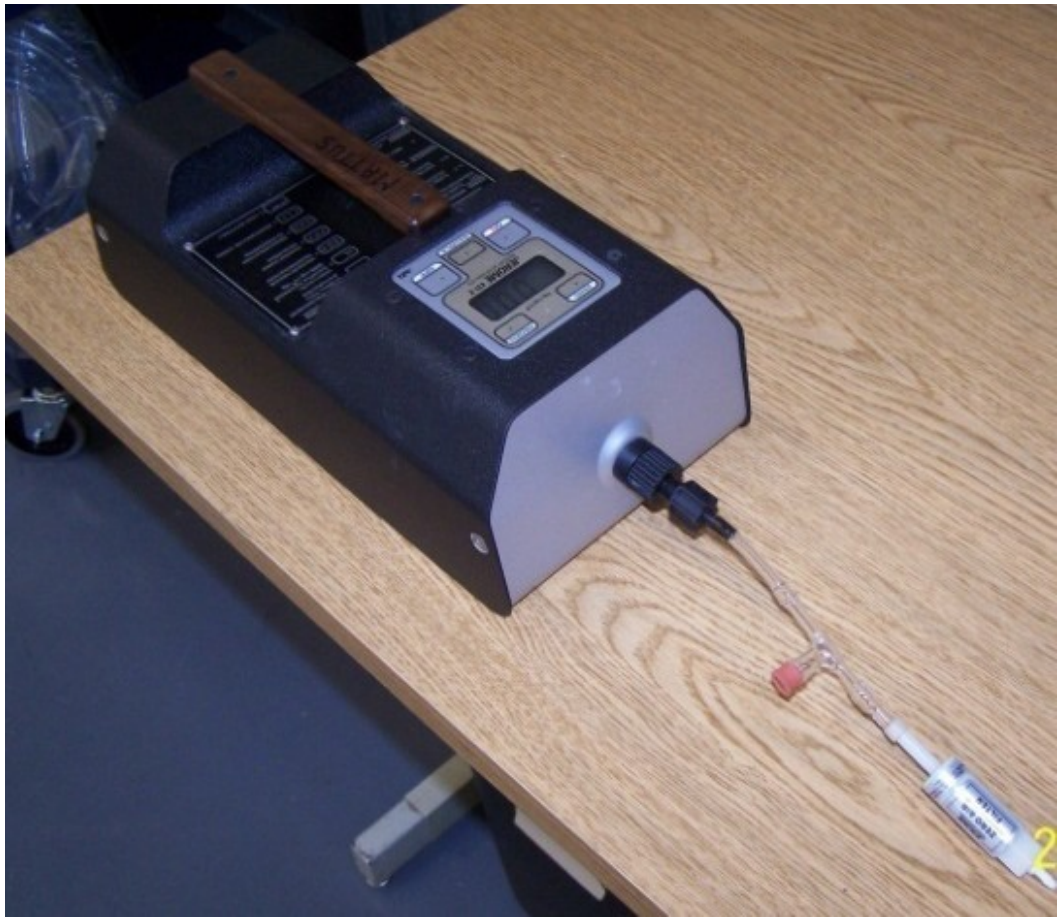
- Suggested and mandated mercury vapor concentrations in air are frequently specified in milligrams per cubic meter: mg/m^3
- Because mercury vapor concentrations can vary widely, the concentrations may also be measured in
  - micrograms per cubic meter ($\mu g/m^3$), where 1 mg/m^3 equals 1,000 $\mu g/m^3$ or
  - nanograms per cubic meter (ng/m^3), where 1 mg/m^3 equals 1,000,000 ng/m^3
- The Jerome mercury analyzer displays directly in mg/m^3 and that instrument displays the HWAD action level as 0.025 mg/m^3
- The mercury vapor concentration in air in the 110 Area warehouses is expected to be much below the HWAD action level
- The Ohio Lumex mercury analyzer displays directly in ng/m^3 and that instrument displays the HWAD action level as 25,000 ng/m^3

Ohio Lumex Mercury Analyzer

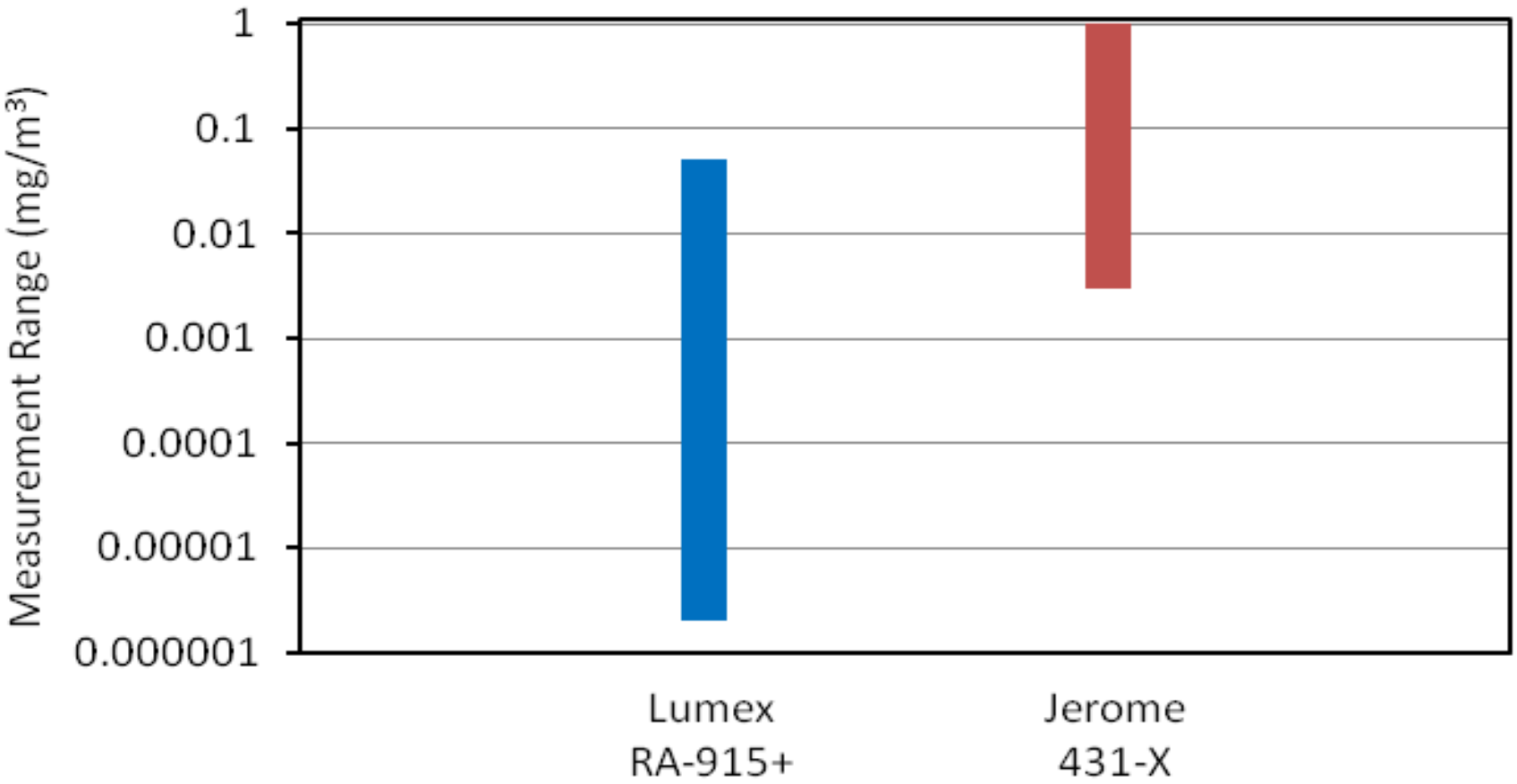
- Model RA-915+ analyzer
- Portable atomic absorption spectrometer
- Based on differential Zeeman atomic absorption spectrometry using high frequency modulation of light polarization
- There are no known interfering elements
- Calibrated by the manufacturer
- Measurement range: 2 – 50,000 ng/m^3 (0.000002 – 0.05 mg/m^3)

Arizona Instrument Jerome Mercury Analyzer

- Model 431-X
- Calibrated by the manufacturer
- Mercury forms an amalgam with gold foil and corresponding change in electrical resistance of the foil is measured
- Measurement range: 0.003 to 0.999 mg/m^3



Comparison of Concentration Measurement Ranges of the Lumex RA-915+ and the Jerome 431-X Mercury Analyzers as Cited by the Manufacturers



ORNL's Study of the Stockpile

ORNL Was Asked to Assess the Integrity of the Flasks from the Mercury Stockpile

- The stockpile contains ~ 128,000 mercury flasks that are over 40 years old and for which little data exists
- The goal of the project is to assess the long term storage integrity of the mercury stockpile
- ORNL used the data collected during the 2008 drum inspection and repackaging campaign to select a limited number of flasks representing the stockpile for flask characterization
- ORNL received 236 flasks for examination and characterization

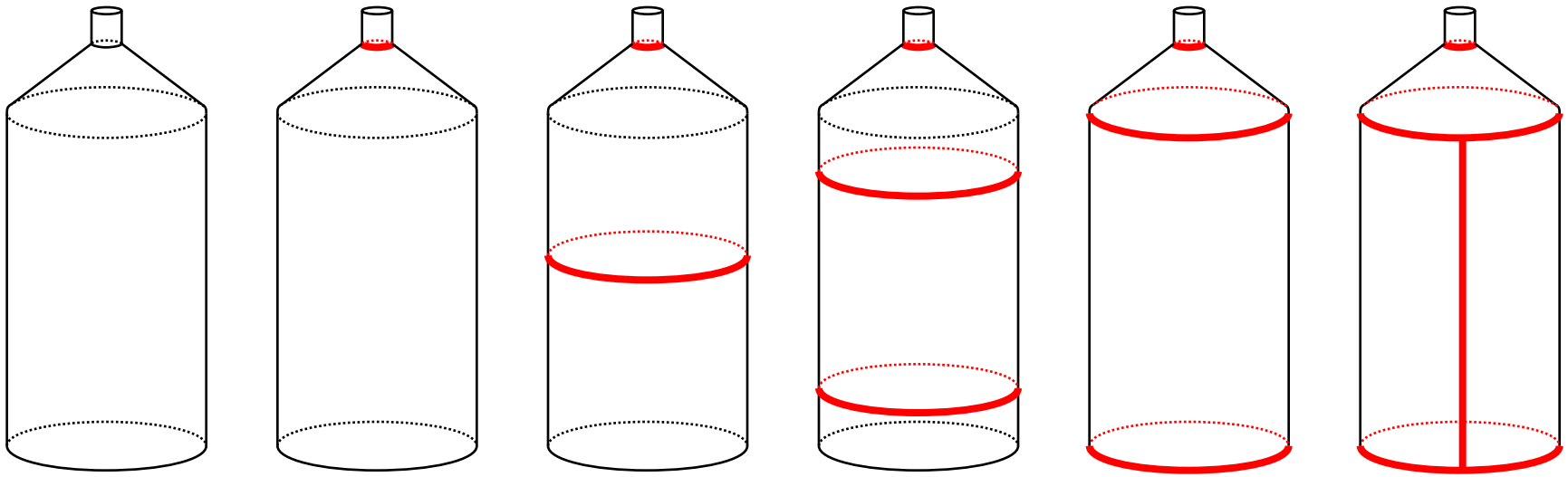
Summary of the Number of Flasks and Test Performed During the Flask Characterization Phase

Number of Flasks	Test Performed
236	Drum headspace
236	Flask sniffing with Lumex (ES&H)
238	Flasks visual observation – pictures
236	Wiping flasks
60	Wipe analyses
225	Physical measurements
192	Ultrasound thickness testing
192	X-ray fluorescence
236	Weight flask
31	Flask emptying
22	Chemical analysis – x-rays
18	Flask volume
18	Hydrotesting
31	Cutting
24	Internal corrosion examination
28	Thickness vernier
28	Metallography
23	Chemical analysis – burn test

Early Findings from the Testing

- At least 32 types of flasks were identified with different construction
- The mercury concentration measured in the drum headspace varies greatly from drum to drum. It is correlated to the degree of external contamination of the flasks
- The flasks are and look old but they were able to contain the mercury for 40+ years

Six Different Types of Flasks Construction



Seamless	1 weld	2 welds	3 welds	3 welds	4 welds
22.494%	15.65%	1.84%	6.09%	0.412%	44.65%
	T3*-15.55%	T1-1.71%	T2-6.09%	T7-T7B-0.12%	T5-44.55%
	T10-0.05%	T20-0.13%		T9-0.15%	T11B-0.01%
	T17B-<0.005%			T11-0.01%	T16-T16B-0.06%
	T28-0.009%			T14-0.07%	T24-0.03%
	T30-0.04%			T22-0.002%	
				T27-0.06%	

*** T3 AND T4 HAVE A BOTTOM PLUG**

Views of Some Flasks

Flask Size and Volume are not Uniform in the Stockpile (here are the extremes)

NH-02612-E-T11B
~ 220 mm tall and 140 mm diameter

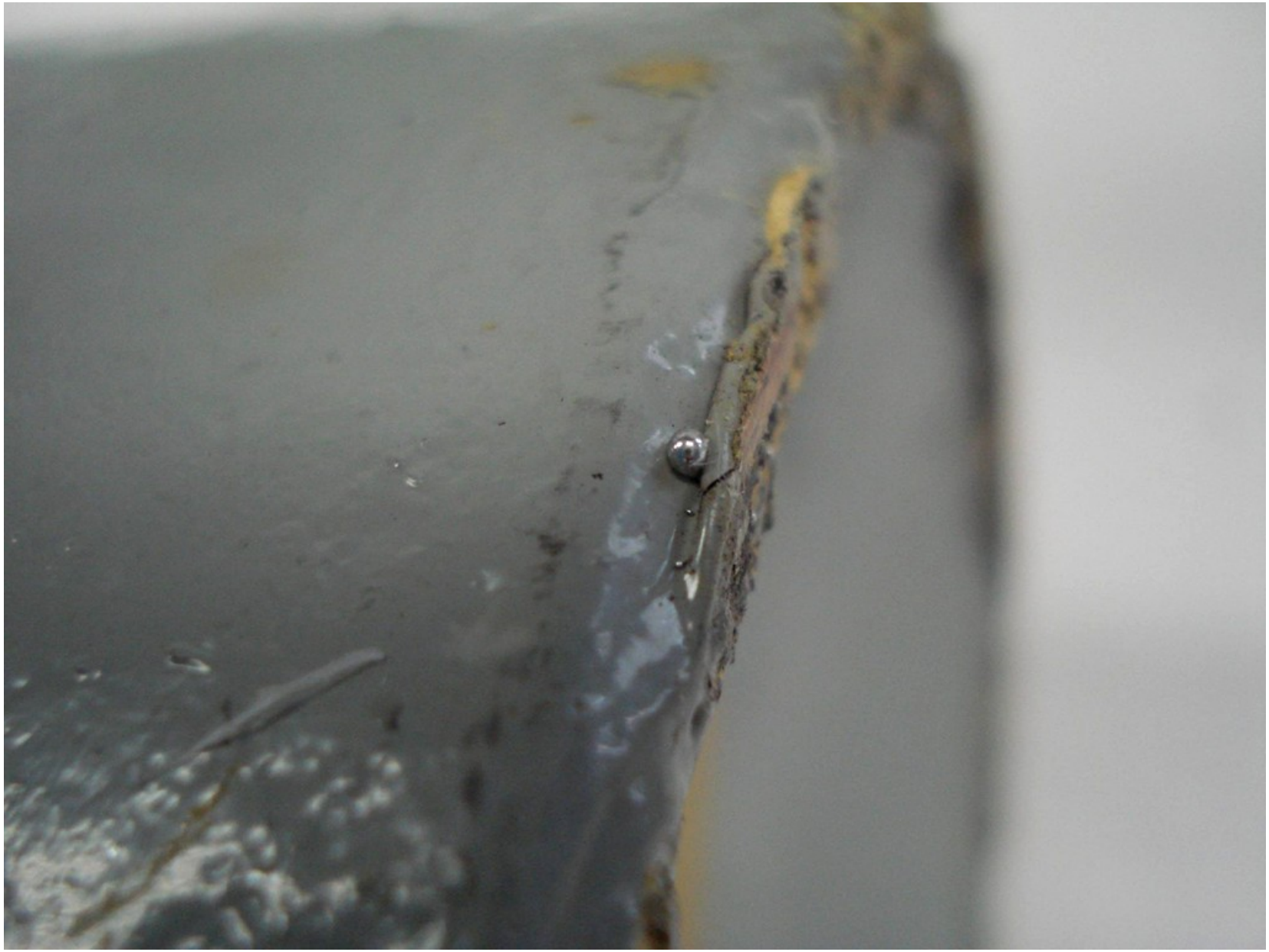
NH-02149-A-T7
~ 490 mm tall and 100 mm diameter

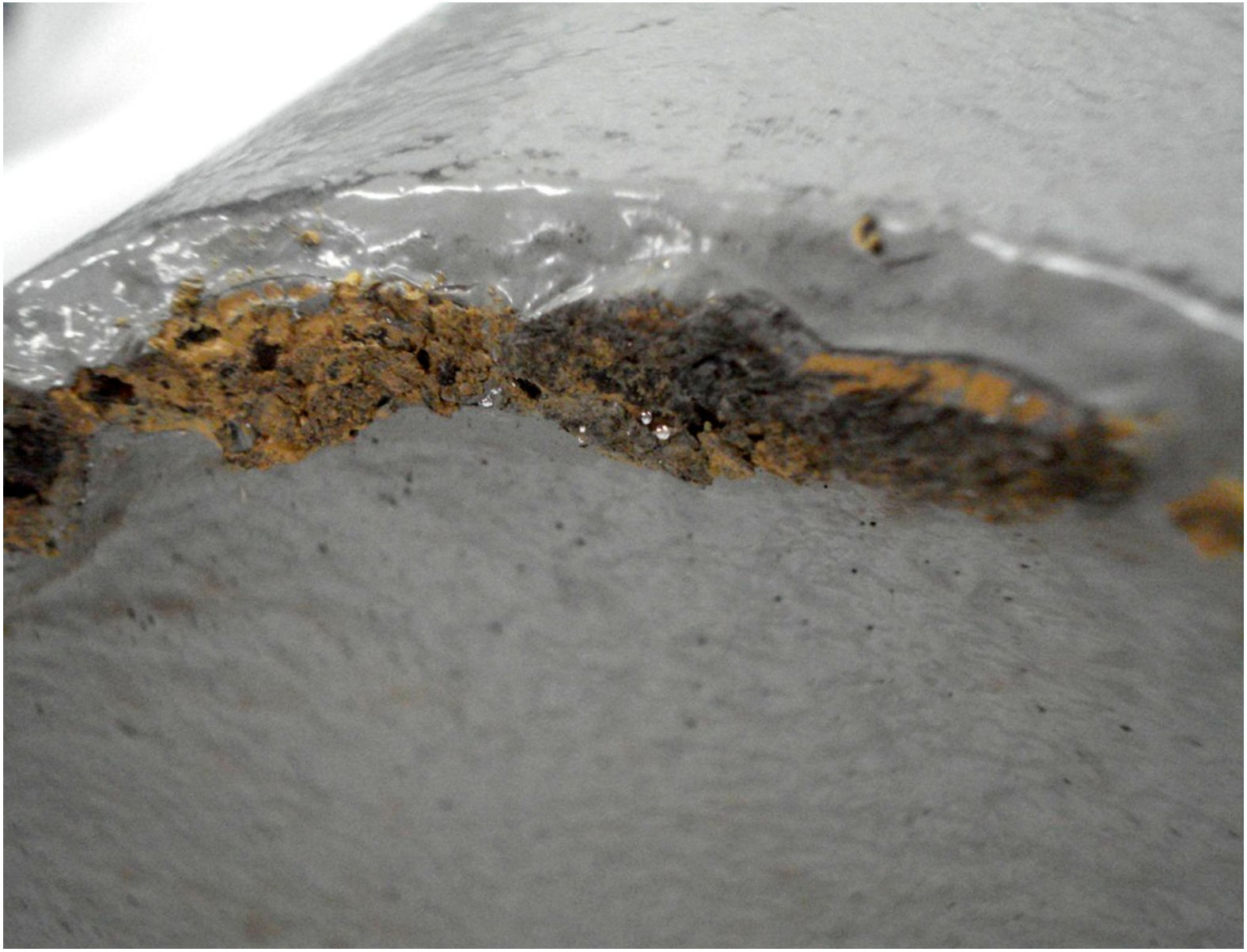
Important Safety Finding From Testing

- **Because of possible contamination on the outside of the flasks, gloves should always be worn when handling flasks; however, HWAD personnel are not anticipated to handle flasks**

CESCO
2008/03/26

Mercury Contamination Present on the Flasks

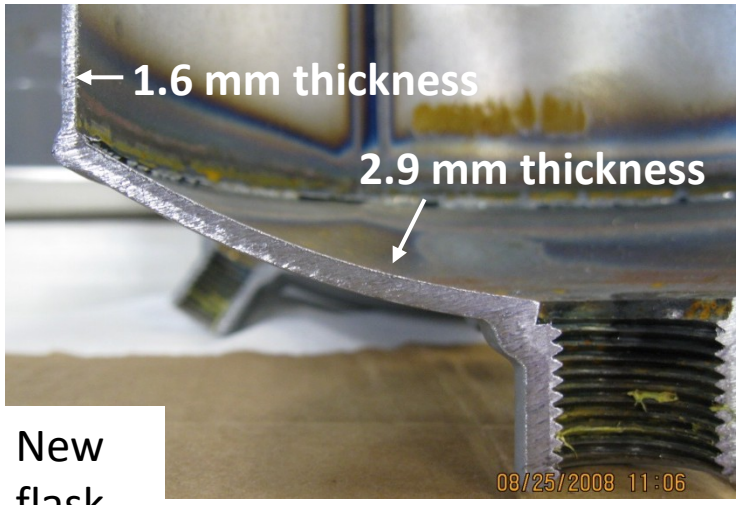




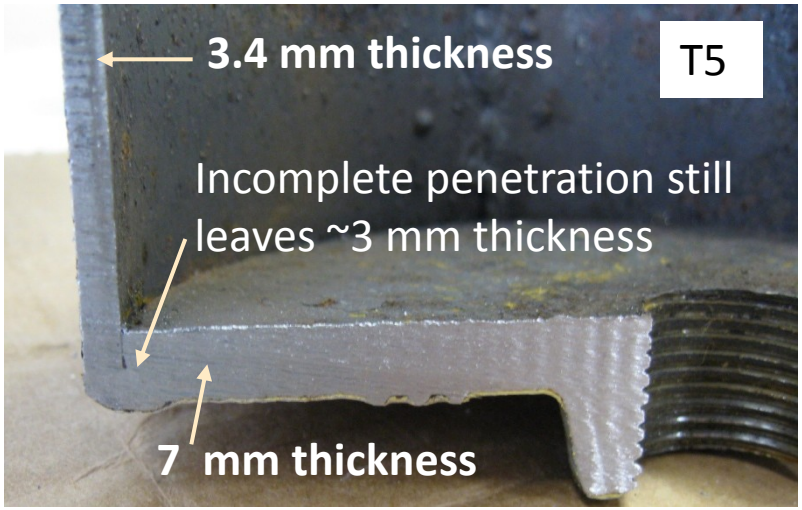
Major Findings From Testing

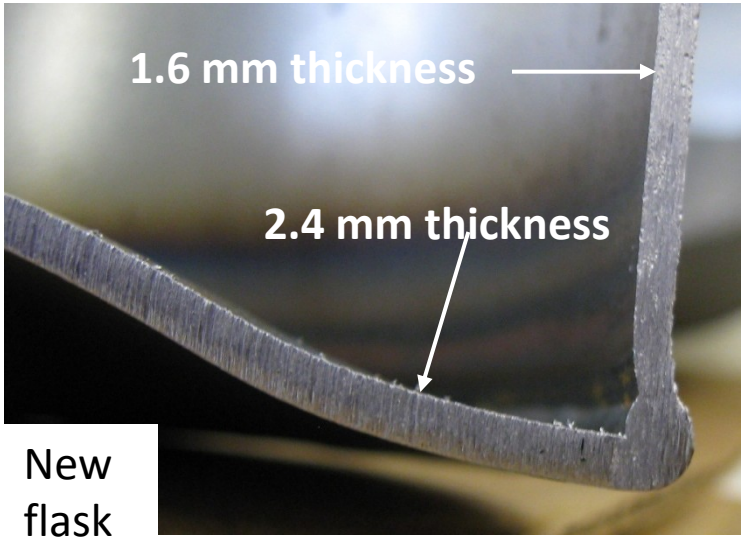
- The external appearance of some of the flasks is poor, but this does not correlate with actual poor condition or internal corrosion of the containers
- Welds are of lower quality compared with the state of the art today, but the flasks tested were able to withstand hydrostatic pressures substantially higher than commercial flasks manufactured today
- The flasks are suitable for containing the mercury for 40+ additional years

Thickness of the Material Used for Flask Construction is at Minimum Twice of Today's Flasks

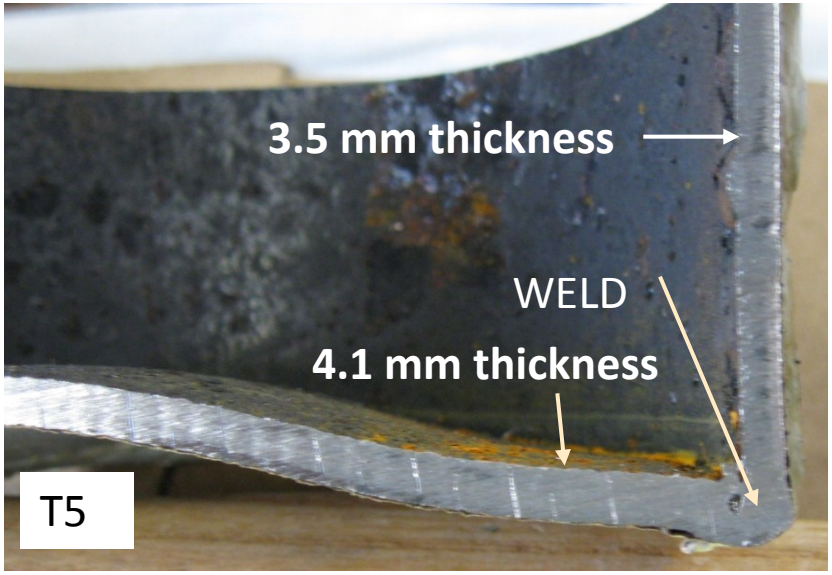


New flask





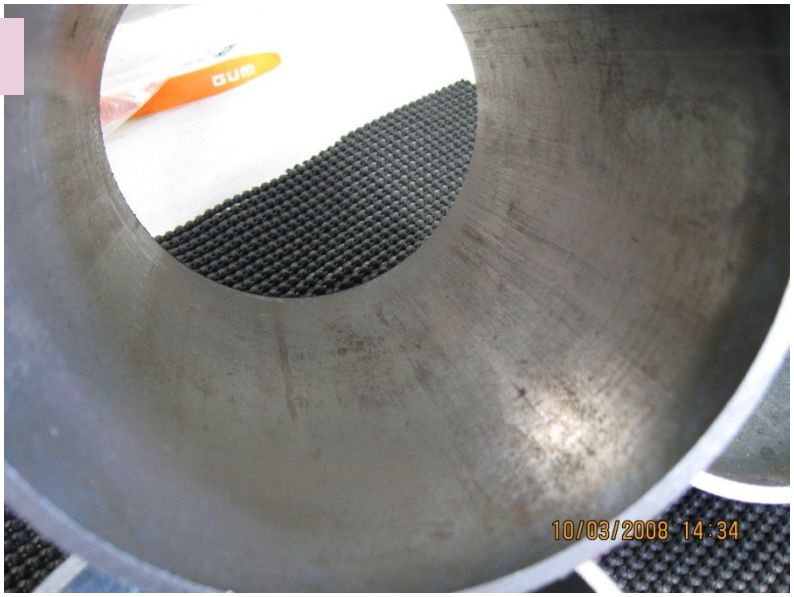
New flask



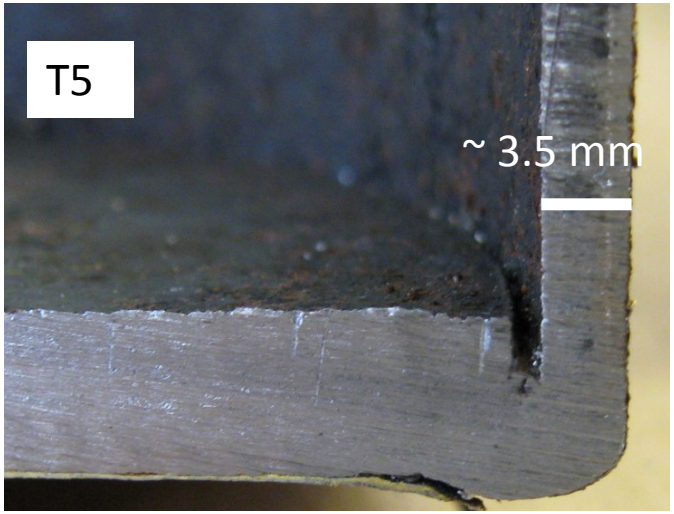
Interior of the Flasks Does Not Appear Corroded

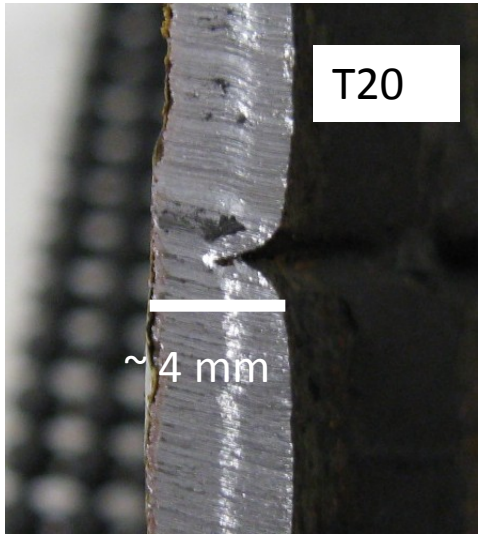
T2

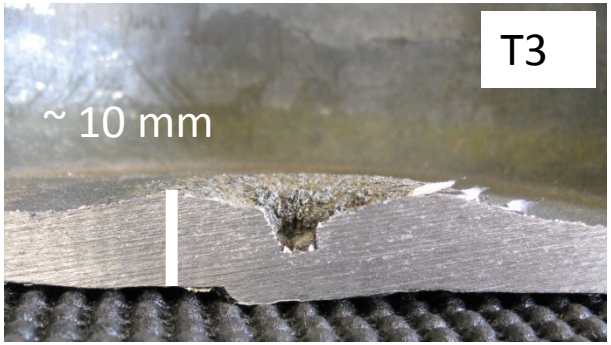
T3

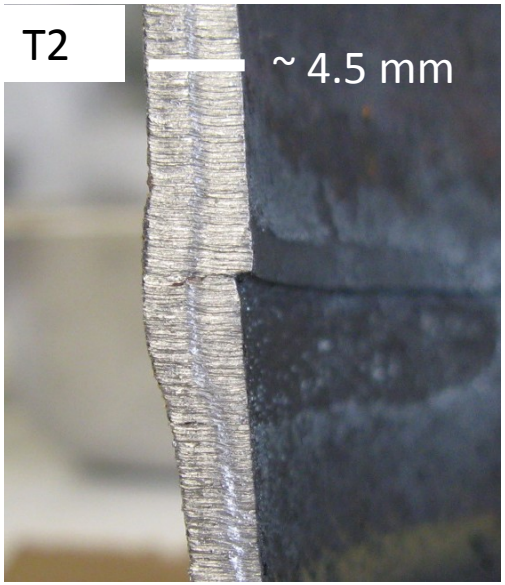


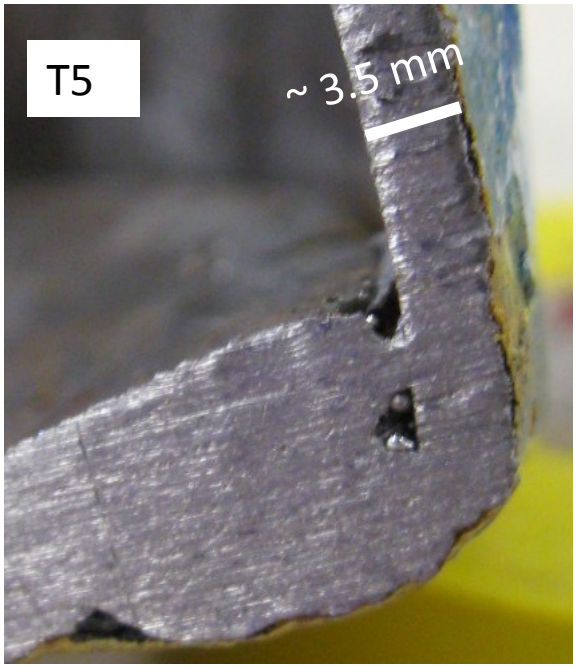
Welds and Flask Construction

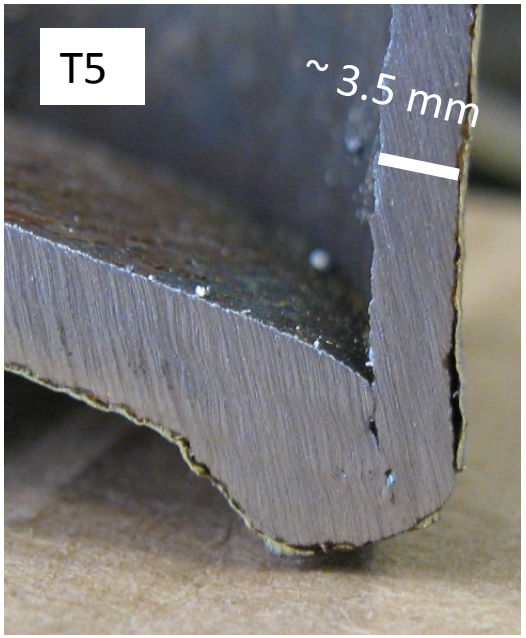












Drum Configuration

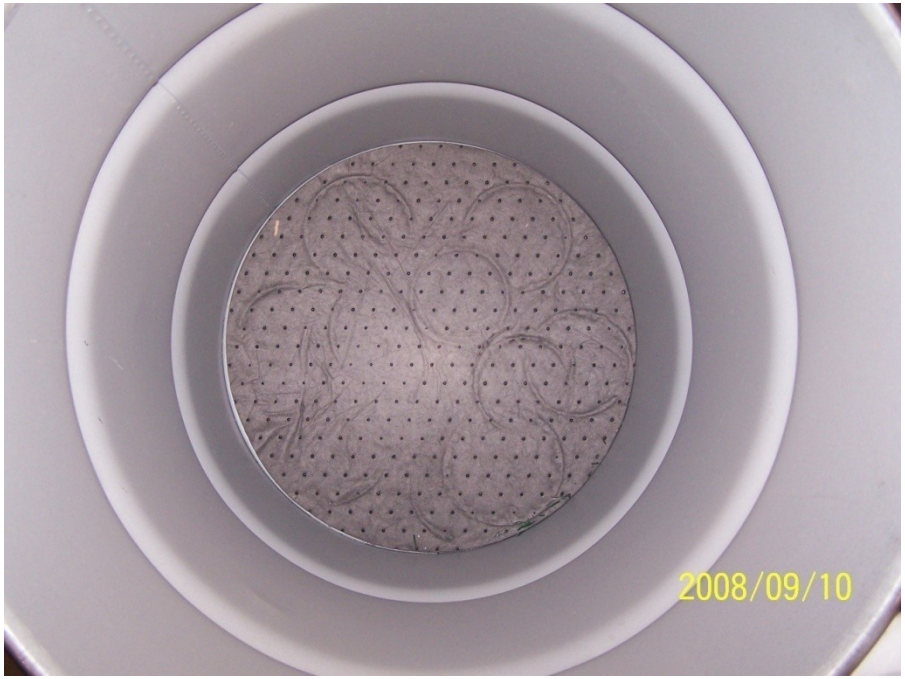
5 drums on a drip pan and a pallet. The drums are banded.

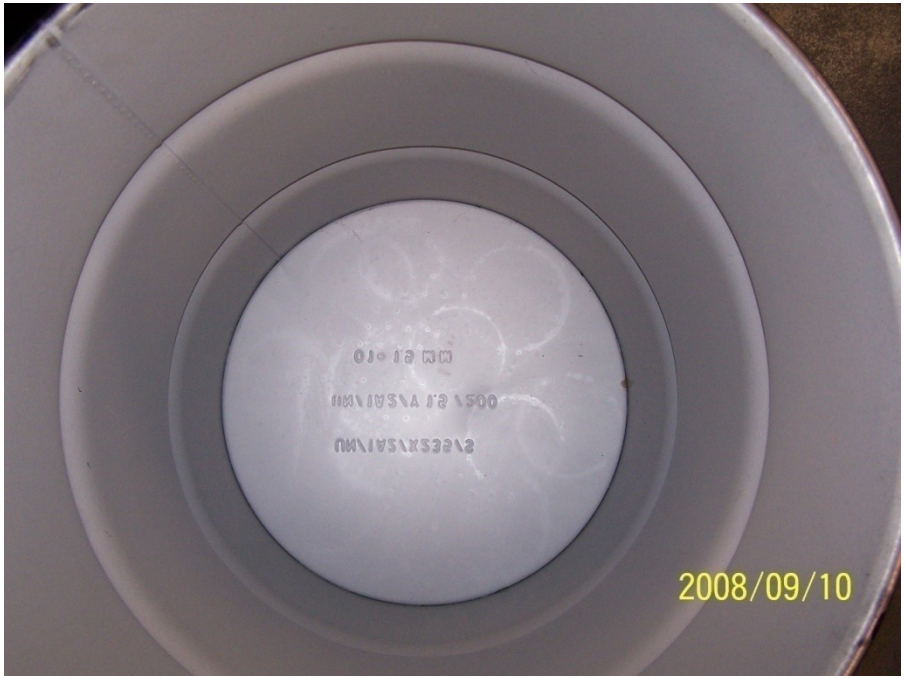
Lid removed – flasks are placed in a sealed drum liner

Inside of Drum Liner

(before and after retrieval of mercury flasks)

Drum Pad and Bottom Inspection





Transfer of a Flask From a Drum

2008/03/26
CESCO-
PHOTOQUIP INC. U.S.

Monitoring of DNSC's Mercury Warehouses

2007 - 2010

- The configuration of the stockpile – flasks stored in airtight drums – limits the presence of mercury vapors in the warehouses
- Following is a report of air monitoring in the DNSC warehouse at New Haven, Indiana. DNSC gave ORNL three years of inspection data from the warehouses at New Haven, Indiana; Somerville, New Jersey; and Warren, Ohio
- The mercury vapor concentrations at New Haven Depot were the highest. Even the highest mercury vapor concentrations measured are much lower than the HWAD action level

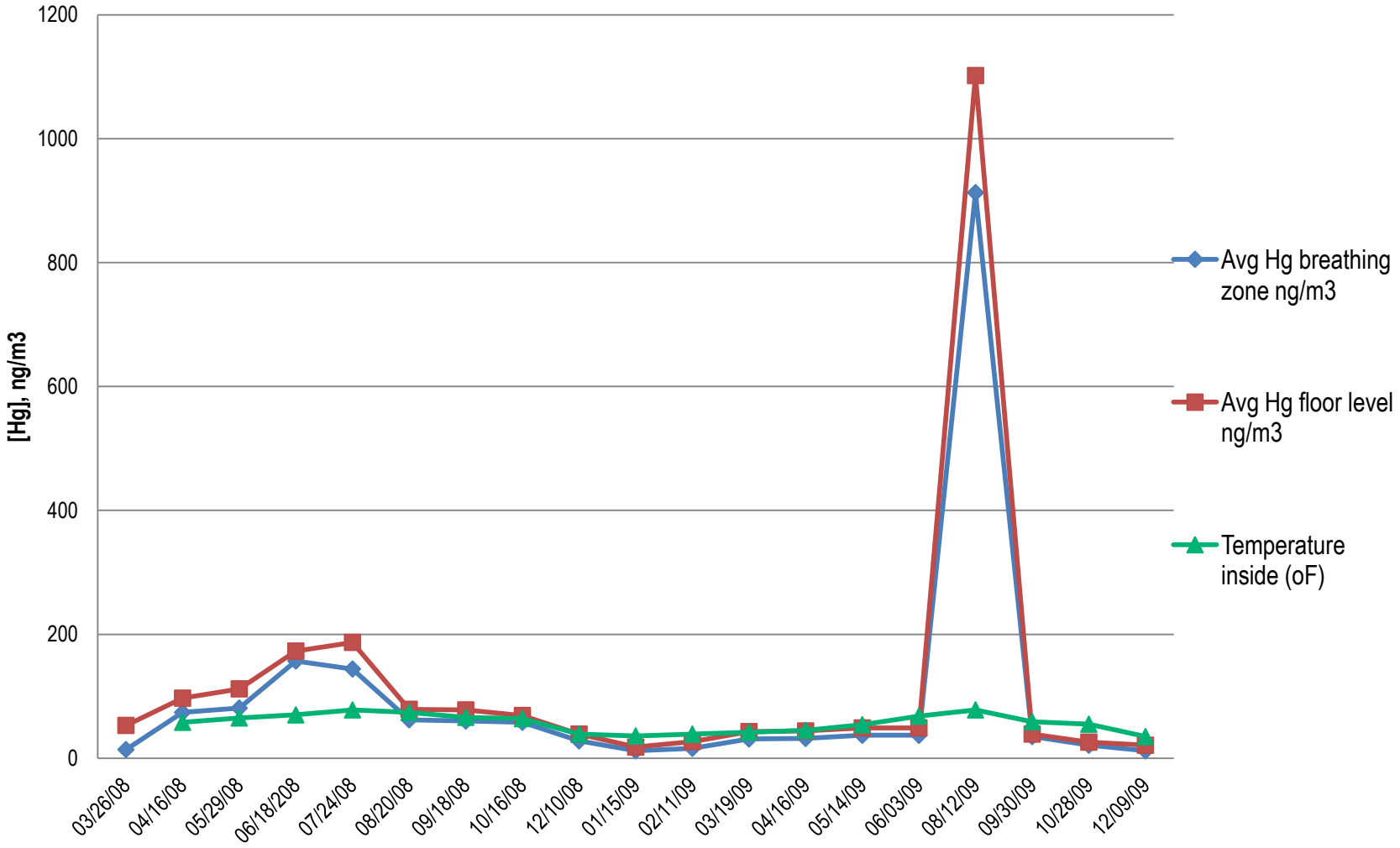
RECORD OF WAREHOUSE INSPECTIONS - New Haven

date	3/26/08	4/16/08	5/29/08	06/18/208	7/24/08	8/20/08	9/18/08	10/16/08	12/10/08
start-end time	nr	7:30 - 14:00	7:30 - 13:30	7:15 - 15:30	7:00 - 13:00	7:15 - 14:30	7:45 - 14:30	7:55 - 14:50	7:55 - 14:30
serial No	164	165	166	167	168	169	170	171	173
warehouse	214	214	214	214	214	214	214	214	214
section	4	4	4	4	4	4	4	4	4
inspector	J. De Renzis	R. Skruck	R. Skruck	R. Skruck	J. De Renzis	R. Skruck	R. Skruck	R. Skruck	R. Skruck
Temperature inside (°F)	nr	58	65	70	78	74	66	64	39
Temperature outside (°F)	nr	55	68	72	89	81	69	63	33
% humidity	nr	61	72	81	nr	57	83	68	71
barometric pressure	nr	30.07	29.93	29.88	nr	30.11	30.23	30.03	29.84
weather	nr	p. cloudy	p. cloudy	p. cloudy	p. cloudy	p. cloudy	clear-cool	cldy-rain	cldy-rain
date calibration Lumex	2/14/08	2/14/08	2/14/08	2/14/08	2/14/08	2/14/08	2/14/08	2/14/08	2/14/08
Lumex serial #		473	473	473	473	473	473	473	473
# reading breathing zone		40	40	40	40	40	40	40	40
Avg Hg breathing zone ng/m^3	min 14	74	81	157	144	62	60	58	28
# reading floor level		40	40	40	40	40	40	40	40
Avg Hg floor level ng/m^3	max 53	97	112	173	187	79	78	69	39
pallets visually inspected		yes	y	y	y	y	y	y	y
drum visually inspected		yes	y	y	y	y	y	y	y
drip pans visually inspected		yes	y	y	y	y	y	y	y
was Hg visible?	no	no	no	no	no	no	no	no	no
intrusion system was armed		yes	y	y	y	y	y	y	y
entry doors locked and sealed		yes	y	y	y	y	y	y	y
seal # on door @ entry		4378	4371	4375	4375	4365	4367	4350	4354
seal # on door @ end work		4377	4372	4376	4376	4366	4368	4351	4355
nb drums counted	2684								
drum computer counted	2693	2693	2693	2693	2693	2693	2693	2693	2693
comment	2691 dr @6 flk 1 dr @ 3 flk 1 dr @ 2 flk 9 drums sent to ORNL	same entries as last inspection	1 dr @ 2flk sent to ORNL all material is stored ready for shipment to HWAD 14 pallets/truck	dr. with 3 flasks was located and marked	same entries as last inspect.	same entries as last inspect.	same entries as last inspect.	same entries as last inspect.	same entries as last inspect.

RECORD OF WAREHOUSE INSPECTIONS - New Haven

date	1/15/09	2/11/09	3/19/09	4/16/09	5/14/09	6/3/09	8/12/09	9/30/09	10/28/09	12/9/09
start-end time	7:55 - 14:30	6:55 - 14:30	7:15 - 16:10	7:15 - 16:00	7:15 - 16:00	7:05 - 16:00	7:30 - 16:00	7:35 - 16:00	7:35 - 16:00	7:340- 16:00
serial No	174	175	176	177	178	179	180	181	182	184
warehouse	214	214	214	214	214	214	214	214	214	214
section	4	4	4	4	4	4	4	4	4	4
inspector	R. Skruck	R. Skruck	R. Skruck	R. Skruck	R. Skruck	R. Skruck	R. Skruck	R. Skruck	R. Skruck	R. Skruck
Temperature inside (°F)	36	39	42	45	54	68	78	59	55	35
Temperature outside (°F)	4	51	62	48	61	73	87	52	58	32
% humidity	79	86	77	91	86	94	90	88	85	81
barometric pressure	30.34	29.88	29.98	29.76	29.98	29.99	29.86	29.92	29.98	29.91
weather	snow- wind	rain 3"-wind	sunny	cldy-rain	cldy-rain	cldy-rain	p. cloudy	wind-rain	cldy-rain	rain - snow
date calibration Lumex	2/14/08	2/14/08	2/19/09	2/19/09	2/19/09	2/19/09	2/19/09	2/19/09	2/19/09	2/19/09
Lumex serial #	473	473	867	473	473	473	473	473	473	867
# reading breathing zone	40	40	40	40	40	40	40	40	40	88
Avg Hg breathing zone ng/m^3	12	16	31	32	37	37	913	35	21	12
# reading floor level	40	40	40	40	40	40	40	40	40	88
Avg Hg floor level ng/m^3	18	27	43	44	49	49	1102	39	26	21
pallets visually inspected	y	y	y	y	y	y	y	y	y	y
drum visually inspected	y	y	y	y	y	y	y	y	y	y
drip pans visually inspected	y	y	y	y	y	y	y	y	y	y
was Hg visible?	no	no	no	no	no	no	no	no	no	no
intrusion system was armed	y	y	y	y	y	y	y	y	y	y
entry doors locked and sealed	y	y	y	y	y	y	y	y	y	y
seal # on door @ entry	4343	4345	4348	7873	7877	4304	4307	4324	4327	4331
seal # on door @ end work	4344	4346	4349	7874	7878	4305	4309	4325	4328	4332
nb drums counted										
drum computer counted	2693	2693	2693	2693	2693	2693	2693	2693	2693	2693
comment	same entries as last inspect.	same entries as last inspect.	same entries as last inspect.	same entries as last inspect.			noted on 05/19/09 very light oxidation on drip pans			Hg staged for shipment and inspection aisle numbers have

Warehouse 214-4 New Haven



Current Storage in DNSC Warehouses

WN - 0061
WN - 0068
CORROSIVE
8
RQ Mercury, UN

WN-1157
RQ Mercury
2809
CORROSIVE
8
1A2/X235/S
1A2/Y1.5/200
01USA/SDCC
CORROSIVE
8

RQ Mercury, UN 2809
RQ Mercury, UN 2809
RQ Mercury, UN 2809
(H) 1A2/X235/S
(H) 1A2/Y1.5/200
01USA/SDCC
WN-379
050
SO# 4486812

Mercury Spill

Discovery of a Spill During a Routine Inspection in a Warehouse

- Contact the emergency response team and try to give them some information on the location and size of the spill
- Secure the building to prevent access by people not involved in the decontamination work
- Follow all procedures relative to mercury spill response
- Monitor the mercury concentration in the breathing zone around the spill and wear appropriate respiratory protection if necessary or use portable local exhaust ventilation. Opening the doors of the building would decrease the mercury concentration

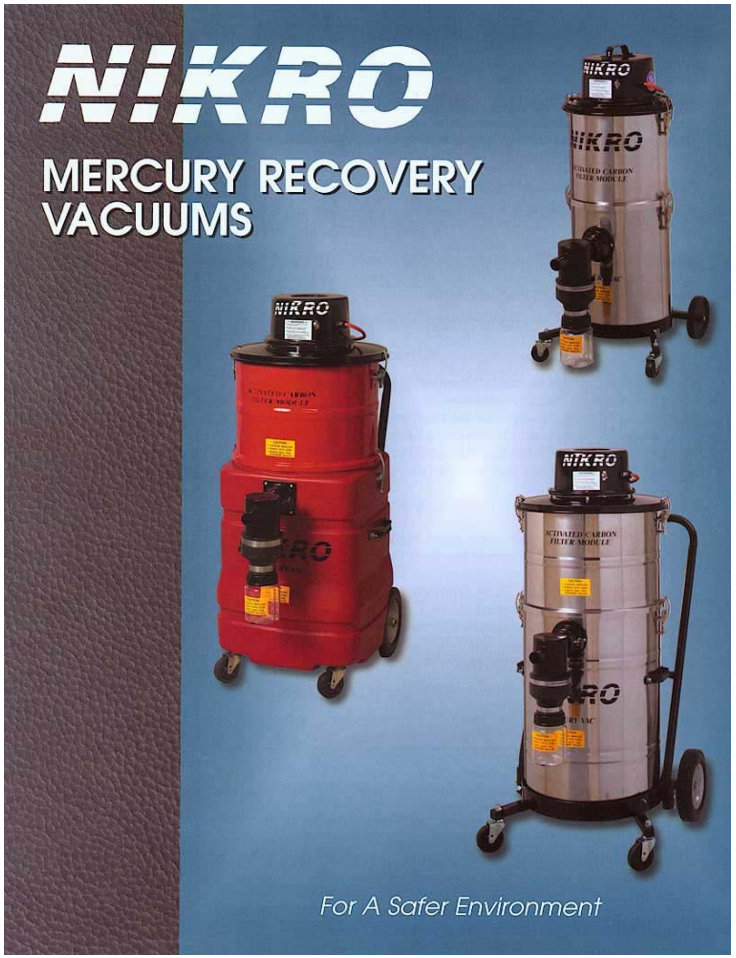
Discovery of a Spill During a Routine Inspection in a Warehouse (cont.)

- Even though the spill has to be removed quickly, do not rush. Prepare a plan of action
- If the spill is on the floor, using a powerful portable light, try to find the limits of the spread mercury. Wear shoe covers to prevent spreading the contamination outside the marked area
- Secure and mark a large area around the spill location. Mercury travels far when falling
- Depending on the size of the spill, the emergency response team will use one of the possible decontamination methods
- Set up a satellite accumulation area near the decontamination zone

Appropriate Safety Equipment and Clothing Includes

- Respirators, spare canisters and parts; half face respirator using dual cartridges approved for mercury by the National Institute for Occupational Safety and Health (NIOSH)
- Impervious type coveralls (TYVEX) with hoods and booties
- Nitrile gloves
- American National Standards Institute (ANSI) approved safety shoes
- Safety goggles or glasses with side shields
- Shoe covers
- Mercury monitoring equipment
- Mercury decontamination products and/or kit
- Mercury high efficiency vacuums
- Aspirator bottles
- Appropriate containers, labels
- Duct tape, plastic bags
- Waste disposal containers for any mercury contaminated waste generated during the cleanup operation

Mercury Recovery Vacuums



Recommendations for the Spill Response Team

- Physically remove all visible mercury using an approved mercury-specific vacuum. If elemental mercury is still visible, an eyedropper, duct tape, or other suitable technique may be used to recover the rest of the mercury
- Wash the affected area with a mercury vapor suppression solution, such as HgX®. A HgX® solution can convert low levels of mercury contamination into a nonhazardous inorganic salt. Leave the solution in place for about 24 hours before removing it
- Check the mercury concentration in the air just above the spill area. Using a powerful light, ensure that no small mercury droplets are left. If the concentration of mercury above the floor is still too high, clean the floor again with HgX® and recheck with the mercury vapor analyzer

Useful Tips

- Remove all jewelry prior to starting decontamination
- It is usually easier to see the mercury droplets when using a powerful light to illuminate from the side rather than from directly overhead
- The smallest microdroplets may elude capture with a vacuum or an eyedropper. Use a metal spatula to join small microdroplets together. Use an eyedropper to collect the large mercury microdroplets. Alternatively wrap duct tape around three fingers (sticky side out) and carefully use it to pick up any remaining microdroplets. Place the contaminated tape in the waste container
- The personnel directly engaged in the cleanup and decontamination operation shall thoroughly wash, shower at the end of the shift, and change clothes

Additional Sources of Information

DLA/DNSC Mercury Reports Published as ORNL/TMs

ORNL/TM-2008/074, Special Testing of Type 5 Mercury Flasks, J. W. Terry et al., June 2008

ORNL/TM-2009/001, DNSC Mercury Stockpile Inventory Definition Report, J. W. Terry et al., February 2009

ORNL/TM-2009/002, Drum Characterization for the DNSC Mercury Stockpile, T. D. Hylton et al., April 2009

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ORNL/TM-2009/004, Evaluation of Steel Flasks for Long-Term Storage of Elemental Mercury: Chemical Compatibility and Metallographic Assessment, S. J. Pawel and H. F. Longmire, April 2009

ORNL/TM-2009/005, Laser Scanning of Flasks in the DNSC Mercury Stockpile, V. K. Varma and A. M. Aaron, August 2009

ORNL/TM-2009/010, Mercury Stockpile Stewardship Program—Phase 2: Executive Summary, W. H. Hermes et al., December 2009

ORNL/TM-2009/131, Analysis of Storage Options for the Mercury Stockpile Stewardship Program, A. J. Carroll et al., November 2009

DLA/DNSC Mercury Reports Published as White Papers (MSSP series)

MSSP-01, *Test Plan for the Evaluation of the Integrity –During Long Term Storage – of Mercury Flasks from the DLA/DNSC National Stockpile – Phase II* , C. H. Mattus, May 30, 2008

MSSP-02, *Drum Characterization Test Plan,* T. D. Hylton, May 30, 2008

MSSP-03, *Interpreting Mercury Concentrations in Drum Head Spaces,* L. N. McCold, July 2008

MSSP-04, *Cost Estimation for HWAD Layout Options Upon Receipt at Dock,* A. J. Carroll, March 2009

MSSP-05, *Vibration Testing of a 30-Gallon Drum Containing Six Mercury Flasks,* A. J. Carroll, M. R. Feldman, and D. R. Giuliano, December 2009

MSSP-06, *Drum and Packaging Condition,* J. W. Terry et al., July 2008

MSSP-07, *Plug Leak Rate Testing and Flask Sealant Selection (A. M. Aaron,* P. T. Spampinato, and J. M. Pryor) August 2009

MSSP-08, *Review of Real Time Radiography as a Drum Inspection Method,* A. M. Aaron et al., August 2009

MSSP-09, *DLA/DNSC Mercury Container Specifications,* A. J. Carroll et al., August 2009

MSSP-10, *Guidance for Container Handling and Mercury Transfer in a Laboratory Setting,* P. T. Spampinato et al., August 2009

MSSP-11, *New Flask Cutting (P. T. Spampinato and W. Hermes) September 2009*

DLA/DNSC Mercury Reports Published as White Papers (MSSP series)

MSSP-12, *Analyzer Assessment,* (Appendix B to MSSP-15), T. D. Hylton October 2009

MSSP-13, *Review of Spill Clean Up Methods and Waste Disposal,* C. H. Mattus, August 2009

MSSP-14, *Review of Double Stacking Pallets as a Mercury Storage Method,*

A. M. Aaron, August 2009

MSSP-15, *DNSC Mercury Stockpile: Warehouse, Drum, and Flask Monitoring and Inspection Requirements Plan, T. D. Hylton et al.,* October 2009 (updated)

MSSP-16, *Surface Microbeads on Drums,* C. H. Mattus, October 2009

MSSP-17, *Data Acquisition, Analysis, and Trending,* J. W. Terry et al., December 2009

MSSP-18, *Evaluation of Mercury Flasks Being Used as a Non-Specification Packaging,* Mark Hawk et al., September 2009

MSSP-19, *DLA/DNSC Mercury Stockpile Stewardship Project – Phase 2 Closure: Final Drum Closure, Waste Disposal, and Equipment Shipment to HWAD,* P. T. Spampinato et al., September 2009

MSSP-20, *Drum Compression Testing,* T. D. Hylton et al., August 2009

MSSP-21, *Elemental Mercury Simplified Vapor Pressure and Storage Emission Models,* T. D. Hylton, W. H. Hermes, and J. W. Terry, September 2009

MSSP-22, *Mercury Transfer Options – Design Methodology and Scale Considerations,* A. J. Carroll et al., November 2009

Web Sites for Additional Information

http://ndep.nv.gov/mercury/index.htm

http://www.epa.gov/mercury/spills/index.htm

http://www.cdc.gov/niosh/ershdb/EmergencyResponseCard_29750021.html

http://www.chem.unep.ch/mercury/default.htm

http://www.zeromercury.org/

http://www.epa.gov/mercury/stocks/

http://www.mercury2006.org/

https://www.dnsc.dla.mil/eis/

SOC CAPP Orientation for the Mercury Repackaging Project

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