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Chemical Technology Division

Mixed Waste Focus Area Mercury Working Group: An Integrated Approach to Mercury Waste Treatment and Disposal

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ABSTRACT

In May 1996, the U.S. Department of Energy (DOE) Mixed Waste Focus Area (MWFA) initiated the Mercury Working Group (HgWG). The HgWG was established to address and resolve the issues associated with mercury-contaminated mixed wastes. During the MWFA's initial technical baseline development process, three of the top four technology deficiencies identified were related to the need for amalgamation, stabilization, and separation/removal technologies for the treatment of mercury and mercury-contaminated mixed waste. The HgWG is assisting the MWFA in soliciting, identifying, initiating, and managing efforts to address these areas.

The focus of the HgWG is to better establish the mercury-related treatment technologies at the DOE sites, refine the MWFA technical baseline as it relates to mercury treatment, and make recommendations to the MWFA on how to most effectively address these needs. Based on the scope and magnitude of the mercury mixed waste problem, as defined by HgWG, solicitations and contract awards have been made to the private sector to demonstrate both the amalgamation and stabilization processes using actual mixed wastes. Development efforts are currently being funded that will address DOE's needs for separation/removal processes. This paper discusses the technology selection process, development activities, and the accomplishments of the HgWG to date through these various activities.

BACKGROUND AND OVERVIEW

Mercury in various elemental and speciated forms is present in numerous U.S. Department of Energy (DOE) mixed waste (MW)* streams. In 1996, over 38,000 m^3 of mixed low-level and transuranic waste containing mercury had been inventoried in the DOE complex. The locations of sites that make up the DOE Complex are shown in Fig. 1. DOE's MW, like its low-level radioactive waste (LLW), is generated by various institutions and facilities that use radioactive materials, including (1) nuclear power plants; (2) defense, energy, medical, and other research laboratories and reactors; (3) industrial plants and laboratories; and (4) decommissioning and remedial actions. The waste takes a variety of forms, such as medical treatment and research materials, contaminated wiping rags and paper towels, used filters and filter sludge, protective clothing, hand tools, equipment, parts of decommissioned nuclear power plants, and so forth. This study is concerned with LLW that is or contains mercury. Since mercury is an EPA-listed hazardous constituent, LLW that contains mercury is actually mixed waste.

This paper discusses the technology selection process, HgWG technology development activities, and the accomplishments of the HgWG to date in addressing treatment technology development needs for mercury-contaminated mixed waste.

*Mixed waste is waste that contains both hazardous chemical components, subject to the requirements of the Resource Conservation and Recovery Act (RCRA), and radioactive components, subject to the requirements of the Atomic Energy Act.

THE MIXED WASTE FOCUS AREA

The Mixed Waste Focus Area (MWFA), a program management function of DOE, has documented the needs delineated by each of the DOE sites in the MWFA Integrated Technical Baseline Report. The MWFA is responsible for providing acceptable technologies to implement mixed waste treatment systems. The U.S. Environmental Protection Agency (EPA), U.S. Nuclear Regulatory Commission (NRC), and DOE share responsibility for mixed waste and so must work together to streamline its regulation and resolve conflicts among federal regulations. The Federal Facilities Compliance Act, passed by Congress in 1992, requires EPA to develop treatment requirements for mixed waste. Under the Federal Facilities Agreement, DOE is committed to develop plans and deploy facilities to treat its mixed wastes.

Since its inception, the MWFA has brought a national focus to DOE's mixed waste problem. Previously, each of the 48 sites where DOE stores mixed waste worked to develop its own cleanup technologies independent of the other sites. Now, the MWFA consolidates technology development at a national level within one organization, with individual sites as customers. The focus area has been described as a team composed of the problem holders in the DOE Office of Waste Management (EM-30) and the technology developers in the DOE Office of Science and Technology (EM-50).

Place Fig. 1 here.

THE MERCURY WORKING GROUP

The MWFA established the Mercury Working Group (HgWG) in May 1996 to address and resolve issues associated with mercury and mercury-contaminated mixed wastes. The primary goals of the HgWG are to help establish strategy and coordinate technology development. The HgWG seeks to better establish mercury-related treatment needs at DOE sites, refine the technical baseline as it relates to mercury waste treatment, and make recommendations to the MWFA on effective means to address these needs. To that end, HgWG membership includes representatives from sites with the largest mercury-contaminated mixed waste inventories. These sites include the Oak Ridge Reservation [East Tennessee Technology Park (formerly the K-25 Site), Oak Ridge National Laboratory, and the Y-12 Plant], Savannah River Site (SRS), Rocky Flats Environmental Technology Site (RFETS), and Idaho National Engineering and Environmental Laboratory (INEEL).

During the initial technical baseline development process, three of the top four MWFA technology deficiencies identified across the DOE complex were related to the need for amalgamation, stabilization, and separation/removal technologies for mercury and mercury-contaminated mixed waste. Working through a "Unique Wastes Waste-Type Manager," the HgWG assists the MWFA in soliciting, identifying, initiating, and managing efforts to address technology development needs.

From its inception, the mission of the HgWG has been to develop a thorough understanding of the physical and chemical characteristics of mercury-contaminated mixed waste throughout the DOE Complex. Often, the greatest barrier in the establishment of a path forward to disposition for waste is the lack of information about the waste. Hence, the initial strategy of the HgWG has been to work towards understanding mercury-contaminated waste and verifying inventories across the DOE Complex.

Armed with a greatly improved understanding of the waste streams across the DOE Complex, the HgWG has worked to sponsor private-sector technology demonstrations. The demonstrations are intended for application to as a broad a range of actual wastes as practicable. It is anticipated that the results of

HgWG-sponsored technology demonstrations will include two important accomplishments. First, the technology capabilities of the private sector will be defined. Second, the demonstrations will provide defensible cost and performance data that will be essential in addressing treatment needs.

TECHNICAL BASELINE AND DEFICIENCIES

In 1996, the MWFA established a technical baseline for determining technology development activities to be supported by the MWFA. This baseline is revised each year to reflect changes in DOE's strategies for mixed waste management, changes in the technical baseline development process, and MWFA accomplishments. The published technical baseline report (Ref. 1) presents a process for technology development management and a prioritized list of deficiencies—those mixed waste treatment technology needs that the MWFA will address. One HgWG function is to assist the MWFA by providing input to the technical baseline development process for mercury waste.

The technical baseline development process identified two dozen deficiencies for mixed waste management, including three which serve as the focus for the HgWG. These three deficiencies, which set the priorities for mercury-related technology development in the working group, are shown in Table I and are described in greater detail in Ref. 1. These three priority deficiencies were initially ranked among the top four deficiencies identified in the technical baseline development process and emphasize the need for technologies to treat mercury waste and waste contaminated with mercury.

Place Table I here.

DEFINING THE SCOPE OF THE PROBLEM

Mercury, in various elemental and speciated forms, is present in numerous DOE mixed waste streams. In 1996, over 38,000 m^3 of mixed low-level and transuranic waste containing mercury were identified in the DOE complex. Traditionally, mercury has been one of the most difficult contaminants to stabilize in hazardous or mixed waste. Portland cement does not directly stabilize either elemental mercury or mercury salts, and high-temperature techniques such as incineration and vitrification will volatilize mercury, producing off-gases that are dangerous to workers. Even at lower temperatures, such as those used in sulfur polymer cement (SPC), encapsulation can volatilize mercury contaminants. Thus, the volatility of mercury poses a challenge for mercury waste treatment technologies.

The RCRA defines several categories of mercury wastes (40 CFR 268.40), each with a defined technology-based treatment standard, or a Universal Treatment Standard (UTS). For non-wastewaters with mercury concentrations at or above 260 mg/kg (ppm) and RCRA-regulated organic contaminants (other than incinerator residues), incineration (IMERC) or retorting (RMERC) is the identified treatment standard. For non-wastewaters with mercury concentrations at or above 260 ppm that are inorganic, including incinerator and retort residues, RMERC is the identified treatment standard. Amalgamation (AMLGM) is identified as the treatment standard for elemental mercury. However, mercury condensates from RMERC processes also require amalgamation. Residues from IMERC processes with contamination levels at or above 260 ppm of mercury will require RMERC, followed by AMLGM of the condensate. IMERC residues with less than 260 ppm will also require some form of stabilization

(e.g., SPC) to meet the RCRA Toxicity Characteristic Leaching Procedure (TCLP)* limit for mercury of 0.20 mg/l.

DEVELOPING TECHNOLOGY SOLUTIONS

The technology development path from requirements to commercially viable technology for each identified deficiency may be complex and multifaceted based on the number of requirements, the variety of waste media to be treated, and the number and amount of different radiological contaminants and hazardous co-contaminants in the waste. The existence of different customer criteria at different sites combined with different stakeholder issues, varying regulatory concerns, and inconsistent final waste form disposal requirements further complicate the technology development path for deficiency resolution. Hence, parallel technology development paths are sometimes needed to ensure that all requirements are satisfied and the optimal (end-user serving and cost-effective) solutions are advanced through the various stages of development, deployment, and commercialization. The overall MWFA technology development path is discussed more in the technical baseline report (Ref. 1).

The development path for a particular deficiency or group of related deficiencies is managed by the MWFA through a document known as the Development Plan. The Development Plan for mercury (Ref. 2) defines the approach to addressing deficiencies associated with the treatment and stabilization of mixed wastes consisting of or containing mercury.

HGWG TECHNOLOGY DEVELOPMENT ACTIVITIES

Several development activities have been initiated or are planned by the HgWG to resolve the deficiencies related to mercury and mercury-containing waste (Table I). These activities were selected based on the deficiency requirements and the need to provide the best opportunity for equipping the end users with optimized, cost-effective technology alternatives within their respective schedule constraints. Activities now under way focus on the execution of a series of demonstrations for amalgamation and stabilization, in addition to efforts to improve understanding of the depth and extent of mercury contamination within the DOE Complex. Work sponsored in the area of separations is currently limited to tracking the progress of demonstrations and studies funded elsewhere.

Mercury Amalgamation

Table II lists development activities, schedule, and current status for amalgamation technologies sponsored by the HgWG. As indicated in Table II, contracts have been let for mercury amalgamation demonstrations to two private firms: Nuclear Fuels Services (NFS) in Erwin, Tennessee, and ADA Technologies in Englewood, Colorado. Quantities of elemental mercury from six different sites will be used for these demonstrations. NFS will process waste from INEEL, the East Tennessee Technology Park, and SRS. ADA will process wastes from Fernald, Lawrence Berkeley National Laboratory (LBNL), and Lawrence Livermore National Laboratory (LLNL). These demonstrations are expected to eliminate at least four Mixed Waste Inventory Report (MWIR) streams (Ref. 3) while presenting the subcontractors with the broad range of expected co-contaminants to challenge their processes.

Place Table II here.

*This procedure (TCLP) is described in Method 1311 of U.S. Environmental Protection Agency (EPA) Publication SW-846.

Mercury Stabilization

Table III lists HgWG development activities, schedule, and current status for stabilization technology development activities, similar to Table II for amalgamation. Wastes for demonstrations of stabilization technologies were selected in June 1997. Contracts have been let to NFS, International Technologies in Oak Ridge, Tennessee, and Allied Technology Group in Fremont, California.

Place Table III here.

The waste streams selected for these demonstrations are an ion-exchange resin from Portsmouth and a sludge from Los Alamos. The test plans have been received and commented on.

Inventory Evaluation and Update

The contract award process has been significantly impeded by incorrect and missing information for waste streams nationwide. Information listed in the MWIR for mercury-contaminated wastes was greatly improved as part of the HgWG activities. Table IV summarizes inventory information on mercury and mercury-contaminated mixed waste for the DOE Complex before and after HgWG activities. As a result of working group efforts, the amount of waste that must actually be dealt with was reduced by a factor of about 3. Likewise, the amount of waste that could not be categorized was reduced by a factor of about 5.

Place Table IV here.

Stabilization Demonstrations with High-Mercury Waste

Heretofore, most sites have not pursued the stabilization of highly contaminated mercury debris because of the misconception that since there is a Best Demonstrated Available Technology (BDAT) standard for wastes with mercury at concentrations $\geq$260 ppm, the alternate debris treatment standards (under the Debris Rule) could not be utilized. Clarification of this issue has been received from EPA, indicating that the intent was to exclude only those waste codes (technologies) specifically listed in the preamble to the Debris Rule's promulgation—not all that had BDAT standards. The stabilization of debris at with mercury concentrations $\geq$260 ppm has not been accomplished beyond the bench scale. This activity will demonstrate the stabilization of high-mercury waste and set the precedent for other DOE sites to follow.

As mentioned previously, wastes (not debris) contaminated with mercury at concentrations $\geq$260 ppm are subject to treatment by one of the two designated BDATs, IMERC or RMERC. In meetings with EPA personnel responsible for rewriting the RCRA regulations associated with mercury, they have made it clear that they are very interested in increasing the contamination level at which these prescribed technologies/processes must be used. One of the major impediments to this change is a lack of performance data on stabilization of wastes at concentrations >>260 ppm. The HgWG intends to work with the EPA to provide some of the needed data.

Future Activities of the HgWG

Development and demonstration activities for mercury and mercury-contaminated waste are ongoing. Future activities may be summarized as follows:

- Continue characterization and evaluation of mercury wastes
- Complete amalgamation demonstrations (elemental mercury), testing, evaluation, and reporting
- Complete stabilization demonstrations (<260 ppm mercury), testing, evaluation, and reporting
- Continue to work with EPA to develop stabilization standards for high-mercury waste (>260 ppm) waste
- Initiate demonstrations for stabilization of high-mercury wastes

SUMMARY AND CONCLUSIONS

The first task of the HgWG was to develop a thorough understanding of the physical and chemical characteristics of the mercury-contaminated mixed wastes throughout the DOE complex. This task has achieved significant results to date. Over the past year, estimates of the amount of waste to be treated have been refined based on improved information gathered by the HgWG to eliminate two-thirds of the previous mercury waste inventory. The planned treatment for these wastes is now better understood. The HgWG continues to work with site representatives to identify and understand technology development needs for each site, focusing on those sites with the most mercury contaminated mixed wastes, with representatives on the HgWG. The HgWG will also work with sites having less inventory so as to maximize the effectiveness of efforts to address mercury-related needs across the DOE Complex.

The HgWG, with a more thorough understanding of the DOE Complex needs, has enabled the MWFA to begin addressing these needs. This has been accomplished through two primary mechanisms: (1) Requests for Proposals (RFPs) to industry for amalgamation, stabilization, and separation/removal technologies and (2) Calls for Proposals (CFPs) to DOE for mercury separation/removal technologies. The CFP was issued in July 1996, and responses are currently being reviewed and evaluated. The HgWG prepared an announcement published in the *Commerce Business Daily* (CBD) in July 1996 soliciting interest from the private sector for participation in the upcoming RFP. Nearly 50 expressions of interest were received by the HgWG.

This course of action was determined based on the responses received from a Request for Information (RFI) related to the three primary mercury technology needs. RFI responses indicated that the technical bases exist in private industry to treat, at or near the production scale, those mercury-contaminated wastes that would require stabilization or amalgamation. Demonstrations of specific related technologies planned or now under way serve as the venue through which the technical bases will be applied to the unique problems associated with the DOE Complex mercury-contaminated mixed waste. Demonstrations have been identified and have either been initiated within the past year or will be initiated during the coming year. Demonstrations are at a sufficiently large scale to assist smooth, timely transition of the successful processes to production readiness for implementation as available treatment systems for applicable DOE wastes.

RFI responses also indicated that mercury separation/removal is a technology area that still requires the efforts of the research and development community within both DOE and the private sector. Consequently, in addition to the RFP, a CFP for mercury separation/removal technologies was issued in July 1996, which has led to plans for future demonstrations.

The HgWG is handling the procurement actions associated with these demonstrations and coordination with the affected sites. In addition, research and development activities initiated through other efforts that have an impact on meeting DOE Complex needs related to mercury-contaminated mixed waste are also administered and coordinated for the MWFA by the HgWG. In short, the HgWG provides the

central focal point for all MWFA mercury-related technology development activities, thus ensuring thatthe deficiencies are adequately defined, needs are effectively addressed, duplicative efforts are eliminated, and that DOE sites can attain full regulatory compliance relative to mercury-contaminated mixed waste.

REFERENCES

1. "Mixed Waste Focus Area Integrated Technical Baseline Report, Phase 1," Volume 1, DOE/ID-10524, Revision 0, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho (January 16, 1996).

2. I. W. OSBORNE-LEE, "Mercury and Mercury-Containing Waste Technology Development Plan," Oak Ridge National Laboratory, Oak Ridge, Tennessee (in preparation).

3. U.S. Department of Energy, "Interim Mixed Waste Inventory Report: Waste Streams,Treatment Capacities, and Technologies," DOE/NBM-1100, Washington, D.C. (April 1993).

Table I. Prioritized list of technology deficiencies for mercury and mercury-contaminated wastes

Activity	Description
1. Mercury Stabilization (MWFA priority 2)	Toxic metal contaminants regulated under the Resource Conservation and Recovery Act (RCRA) contained in mixed wastes require removal or stabilization to control solubility under the conditions of the Toxic Characteristic Leach Procedure (TCLP) before the wastes can be disposed of. Under RCRA, mercury at contamination levels less than 260 ppm (<260 ppm requires retorting) require stabilization to control mercury solubility to the Universal Treatment Standards (<0.2 ppm). Verification of treatment (i.e., penetrating the entire matrix and stabilizing essentially all of the mercury in the system) is required.
2. Mercury Separation/ Removal (MWFA priority 7)	The presence of mercury complicates the design of off-gas systems, stabilization of residuals, and monitoring of all effluents. It may be advantageous to remove the mercury as a pretreatment to simplify downstream operations. New techniques must be developed to remove (physically or chemically) the mercury for separate stabilization. Waste matrices from which mercury separation may be required include soil, all types of process residues or sludges and particulate materials, and debris. Processing methods must ensure adequate removal and include measuring and monitoring methods to control and verify the process.
3. Mercury Amalgamation (MWFA priority 8)	Elemental mercury may be derived as a product of retorting high-mercury (>260 ppm) wastes or recovered from the off-gas of a thermal treatment unit, in addition to the elemental mercury streams in the DOE mixed waste inventory. Radioactive mercury can probably not be completely purified and verified for recycle. Disposal of the mercury will require amalgamation to form a stable, insoluble product for disposal. Methods and equipment designs are required for amalgamating bulk nonrecyclable mercury.

Table II. HgWG activities to address priority technology deficiencies for mercury and mercury-contaminated wastes requiring amalgamation

Date	Activity	Status
July 1996	*Commerce Business Daily* announcement for scoping demonstrations for the three priority deficiencies.	40 responses received
November 1996	Issued requests for proposals (RFPs) and statements of work (SOWs) for mercury amalgamation treatment	2 vendor responses (Nuclear Fuel Services and ADA Technologies)
February 1997	Waste streams selection	Streams selected
April 1997	Award of contracts to treat six different elemental mercury waste streams from five DOE sites	Contracts awarded to both vendors
June to July 1997	Mercury amalgamation vendor test plan evaluation	Test plans received from vendor
November 1997	Delivery of wastes to both vendors	Wastes already delivered to first vendor
October to December 1997	Amalgamation testing	On schedule for completion
June 1998	Technical Progress Report (TPR)	Scheduled for completion

Table III. HgWG activities to address priority technology deficiencies for mercury and mercury-contaminated wastes < 260 ppm requiring stabilization

Date	Activity	Status
November 1996	Issuance of stabilization demonstrations RFP and SOW	5 vendor responses received
March 1997	Waste stream selection	Initial selections attempted
June 1997	Waste stream selection	Selection completed
August 1997	Award of contracts to treat two waste streams, each from a different DOE site	Contracts awarded to three vendors
December 1997	Delivery of wastes to vendors	On schedule for completion
January to March 1998	Stabilization testing	Scheduled for completion
September 1998	TPR	Scheduled for completion

Table IV. HgWG inventory evaluation for mercury and mercury-contaminated mixed waste

Type of Mercury waste stream	Inventory (m^3) in April 1997	Inventory (m^3) in August 1997
Elemental	12	17
Less than 260 ppm	20,067	6,016
Not less than 260 ppm	120	325
Unknown	9,736	925
Total	**29,935**	**7,283**

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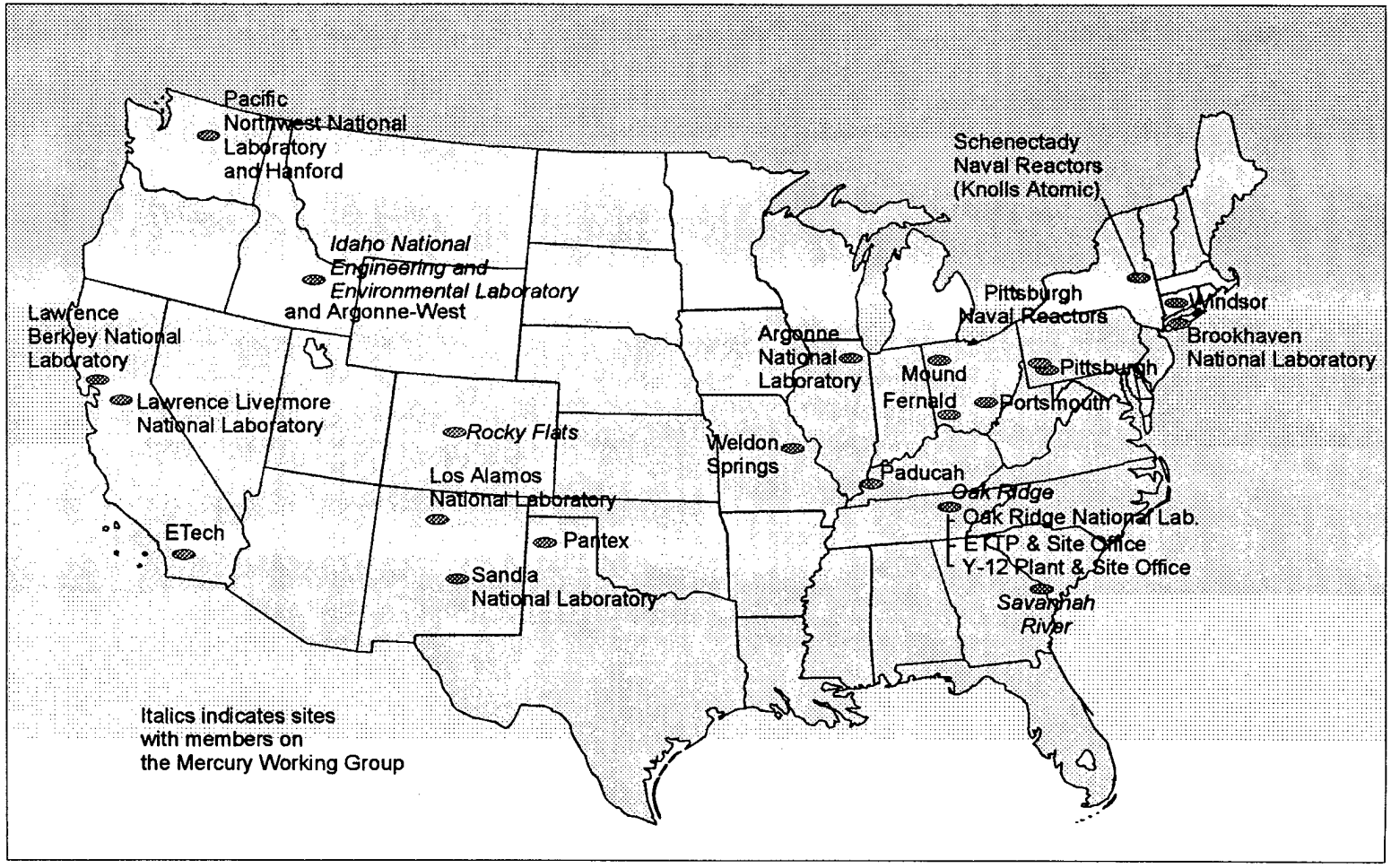

Fig. 1. U. S. Department of Energy facilities with mercury-contaminated mixed wastes.

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