Y-12

**OAK RIDGE
Y-12
PLANT**

MARTIN MARIETTA

**Y-12 Plant Decontamination and
Decommissioning Technology
Logic Diagram for
Building 9201-4**

**Volume 3
Technology Evaluation Data Sheets**

**Part A
Characterization - Dismantlement**

September 1994

Prepared for the Office of
Environmental Restoration

Prepared by
Oak Ridge K-25 Site
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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ACKNOWLEDGMENTS

John M. Googin, a member of the Senior Advisory Group, was a significant contributor to this Technology Logic Diagram project before his death this year. We feel it appropriate to express our appreciation of him and our sense of loss. His insightful comments at project meetings never failed to enliven the discussions and guide our thinking.

The authors acknowledge the significant contributions made by the DOE Overview Team for the Technology Logic Diagram Review and Development: Robert Benedetti, Holmer Dugger, Mitchell Erickson, Ned Hutchins, William Schutte, and Randall Snipes.

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FOREWORD

The *Y-12 Plant Decontamination and Decommissioning Technology Logic Diagram for Building 9201-4* (TLD) was developed to provide a decision-support tool that relates decontamination and decommissioning (D&D) problems at Bldg. 9201-4 to potential technologies that can remediate these problems. The TLD uses information from the *Strategic Roadmap for the Oak Ridge Reservation*, the *Oak Ridge K-25 Site Technology Logic Diagram*, the *Oak Ridge National Laboratory Technology Logic Diagram*, and a previous Hanford logic diagram.

This TLD identifies the research, development, demonstration, testing, and evaluation needed for sufficient development of these technologies to allow for technology transfer and application to D&D and waste management (WM) activities. It is essential that follow-on engineering studies be conducted to build on the output of this project. These studies will begin by selecting the most promising technologies identified in the TLD and by finding an optimum mix of technologies that will provide a socially acceptable balance between cost and risk.

The TLD consists of three fundamentally separate volumes: Vol. 1 (*Technology Evaluation*), Vol. 2 (*Technology Logic Diagram*), and Vol. 3 (*Technology Evaluation Data Sheets*). Volume 1 presents an overview of the TLD, an explanation of the program-specific responsibilities, a review of identified technologies, and the rankings of remedial technologies. Volume 2 contains the logic linkages among environmental management goals, environmental problems, and the various technologies that have the potential to solve these problems. Volume 3 contains the TLD data sheets.

Volume 3 has been divided into five sections comprising two parts. Volume 3, Part A, consists of the characterization and dismantlement data sheets. Volume 3, Part B, consists of the decontamination, robotics/automation, and WM data sheets. Data sheets are arranged alphanumerically.

The technology evaluations contained in these volumes are based on the best information available during compilation of the TLD. New or more accurate information is solicited to improve the TLD data base. Please send comments to R. L. Fellows, Editor, *Y-12 Plant Decontamination and Decommissioning Technology Logic Diagram for Building 9201-4*, Martin Marietta Energy Systems, Inc., P.O. Box 2003, Oak Ridge, TN 37831-7274. FAX 615-576-8558.

CHARACTERIZATION

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Electron spectroscopy for chemical analysis (ESCA). A surface technique that operates using the photoelectric effect. Electrons are ejected from the core of the atom with kinetic energies specific to the element. Chemical shifts in energy add information about the chemical state of the element. Some chemical bonding information is provided.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, CrO₄, Hg, Pb, ...)

Waste produced—About a 5-mg sample is required. Sample and sample holder become waste.

Overall cost— \$200–\$600/sample

Efficacy/strengths—Elemental and chemical state information from the outermost surface material (<10 nm) provide information about contaminant attachment and bonding mechanism. This is a mature technology. Provides semiquant surface elemental analysis, some chemical information.

Weaknesses—Not very sensitive (~1%). Sample size limited. Throughput low. Some instruments can examine small spots of a sample.

Science/Technology Needs: Model studies are needed to identify binding energies for standard compounds of technetium and uranium for suspected matrices.

Implementation Needs: Instrumentation and personnel currently exist at ORNL, K-25 Site, and Y-12 Plant. Capital costs, >\$200K.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. A. Basford/615-576-4337, J. C. Franklin/615-574-2284, and N. J. Williams/615-574-0952.

Reference:

1. F. J. Gruthaner, *MRS Bulletin* **12**(6), 60-63 (1987).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Auger electron spectroscopy (AES). A surface characterization technique with high spatial resolution. An electron beam is used to eject primary electrons. The auger electrons are ejected by the cascade effect. An electron energy system is used to measure the kinetic energy of the electron, which is elementally specific.

Status: Accepted. This technology is the same as XPS (ESCA) but mapping of sample surface or studying of small spot possible.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, CrO₄, Hg, Pb,...); Al₁Mg₁ alloys (Co-Ni)

Waste produced—About a 5-mg sample is required. Sample preparation varies from none to extensive. Sample and sample holder become waste.

Overall cost—\$300–\$800/sample

Efficacy/strengths—Elemental, spatial, and depth profiling information is obtained from the surface region (<10 nm) of the sample. It is applicable to monitoring contaminant interaction with the host matrix and identifying complexation, location, and binding sites of the contamination. This is a mature technology.

Science/Technology Needs: Mature model studies are needed to probe the host/contaminant effects for accurate depth profiling.

Implementation Needs: Instrumentation and personnel exist at ORNL, K-25 Site, and Y-12 Plant. Capital costs, >\$200K.

Author: D. P. Hoffmann/615-574-3896. Reviewed by J. A. Basford/615-576-4337

References:

1. C. C. Chang, *MRS Bulletin* **12**(6), 70-74 (1987).
2. N. H. Turner and J. A. Schreifels, *Anal. Chem.* **64**(12), 302R (1992).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the regulatory compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Secondary ion mass spectroscopy (SIMS). Ionized gas impinges on sample to eject secondary ions that are subsequently mass analyzed.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—About a 5-mg sample is required. Minimal sample preparation is required.

Overall cost—\$500/sample

Efficacy/strengths—Elemental and compound identification from the sample surface, spatially resolved information, and depth profiling are possible. Enrichment information is also possible. Nonconduction materials may present problems.

Weaknesses—Organic applications are very specialized and require significant development efforts.

Science/Technology Needs: This is a mature technology. Model studies are needed to calibrate for depth-profiling studies. Routine use of this technology for organic characterization requires significant study.

Implementation Needs: Instrumentation and personnel exist at ORNL, K-25 Site, and Y-12 Plant. Capital costs, \$400K–\$1M.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. M. Hiller/615-574-0287, J. C. Franklin/615-574-2284, and N. J. Williams/615-574-0952.

References:

1. W. Katz and J. G. Newman, *MRS Bulletin* **12**(6), 40-47 (1987).
2. D. W. Koppenaal, *Anal. Chem.* **62**(12), 303R (1990).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Portable volatile organic compound (VOC) detectors. A valuable, quick, and yet inexpensive method to screen for the contamination of soils based on flame ionization or photoionization of sample. Useful at a variety of sites including leaking underground tanks, pits, and drain spillage. Depending on the sophistication of the instruments used, quantitative and qualitative information can be provided.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment

Deployment evaluation: Manual, automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, VOCs, trichloroethylene, ...)

Waste produced—None

Overall cost—Low capital costs; very low costs per field screening analysis (~\$1)

Efficacy/strengths—These portable units allow real-time field monitoring of organic vapors. Some units are specifically calibrated for certain gases. Others allow a wide range of gas detection. There are various sizes ranging from pocket to briefcase size, with a variety of data logging and sample collection options. Detection limits can be as low as the ppb range.

Science/Technology Needs: This is a mature technology

Implementation Needs: Instruments are available for quick screening and surveying. Interfacing the instruments with an ion mobility mass spectrometer would allow detection of individual compounds (~\$30K). Capital costs, ~\$500.

Authors: D. P. Hoffmann/615-574-3896, J. M. Storey/615-574-5042, Reviewed by: D. D. Smith/615-574-0917

References:

1. Vendor literature
MDA Scientific
Sensidyne, Inc.
Graseby-Andersen Instruments, Inc.
Sentex Systems, Inc.
2. L. Clement, M. L. Langhost, and G. A. Eiceman, "Environmental Analysis," *Anal. Chem.* **63**(12), (1991).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Fourier transform infrared spectroscopy (FTIR). A spectroscopic technique used for identifying and quantitating multiple inorganic and organic materials by measuring the absorbance spectrum of the material in the infrared spectral region.

Status: Accepted; commercially available. Demonstrated at the K-25 Site TSCA incinerator in July 1993. Large data bases and libraries are available for rapid identification of large numbers of compounds. Software for quantitation exists.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene)

Waste produced—None to a few milliliters per sample; sample becomes waste.

Overall cost—\$50–\$500/sample

Efficacy/strengths—A multitude of detector and sampling devices exist, allowing gas, liquid, solid, and microanalysis to be performed. Detection limits are typically submilligram.

Weaknesses—Applicability to specific compounds and matrices needs to be demonstrated. A fingerprint technique for pure compound mixtures will present data interpretation challenges.

Science/Technology Needs: A data base for rapid materials identification and model studies of materials interaction is needed.

Technical Task Plan RL421206 (FY 1992); relevance: high

Implementation Needs: Hardware costs, \$25K–\$500K; development costs, <\$200K; \$75K hardware cost projected for EPA—certified unit. Instrumentation is available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. C. Franklin/615-574-2284 and N. J. Williams/615-574-0952.

Reference:

1. C. L. Putzig et al., *Anal. Chem.* **64**(12), 270R (1992).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Ultraviolet/visible spectroscopy (UV-VIS). Compounds are identified by wavelength of absorption and are quantified by their absorbance.

Status: Accepted; commercially available.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic; inorganic (U, Tc, Cr, CrO₄, Hg, Pb, metals, anionic species...)

Waste produced—None to a few milliliters per sample

Overall cost—\$50–\$200/sample

Efficacy/strengths—This mature technology can be used in a variety of field and laboratory procedures for the identification of materials. It can provide rapid screening capabilities for sample selection. Not typically compound-specific. Poor "fingerprint" technique, typically. It will be used often as part of routine lab analyses.

Science/Technology Needs: Model studies and application design are needed.

Implementation Needs: Hardware costs, <\$200K; development costs, <\$100K; \$50–\$500/sample. Available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. M. Hiller/615-574-0287

References:

1. MMES staff
2. L. G. Hargis and J. A. Howell, *Anal. Chem.* **64**(12), 66R (1992).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods; field methods

Technology: Electrochemical methods (e.g., electrogravimetry, polarography, coulometry, voltametry). Oxidizable or reducible species, excited by a voltage or current function in an electrical circuit, yield quantitative and qualitative information about species of interest. It is useful for on-line/field-methods for cation in water.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); inorganic (U, Cr, Hg, Pb, Cd, Ni, Cu, Zu)

Waste produced—5–100 mL/sample

Overall cost—Widely variable (~\$1K–\$50K), minimum of \$100/sample

Efficacy/strengths—A good method for quantification of Hg in process or wastewater streams. It provides a wide variety of electrochemical techniques can provide chemical and materials interaction information. These are selective and sensitive in many situations, but applicability must be demonstrated for sample/matrix combinations. These techniques could be useful in waste treatment and interaction studies, as well as identifying species present in waste streams. Detection limits: submicrogram for electro-active species.

Science/Technology Needs: Instrumentation and laboratory tests to be performed on complex systems are needed.

Implementation Needs: Hardware costs, \$50K–\$250K; development costs, \$250K. Instruments exist at Y-12 and ORNL.

Author: D. P. Hoffmann/615-574-3896. Reviewed by R. D. Shelton/615-574-6829 and D. D. Smith/615-574-0917

References: M. D. Ryan and J. Q. Chambers, "Dynamic Electrochemistry: Methodology and Application," *Anal. Chem.* **64**(12), (June 15, 1992).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury in air

Reference Requirements: Refer to Volume 1, Chapter 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

To be eligible for exemption from EPA regulation, the maximum concentration of mercury must be less than 50 pg/m³ at the plant property line.

Personnel exposure limits to mercury in air

Contaminant	Time-weighted average		Short-term exposure limit	
	ICGIH	Y-12	ICGIH	Y-12
Mercury alkyls	0.01 mg/m ³	0.005 mg/m ³	0.03 mg/m ³	0.015 mg/m ³
All mercury except alkyls	0.05	0.025	NA	NA
Aryl and inorganic mercury	0.1	0.05	NA	NA

The OSHA air contaminant limit for mercury vapor is 0.05 mg/m³.

Subelement: Characterization

Alternative: Field methods

Technology: Surface acoustic wave (SAW) sensor. A SAW device is a sensor that detects specific gases or compounds. Adsorption of analyte on its surface alters the speed, frequency, or phase of a traveling surface acoustic wave. For Mercury the SAW crystal is coated with a gold film. Mercury-contaminated air to be sampled flows across the crystal and the mercury is deposited on the gold film because of amalgam formation. The additional mass causes the SAW to be modified and is the basis for detection and quantification.

Status: Predemonstration. The technology has been demonstrated for polychlorinated biphenyl (PCB) detection. Modification for Hg detection is straightforward because a highly selective film for Hg retention, gold, is known and often used in various Hg sampling and analysis technologies.

Temporal Areas of Evaluation: pretreatment, during treatment, and posttreatment.

Deployment Evaluation: manual applications, automated applications, and robotic applications.

Driver Evaluation: regulatory, risk assessment, and technical assessment.

Applicable Contaminant Evaluation: Mercury

Amount of waste produced--None

Overall cost--The cost per unit is low (\$2K-\$10K), and the cost per sample is also low (\$1-\$10).

Efficacy/strengths--It has a fast response time and provides a direct measure of mercury vapor concentration. Various sampling scenarios are possible. Detection levels well below ppm are possible.

Science/Technology Needs: Higher temperature and small probe unit devices need to be optimized. Laser/thermal desorption sampling capabilities and on-line process monitoring also need to exist for large scale D&D efforts. These will allow more direct monitoring of D&D processes and minimize restrictions as to their application.

Implementation Needs: Normal

Author: D. P. Hoffmann/615-574-3896 and R. L. Fellows/615-576-5632

References:

1. C. G. Fox, J. F. Alder, *Analyst*, 1989, 114, page 997

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Infrared spectroscopy (wavelength dispersion) (IR). This method includes long-path diffuse reflectance (LP) and attenuated total reflectance (ATR) for determination of compounds found in the air and water and on surfaces. Measures photon absorption due to molecular vibrations. Photon wavelength is scanned sequentially across detection range.

Status: Accepted. Useful for surface contamination and in water.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene); inorganic (anions, select dissolved gases, gases)

Waste produced—Ranges from none to a few milliliters

Overall cost—\$100/sample for liquids not needing special preparation; \$50/sample for noncorrosive gases.

Efficacy/strengths—Both LP and ATR methods have a long path range that allows averaging of emissions over a large area. Remote sensing is easily performed, with real-time results and simultaneous multiple species identification.

Science/Technology Needs: Software development would enhance site-specific applications.

Implementation Needs: Field tests are needed.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: D. D. Smith/615-574-0917

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1. R. H. Kagann, O. A. DeSimone, and W. F. Herget, *Proc. EPA/A & WMA Int. Symposium on Toxic and Related Air Pollutants*, 1989.
2. C. L. Puttig, et al., *Anal. Chem.* **64**(120, 270R (1992).
3. See CHAR-8-OL for Fourier transform infrared.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample preparation

Technology: Microwave digestion. Radiation in the microwave region is used to excite polar molecules to speed sample dissolution in closed systems. This is very useful in preparing soil and other environmental samples.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); Radioactive (α, β, γ)

Waste produced—Ranges from 0–20 mL of aqueous RCRA waste per sample, depending on the solvents used in protocol

Overall cost—\$50/sample for labor and materials

Efficacy/strengths—It has the ability to digest soil samples completely and cause extraction of trace elements from soils and complex matrices before analysis.

Science/Technology Needs: This technology shows much promise in reducing the amount of waste produced in analyzing samples, as well as increasing the quality of the data obtained.

Implementation Needs: Protocols are needed to optimize the digestion of environmental samples in preparation for subsequent analytical techniques. Development costs are estimated at ~\$200K. Equipment costs, ~\$15K for microwave digester and hood.

Authors: C. S. Dudney/615-576-2712, D. P. Hoffmann/615-574-3896. Reviewed by T. Ross/615-574-4888

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1. U.S. Patents 4,835,354 and 4,877,624.
2. S. A. Malthes, R. F. Farrell, and A. J. Mackie, "A Microwave System for the Acid Dissolution of Metal and Mineral Samples," *Bureau of Mines Technical Progress Report* **120**, April 1983.
3. S. Kokot et al., "Microwave Digestion: An Analysis of Procedures," *Analytica Clinica Acta* **259**, 1992.

EM Problem: Decontamination and decommissioning; waste management

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Ultrasonic extraction. Solvent is pumped across and into a porous material surface in the presence of intense ultrasonic irradiation, which produces good solvent contact with and penetration of the sample surface, resulting in a faster and more efficient extraction of the sample for analysis.

Status: Predemonstration; technology not yet demonstrated

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (α , β , γ); inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced— >5 mL, dependent on the sampling scenario, plus solvent

Overall cost—\$400/sample

Efficacy/strengths—It utilizes low-temperature, high-energy solvent extraction for removal of materials from porous media; can be conducted on-site. It is also a method for surface decontamination of objects.

Science/Technology Needs: Testing to define efficiency and to establish the enhancement of material retrieval from porous media using various solvents, acids, and bases is needed.

Implementation Needs: Hardware costs, \$2K–\$5K; development costs, \$200K. Inverse heads need to be designed for sampling from the floors and other horizontal (top side) applications. Needs field tests to define in situ cleaning.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: D. D. Smith/615-574-0917

References:

1. Personal experience.
2. Interaction with various vendors for possible applications.
3. EPA SW-846 method 3550.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory methods

Technology: Cold vapor (mercury) analysis. Based on the atomic ultraviolet and visible light absorption and fluorescence spectroscopy of mercury. The technology is very sensitive and highly selective.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Elemental inorganic (Hg, Se, As)

Waste produced—About 5 mL/sample

Overall cost—Sample preparation comprises most of the sample cost.

Efficacy/strengths—It is automated; a mature technology; EPA approved; and detection is possible at ppt levels. Atomic absorption detection limits in 10–100 pg range. Atomic fluorescence detection limits in sub-pg range. Some fluorescence instruments have an elemental mercury detection limit of 0.002 pg if high purity inert gas is used for sample transport. More development work would help bring this detection level to commercial instruments.

Science/Technology Needs: Routine procedure development. Portable equipment commercially available.

Implementation Needs: Can be part of a mobile laboratory. Capital costs, ~\$15K for absorption spectroscopy.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. M. Storey/615-576-7607 and T. Ross/615-574-4888

References:

1. Vendor information (LDC Analytical, 1-800-532-4752).
2. K. W. Jackson and H. Qiao, *Anal. Chem.* **64**(12), 50R (1992).
3. K. R. Henke et al., *Critical Review of Mercury Contamination Issues Relevant to Manometers at Natural Gas Industry Sites*, GRI-93/0117, Research Institute, Chicago, Illinois, August 1993.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Fiber-optic chemical sensors. Remote detection using a variety of methods, including optical absorption, Raman scattering, and luminescence spectroscopy. The fiber-optic waveguide is used to deliver and/or collect the sample light. This technique allows remote sensing in hazardous environments. Perhaps also useful for more routine environmental and industrial hygiene monitoring.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic; organic (oils, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—None

Overall cost—The cost is variable (~\$1K and up) for the fiber-optic probe. For luminescence detection (e.g., fluorescence, phosphorescence, chemiluminescence) method costs, see CHAR-92-OL. For Raman spectral detection method costs, see CHAR-84-OL. For optical absorption (e.g., UV-VIS, NIR), see CHAR-27-OL.

Efficacy/strengths—The waveguides allow a variety of spectroscopic probes to be located in remote regions and limited access areas. This technology allows remote sensing in hazardous environments and can be robotically placed within remote locations. Although this can be a "sampling" attachment for many spectroscopies, it can also be used in conjunction with a variety of physical measurements. Absorption and Raman detection limits, hundreds to thousands ppm. Luminescence detection limit to ppm for select compounds.

Science/Technology Needs: A combination of waveguides and spectroscopic techniques that have been matched not only for each other but also for specific monitoring scenarios are needed.

Technical Task Plan SF211203 (FY 1992); relevance: high
SF221104 (FY 1992); relevance: high

Implementation Needs: Waveguides that can withstand the harsh chemical environment that may be present in some of the sampling locations are needed.

Author: D. P. Hoffmann/615-574-3896. Reviewed by E. A. Wachter/615-574-6248 and J. M. Hiller/615-574-0287

References:

1. R. E. Dessey, *Anal. Chem.* **61**(19), 1079R (1989).
2. J. Janata, "Chemical Sensors," *Anal. Chem.* **64**(19), June 15, 1992.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Detection/Measurement-Field

Technology: Particle size analysis. Photographic, photometric, and electrometric techniques produce size measurement and distribution data for particulates in powder and slurry samples.

In addition, the technique can measure air-borne particles from dusty areas.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (α , β , γ , Cr, Pb, Zn, Al, Ti, paint particles, and U- and Hg-contaminated particles)

Amount of waste produced—None to very little

Overall cost—About \$10K and up

Efficacy/strengths—There are a variety of particle-size determinators on the market. This is a mature technology that can collect samples for particle-size distribution, and then allow further analysis to be performed on the collected material. There are several in situ, real-time monitoring devices, and the lower limit of detection is constantly being pushed back.

Science/Technology Needs: None, mature technology. Laser based forward light scattering particle counters are available in-house in the 0.3 μm to 50 μm detection range.

Implementation needs: In situ devices need to be implemented for more aggressive industrial hygiene/health physics protection of personnel and to ensure the control (i.e., prevent spread) of radioactive contamination. Field tests will be required.

Author: D. P. Hoffmann/615-574-3896 Reviewed by: D. D. Smith/615-574-0917

References: Vendor literature.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organics, inorganics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Optical absorption spectroscopy (OAS). Measures the transmission of ultraviolet (UV), visible, and near infrared (IR) to determine the concentration of chemical species in gases, liquids, or solids. OAS can be applied to the analysis of any species that absorbs electromagnetic radiation in the region of excitation, UV through IR. Instrumentation varies from simple, inexpensive spectrometers and colorimeters to sophisticated systems that offer highly selective analysis of complex samples.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic; inorganic

Waste produced—None to minimal, solvent

Overall cost—\$10–\$50/sample; instrumentation, \$1K–\$100K

Efficacy/strengths—Fast response time, ppm to ppb level of detection for selected compounds, and remote nondestructive field analysis proven. Mixtures may be an analysis challenge.

Science/Technology Needs: Mature, field-portable IR technology is available; UV technology is being developed at ORNL. Needs specific instrument lab and field test beds.

Implementation Needs: It can be implemented for direct site/scenario needs. Needs limits of application to surface or water characterization techniques.

Authors: D. P. Hoffmann/615-574-3896, E. A. Wachter/615-574-6248. Reviewed by: D. D. Smith/615-574-0917

References:

1. Edner et al., *Appl. Opt.* **25**, 403 (1986).
2. L. G. Harsts and J. A. Howell, "UV and Light Absorption Spectrometry," *Anal. Chem.* **64**(12), June 15, 1992.
3. C. L. Putzig et al., *Anal. Chem.* **64**(12), June 15, 1992.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Inorganic, asbestos

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Powder X-ray diffraction (XRD). X-ray powder diffraction technique for phase identification based on measurement of structure-sensitive diffracted X-ray lines. It involves the characterization of materials by use of data that are dependent on the atomic arrangement in the crystal lattice.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...). Maybe useful for asbestos definition, in situ.

Waste produced—None to 5 mL/sample

Overall cost—High capital costs for equipment, >\$100/sample

Efficacy/strengths—Phase identification of crystalline phases in solid samples. Approximately 1 wt% lower limit of detection. It can supply quantitative, stress/strain, and particle size information to perhaps >20% accuracy. Noncrystalline materials and most solid organics are not routinely detectable.

Science/Technology Needs: This is a mature technology. Model studies of the complex mixtures of interest are needed if quantitative analysis is desired.

Implementation Needs: Capital costs, \$50K minimum. Equipment available at ORNL, K-25 Site, and Y-12 Plant. Needs technical definition for possible use.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: D. D. Smith/615-574-0917

Reference:

1. Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Physical, Asbestos

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory methods

Technology: Optical microscopy. Visible light microscopes are used to determine the size, morphology and identification of solid materials.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); organic (solids)

Waste produced—None to 1 mL/sample; sample and sample holder become waste

Overall cost—\$50/sample minimum

Efficacy/strengths—This is a mature technology. A variety of optical parameters and techniques can be used to identify, document, measure, and quantify samples. Sample analysis is labor intensive and requires interpretation of data. Accepts wide variety of samples.

Weaknesses—Requires highly skilled operator for identification of materials. Sample selection method very important. Throughput low.

Science/Technology Needs: A particle atlas of site-specific materials is needed to allow rapid identification.

Implementation Needs: A centralized image collection system is needed to establish a site-specific database. Capital costs, \$5K minimum. Instruments are available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. A. Basford/615-576-4337

Reference:

1. Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals, asbestos

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Scanning electron microscopy (SEM). A focused, high-energy beam of electrons produces secondary and back-scattered electrons when it impinges on a sample in high vacuum. Because of its high-resolution spatial characteristics, the technique is suitable for texture analysis, mapping, and corrosion studies. It is frequently coupled with X-ray excitation to provide elemental information.

Status: Accepted; for spot and broad surface elemental analysis.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, Hg, Pb, ...)

Waste produced—None to 5 mL/sample; includes sample holder

Overall cost—\$500/sample

Efficacy/strengths—The technology allows the documentation and analysis of very small particles approaching tens of angstroms. It allows sample preparation and collection to minimize the waste generated. It can magnify a sample in the range of 10x–800,000x. It is most powerful when used in conjunction with analytical attachments (EDS, WDS, image analysis) and differing electron imaging modes.

Weaknesses—Limited sensitivity, sample size limitation. Little chemical information.

Science/Technology Needs: Routine methods development

Implementation Needs: None

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. A. Basford/615-576-4337, N. J. Williams/615-574-0952, and J. C. Franklin/615-574-2284

Reference:

1. Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals, asbestos

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Transmission electron microscopy (TEM). A beam of high-energy electrons is focused onto a sample in vacuum. Resolution of less than 1 μm permits the determination of microstructure approaching atomic dimensions, particle sizing, and microanalysis. Often coupled with X-ray techniques, this technique can be used to obtain elemental analyses.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...)

Waste produced— 1 mL/sample; sample and sample grid become waste

Overall cost—\$500/sample minimum

Efficacy/strengths—It has ultrahigh resolution (down to .75 Å). It is an accepted method for certain applications (e.g., asbestos, ceramics), and has a wide range of technical applications. It is most powerful when used in conjunction with its analytical capabilities (EDS, image analysis, electron diffraction). Can identify crystals.

Weaknesses—Sample size requires extensive workup. Low throughput of samples.

Science/Technology Needs: Routine analytical procedure development

Implementation Needs: None

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. A. Basford/615-576-4337

Reference:

1. Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field and laboratory methods

Technology: Energy dispersive X-ray spectroscopy (EDS, EDX, EDAX). It is a method for elemental analysis based on the separation of X ray according to their energies, by use of a lithium-drifted silicon proportional detector.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Cr, Hg, Pb, most metals, Al-V, ...)

Waste produced—None if in situ field measurement made, otherwise 5 mL/sample; sample and sample holder become waste.

Overall cost—\$100/sample

Efficacy/strengths—It allows rapid elemental analysis (beryllium and up) and quantitative analysis of solid samples. It is typically used in conjunction with electron microscopy. Although the detection limit is roughly 1 wt%, that is the detection limit of the area of the sample that is being probed (1 micrometer² or less). Thus, it is possible to analyze the individual materials that are present in the ppb range and lower for samples of select morphologies. Good sample throughput at low sensitivities. Can be used in field.

Weaknesses—Not very sensitive as usually configured. Requires radioactive source with its attendant problems.

Science/Technology Needs: Improved resolution in field able equipment.

Implementation Needs: Training of operating personnel requires good knowledge of X-ray techniques. Capital costs, \$50K minimum. Laboratory-based instruments available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896. Reviewed by N. J. Williams/615-574-0952 and J. C. Franklin/615-574-2284

References:

1. Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.
2. S. B. Török and R. E. VanGrieken, *Anal. Chem.* **64**(12), 180R (1992).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field and laboratory methods

Technology: Wavelength dispersive X-ray spectroscopy (WDS, WDX). It is a method for qualitative and quantitative elemental analysis, using the wavelengths of characteristic X-ray emission lines, in which a single diffracting crystal is used to separate the wavelength from the sample.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Cr, CrO₄, Hg, Pb, most metals, Be-V, ...)

Waste produced—None if in situ field measurement made, otherwise about 5 mL/sample; becomes waste along with sample holder.

Overall cost— <\$100/sample

Efficacy/strengths—It allows rapid elemental analysis (beryllium and up) and quantitative analysis of solid samples. It is typically used in conjunction with electron microscopy. Although the detection limit is roughly 1 wt%, that is also the detection limit of the area of the sample that is being probed (1 micrometer² or less). Thus, it is possible to analyze individual materials that are present in the ppb range and lower for samples of select morphologies.

Weaknesses—Slow sample analysis, made much slower by going to higher sensitivity. Delicate apparatus limits portability.

Science/Technology Needs: Field units need improved resolution.

Implementation Needs: Training in operation requires good knowledge of X-ray techniques. Capital costs, \$50K minimum. K-25 Site has a laboratory instrument.

Author: D. P. Hoffmann/615-574-3896. Reviewed by N. J. Williams/615-574-0952 and J. C. Franklin/615-574-2284

References:

1. Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.
2. S. B. Török and R. E. VanGrieken, *Anal. Chem.* **64**(12), 180R (1992).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: In situ characterization and monitoring

Technology: Nondestructive testing (NDT) for concrete

Status: Accepted; commercially available components

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—None

Overall cost—Variable

Efficacy/strengths—The technology can determine the strength and capabilities of concrete without imparting any physical damage to the existing structure. Perhaps useful as XRF analyses deployed on an XY-translation stage.

Science/Technology Needs: Testing protocols for evaluating and characterizing large concrete structures are needed.

Implementation Needs: A testing plan for site buildings and a field testing kit for site-wide deployment are needed.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. M. Hiller/615-574-0287

References: J. R. Clifton; Dialog File No. 265/266, ID No. 62266.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory

Technology: Ion chromatography (IC). A type of liquid chromatography for the separation of ions based on their charge affinity for the ionic functional groups of the column packing. The ions are usually measured by conductivity detection.

Status: Accepted; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); Pu, other translls, RE; halides, PO₄³⁻, NO₃⁻.

Waste produced—To 100 mL/sample

Overall cost—\$100/sample

Efficacy/strengths—It has the ability to separate and quantify anions and cations in solution (ppm to ppb detection limits depending upon the matrix effects). It can be automated and performed in some on-line process applications. Mobile lab use is possible.

Science/Technology Needs: A detector system that is optimized for the expected waste streams that will be generated needs to be determined. This type of system can be used for process control of waste generation.

Implementation Needs: Systems for process control of decontamination and decommissioning efforts are available. Low capital equipment costs, \$20K-\$50K.

Author: D. P. Hoffmann/615-574-3896. Reviewed by T. Ross/615-574-4888

References: P. R. Haddad; Dialog File No. 265/266; ID No. 25460.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. Safe values for mercury exposure (BEI) are 35 µg inorganic mercury/g creatinine in urine and 15 µg inorganic mercury/L blood.

Subelement: Characterization

Alternatives: Field methods/Laboratory methods

Technology: Currently, biological monitoring of body fluids, with laboratory analysis. A field method to detect and measure body containing with mercury would be useful.

Status: Accepted for biological monitoring.

Conceptual for field measurement. Currently, the Y-12 Industrial Hygiene Department uses biological monitoring with laboratory analyses to determine mercury contamination of personnel. Biological monitoring consists of an assessment of overall exposure through measurement of specific determinants in biological specimens collected from the worker at specified times. The determinant can be the chemical itself, its metabolites, or a characteristic reversible biochemical change induced by the chemical. The measurement can be made in exhaled air, urine, blood, or other biological specimens collected from the exposed worker. The measurement can be used to indicate the intensity of a recent exposure, an average daily exposure, or a chronic cumulative exposure. Biological Exposure Indices (BEIs), as provided by the American Conference of Governmental Hygienists (ACGIH), are reference values that are intended to represent determinant levels that are most likely to be observed in specimens collected from a healthy worker who has been exposed to chemicals to the same extent as a worker with inhalation exposure to an accepted exposure limit. BEIs do not indicate a sharp distinction between hazardous and nonhazardous exposure situations, and they should not be used as a direct measure of adverse effects or for distinct diagnosis of occupational illness. Biological variability does make it possible for an individual's measurements to exceed the BEI without incurring an increased health risk. When feasible, biological monitoring should be used in conjunction with air monitoring to determine potential exposure concerns. Biological monitoring for Hg can be conducted for total inorganic Hg in urine or total inorganic Hg in blood. The BEI for total inorganic mercury in urine is 35 µg/g creatinine with samples obtained prior to the start of the work shift. The BEI for total inorganic mercury in blood is 15 µg/L with samples obtained at the end of the shift at the end of the workweek.

Science/Technology Needs: The specific technology to be used for field monitoring is unknown. "It would be reasonable to develop an instrument for measuring body mercury. Such a device would operate like a whole body counter, with off-gases assayed by an ultra-sensitive mercury detector" (John Hillis, Y-12). Another possibility is use of an MSA cartridge (at present the drawbacks are a low capacity, no indication of saturation).

Implementation Needs: Trained personnel are required for gathering, handling, and analyzing samples. Interpretation of sample results should be conducted by qualified personnel.

Author: S. M. Hollenbeck/615-574-9547. Reviewed by: R. L. Fellows/615-576-5632

References: Author

MODELLING MIGRATION OF MOBILE Hg COMPOUNDS IN POROUS MATERIALS

CHAR-53-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Statistics, modeling, and data assessment; field screening

Technology: Modelling the migration of mobile Hg compounds in porous materials such as soil or concrete for surface contamination measurements.

Status: Demonstration. Statistics and modelling would be supplementary to technical expertise in Hg migration (this is not a stand-alone activity).

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Mobile Hg and its compounds

Waste produced—Intended to minimize waste in sampling and analysis.

Overall costs—Computer and personnel

Efficacy/strengths—A better understanding of the migration of mobile Hg compounds in porous materials will allow better predictions as to the extent of remediation or decontamination required for their disposal. This understanding will also allow a more intelligent application of solvent decontamination technologies to be used on porous media.

Science/Technology Needs: Models applicable to site-specific scenarios need to be developed prior to Phase I, to better understand the impact of Hg contamination.

Implementation Needs: Technical knowledge of migration of Hg in porous materials. Software and hardware are needed to implement the modeling systems. Development costs are estimated at ~\$500K.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: M. W. Sherrill/615-574-2569

References: R. B. Wallace; Dialog File No. 265/266; ID No. 2P42ES04911-04 0004.

MEMBRANES FOR SAMPLE COLLECTION AND CONCENTRATION

CHAR-55-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Membranes for field sample collection and concentration. Membranes that are predominantly permeable to selected components in mixtures are exposed, then separated for accumulation or to facilitate analysis/detection.

Status: Accepted; demonstration, predemonstration on selected uses

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk assessment

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); radioactive (α , β , γ)

Waste produced—Used membranes may be waste

Overall cost—\$50/sample

Efficacy/strengths—The use of membrane technology can assist in a large number of characterization and decontamination scenarios. The ability to use membranes for the selective separation and concentration of a contaminant allows the contaminant to be identified by cheaper, less-sensitive (typically) field-portable instrumentation. Possible use in on-line mass spectrometers, electron capture detectors for pesticides, and halocarbons

Science/Technology Needs: System development or adaptation for specific applications; validation of the method with concurrent sampling.

Implementation Needs: Sample collection systems for site-specific applications are needed. Development costs are estimated at ~\$300K.

**MEMBRANES FOR SAMPLE COLLECTION
AND CONCENTRATION**

CHAR-55-OY

Author: D. P. Hoffmann/615-574-3896. Reviewed by R. D. Shelton/615-574-6829 and D. D. Smith/615-574-0917

References:

1. J. M. Radovich; Dialog; File No. 265/266; ID No. 008194.
2. R. E. Clement, M. L. Langhorst, and G. A. Eiceman, "Environmental Analysis," *Anal. Chem.* **63**(12), 270R, June 15, 1992.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Detection/Measurements-Field

Technology: Air monitoring (AM). Encompasses several methods of monitoring particulate loading and characteristics including filtering, particle size analysis, etc. Collected samples can be analyzed for a host of different species.

Status: Accepted. It is a routine technique, in available at most labs.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); radioactive (α , β , γ); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—None to moderate (where sample filtering is performed or when sample solvent extraction is required)

Overall cost—Collection equipment, \$10K; samples, \$5-\$100/sample, depending on the species of interest.

Efficacy/strengths—Air monitoring during remediation activities should comply with Clean Air Act amendments (CAA, 1990). Hazardous air pollutants (HAPs) have been identified, and monitoring procedures are available for both gas and particle phases.

Science/Technology Needs: This is a mature sampling technology with EPA protocols.

Implementation Needs: This is a mature technology.

Author: D. P. Hoffmann/615-574-3896. Reviewed by J. M. Storey/615-576-7607. Reviewed by: J. M. Hiller/615-574-0287

References:

1. M. D. Hoover; Dialog File No. 265/266; ID No. 62466.
2. F. W. Liberti, A. Febo, and M. Possanzini, *NATO ASI Ser.*, **252** (1988).
3. Graseby-Andersen Instruments Inc. (vendor).
4. D. L. Fox, "Air pollution," *Anal. Chem.* **63**(12), June 15, 1992.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Modeling of heterogeneous materials sampling. This technology allows quantification of contaminant of interest in "difficult-to-collect" substrates; can be applied to polychlorinated biphenyl (PCB)-contaminated concrete.

Status: Evolving; conceptual. This method would use hemometric-based data analysis to compare the collection of contaminants during sampling as a function of the host matrix porosity and collection method.

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); radioactive (α , β , γ); organic (oil, PCBs, volatile organic compounds, trichloroethylene, ...)

Waste produced—Method minimizes sampling waste.

Overall cost—

Efficacy/strengths—Would allow better quantitative evaluation of contaminants or porous media.

Science/Technology Needs: An experimental design, models need to be established.

Implementation Needs: A study needs to be performed. Development costs are estimated at ~\$300K.

Author: D. P. Hoffmann/615-574-3896. Reviewed by: J. M. Hiller/615-574-0287

References: MMES staff members.

MULTIANGLE DRILLING FOR DEPTH PROFILING OF CONTAMINANTS

CHAR-64-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Multiangle drilling for depth profiling of contaminants. Applicable to heterogeneous materials.

Status: Demonstration; this system can utilize standard drilling equipment which is commercially available.

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); radioactive (α , β , γ); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Variable, from drilling activities and samples

Overall cost—Low

Efficacy/strengths—Although core drilling is a preferred technique to remove a sample that remains spatially resolved, it is not always possible to do so. Multiangle drilling should allow a summation of depth artifacts to be determined through analysis of each sample collected.

Science/Technology Needs: Model studies need to be performed.

Implementation Needs: Routine procedure development. Development costs, \$200K.

Author: D. P. Hoffmann/(615)574-3896. Reviewed by: J. M. Hiller/615-574-0287

References: MMES staff members.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium, radioactive elements, alpha emitters

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. DOE Order 5400.5, ANSI N13.12, and NRC 5

Subelement: Characterization

Alternative: Field methods

Technology: Long-range alpha detector (LRAD). It is a screening device for detecting alpha radioactivity on surfaces or personnel and in soil or waste. It measures ionized air drawn from a container holding a contaminated object, irrespective of shape.

Status: Demonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α , β , γ)

Waste produced—None

Overall cost—\$10K/device, price should decrease after commercialization.

Efficacy/strengths—It detects surfaces/objects contaminated at or below release limits.

Measurements are semiquantitative but can be sensitive to ~100 dpm alpha.

Science/Technology Needs: MacArthur et al. (1992) has demonstrated the principle of the measurement technique. Measurement probes and other devices must be developed for specific applications and probe size reduction is needed.

Implementation Needs: Field testing is needed (~\$300K).

Author: C. S. Dudney/615-576-2712

Reference:

1. D. W. MacArthur, et al., "Long-Range Alpha Detector," *Health Phys.* **63**(3), 324-330 (1992).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Gas chromatography-Fourier transform infrared spectroscopy (GC-FTIR). Organic compounds separated by gas chromatograph (GC) are identified by their infrared spectrum as they exit the GC and are quantified by the absorption of one or more wavelengths.

Status: Demonstration; commercial technology is available. This is a routine lab service that might be used on a non-routine basis.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced— <1 mL/sample (not including standard preparation or waste GC column material)

Overall cost—About \$500/sample

Efficacy/strengths—GC-FTIR combines the separation capabilities of gas chromatography with the structural identification capabilities of Fourier transform infrared spectroscopy. The technique is complementary to gas chromatography-mass spectroscopy. It can provide isomer-specific identification.

Science/Technology Needs: Specific methods for targeted analytes and routine methods for unknown identification need to be developed. Software for data interpretation needs to be developed, and different commercial interface configurations for desired characteristics (sensitivity, reproducibility, etc.) need to be evaluated.

Implementation Needs: Instruments are available at Y-12.

Author: G. B. Hurst/615-574-6691. Reviewed by: J. M. Hiller/615-574-0287, J. C. Franklin/615-574-2284, and N. J. Williams/615-574-0952

References:

1. C. L. Putzig et al., *Anal. Chem.* **64**, 270R-302R (especially pp. 288-9) (1992).
2. G. A. Eiceman et al., *Anal. Chem.* **64**, 170R-180R (especially p. 175R) (1992).
3. GC-FTIR manufacturers: Biorad/Digilab, Cambridge, Mass.; Mattson, Madison, Wis., and Nicolet, Madison, Wis.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Metallographic sectioning and preparation

Status: Accepted. Routinely used for preparation of metallic ceramic, and geologic materials.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive; inorganic (metals)

Waste produced—About 1 L liquid and spent abrasive per 1–6 samples

Overall cost— <\$500/sample

Efficacy/strengths—Provides representative sample that shows contaminant depth distribution.

Science/Technology Needs: Procedure development for specific applications is needed; then protocols for standardized preparation should be developed.

Implementation Needs: None. Facilities available at ORNL and K-25 Site (see also core drilling).

Author: G. C. Marsh/615-576-6913. Reviewed by Z. W. Bell/615-574-6120.

Reference: Technique is used routinely for preparation of metallic, ceramic, and geological materials.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Atomic emission spectroscopy. Light emitted by one or more thermally stimulated elements is used for quantitative and qualitative analysis. Common excitation source is an electrical discharge. Element-specific light is detected either on film or photo detector tube.

Status: Accepted; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (all elements)

Waste produced—Very small quantities (<10 mL) of aqueous waste/sample

Overall cost—\$100–\$200/metal determined

Efficacy/strengths—It is a standard, well-accepted methodology for highly sensitive and selective determination of elements alone or in chemical or physical combinations. Analysis is semiquantitative but an excellent screening analysis for most elements.

Possible weaknesses—Sample workshop required. Moderate sensitivity. No chemical information. Moderate throughput. Provides average analysis of sample.

Science/Technology Needs: Automation is necessary to prepare for large sample load.

Implementation Needs: None. The technology is well-developed and applicable as is.

Author: J. R. Stokely/615-574-4907. Reviewed by: J. A. Basford/615-576-4337

Reference:

1. EPA regulations; Office of Solid Waste (SW-846), EPA CLP SOW 88, ASTM methods.

INDUCTIVELY COUPLED PLASMA ATOMIC EMISSION SPECTROSCOPY

CHAR-77-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: EPA regulations, ASTM methods. Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Inductively coupled plasma spectroscopy (ICP). Inductively coupled plasma is an analytical technique that uses a plasma to raise elements to an excited state. In this excited state the electrons in atoms and ions are promoted to higher energy levels. As the analyte travels through the cooler part of the plasma, the electrons fall back to lower energy levels. This change in energy level is accompanied by the emission of light at wavelengths that are specific to each particular element. The intensity of the light is directly proportional to the analyte concentration. This intensity is measured and converted to concentration values.

Status: Accepted; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—Small quantities (<10 mL) of aqueous waste/sample

Overall cost—\$100–\$150/multielement analysis of metals

Efficacy/strengths—It is a standard, well-accepted methodology. It allows multielement analyses in the ppb and sub-ppb region. Detection limit for mercury: 0.5 picogram (pg). Several methods of detection are possible and several elements can be quantified simultaneously.

Science/Technology Needs: It is applicable as is. This is a well-developed technology.

Implementation Needs: This technology is available at ORNL, K-25 Site, and Y-12 Plant.

**INDUCTIVELY COUPLED PLASMA
ATOMIC EMISSION SPECTROSCOPY**

CHAR-77-OY

Author: J. R. Stokely/615-574-4907. Reviewed by: N. J. Williams/615-574-0952 and J. C. Franklin/615-574-2284

Reference:

1. EPA regulations, Office of Solid Waste (SW 846), EPA CLP SOW 88, ASTM Methods Manuals.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Inductively coupled plasma—mass spectroscopy (ICP-MS). Samples brought into a solvent or gas stream are injected into argon plasma and are subsequently mass analyzed trace analysis of metals, isotopic and elemental.

Status: Demonstration. This is a new technology with little formal acceptance by regulatory and standards organizations. Currently, a routine lab method—likely to be used routinely for multielement analysis of aqueous solutions.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, any other metallic element with mass >40 ...); long-lived radioactive elements

Waste produced—Small quantities (<10 mL) of aqueous waste/sample

Overall cost—Sample preparation is the major analytical cost and is similar to ICP spectroscopy (CHAR-77-OL).

Efficacy/strengths—It has multielement capability. It is more selective than ICP/AES. It can perform isotopic analysis.

Science/Technology Needs: It is applicable for multielement analysis of aqueous solutions. Development is in progress to use the technology for surface analysis, using laser ablation techniques and low specific activity, and long-lived radionuclides.

Implementation Needs: Instruments available at Y-12 and ORNL.

Author: J. R. Stokely/615-574-4907. Reviewed by: N. J. Williams/615-574-0952 and J. C. Franklin/615-574-2284

Reference: In-house methods, literature publications.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Sampling and mixing methods

Status: Accepted

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (α , β , γ); inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Samples become waste; methods are intended to minimize analytical waste and effort.

Science/Technology Needs: Methods of collecting representative samples and mixing samples into a homogeneous state need to be optimized.

Implementation Needs: Requires statistical sampling design and proper laboratory blenders, mixers, and other equipment. Development costs are estimated at ~\$250K.

Author: J. S. Watson/615-576-6297. Reviewed by Z. W. Bell/615-574-6120

References:

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to Vol. 1, Chapter 10, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sampling

Technology: Punch cores. Methodology for collecting contiguous core sample of solid objects by punch, drill, or other similar means.

Status: Demonstration

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (α , β , γ); inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Samples become waste; method is intended to minimize sampling waste.
Efficacy/strengths—Produces samples suitable for contaminant depth profiling, versus conventional bulk analysis.

Science/Technology Needs: None

Implementation Needs: Need to set up methods and acquire equipment for coring sample matrices of importance at Y-12 site. Development costs are estimated at ~\$300K. (If concrete core drills are used, available off the shelf at very low costs).

Author: J. S. Watson/615-576-6297. Reviewed by: J. M. Hiller/615-574-0287

Reference: Arid Site Identification.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Detection/measurement-field

Technology: Portable Raman spectrometer. The identification and quantitation of molecular species is based on the principle that the vibrational energy of excited molecules can be observed and monitored. Raman spectra provide fingerprint identification of chemical species. No direct contact with the sample is necessary. Often used for remote sensing in inaccessible areas.

Status: Demonstration; field capabilities at ORNL
Predemonstration; current enhancement techniques

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic; inorganic (Note: mercury is not Raman active.)

Waste produced—None

Overall cost—\$10/sample

Efficacy/strengths—Provides selective detection and identification of many species. No direct contact is necessary. It is nondestructive. Detection limit of hundreds to thousands ppm.

Science/Technology Needs: Portable equipment (laser, etc.) for in situ use is needed. Methods which exploit surface enhancement and resonance excitation for vastly improved sensitivity need to be developed.

Technical Task Plan RL401206 (FY 1992); relevance: high

Implementation Needs: Equipment is available with MMES but has not been assembled for a specific application. Capital cost \$20K-\$50K.

Author: T. E. Barker/615-574-5042. Reviewed by: J. M. Hiller/615-574-0287

References:

1. J. D. Ingle, Jr., and S. R. Crouch, *Spectrochemical Analysis*, Prentice Hall, New York, 1988.
2. D. L. Gerrard and J. Birnie, *Anal. Chem.* **64**(12), (1992).

FLASHLAMP HEATING TO RELEASE OR DESORB SURFACE AND SUBSURFACE CONTAMINANTS

CHAR-87-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Flashlamp heating to release or desorb surface and subsurface contaminants. Method relies on broad spectrum high power to vaporize and ionize sample. Power is lower than that of laser.

Status: Predemonstration. Needs better use definition over traditional thermal methods.

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Technical assessment

Applicable contaminant evaluation: Radioactive; inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced— <1 mL/sample

Efficacy/strengths—Surface and subsurface characterization and potential speed

Science/Technology Needs: Depth profiling and surface area sampled must be determined for each material. Means of sampling the plume must be developed for each analyte.

Implementation Needs: To be determined for specific applications. Development costs are estimated at ~\$150K.

Author: M. R. Cates/615-574-8056. Reviewed by: D. D. Smith/615-574-0917

References:

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic

Reference Requirements: EPA regulations, OSHA-accepted technology. Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Gas chromatography—mass spectrometry. Utilizing the separation characteristics of various chromatographic columns, qualitative and quantitative data are obtained by correlating masses detected with the elution times.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic [oil, polychlorinated biphenyls (PCBs), volatile organic compounds, trichloroethylene, ...]

Waste produced—Near zero for volatiles; about 1 mL/sample organic extract

Overall cost—\$200–\$400/sample for volatiles; \$400–\$800/sample for semivolatiles; \$200–\$600 for PCBs.

Efficacy/strengths—Standard EPA-accepted methods exist. It is useful for chemical identification and confident quantitation.

Science/Technology Needs: Technology is applicable as is. Benefit would be derived from faster chromatography because of shorter analysis time.

Implementation Needs: Technology is available at Y-12 and is routinely available from service labs. It may be of value in characterizing unknown liquids from Bldg. 9201-4.

Author: M. R. Guerin/615-574-4862. Reviewed by: J. M. Hiller/615-574-0287

References: EPA regulations; the Office of Solid Waste (SW-846) Methods Compendium.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic

Reference Requirements: EPA regulations. Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Liquid chromatography—mass spectrometry. Organic compounds are separated by reverse phase liquid chromatography and identified by their mass spectrum. Quantitation is achieved by integrating selected ions.

Status: Demonstration; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); radionuclide complexes

Waste produced—20 mL of aqueous/organic solvent mixture (total) from liquid chromatography, and 1 mL from extract of sample.

Overall cost—\$500/sample

Efficacy/strengths—It is primarily for organic pollutants that cannot be gas chromatographed (polar, thermally labile, higher molecular weight, low volatility). Many of these are DOE-unique compounds. The method is complementary to gas chromatography-mass spectrometry.

Science/Technology Needs: Case-by-case development and demonstration for specific applications is needed. Technology is not currently in routine use; not available in Oak Ridge.

Implementation Needs: Hardware costs, \$200K; development costs, \$300K

Author: M. R. Guerin/615-574-4862. Reviewed by: J. M. Hiller/615-574-0287

References: EPA Office of Solid Waste procedures (SW-846).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic

Reference Requirements: OSHA. Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Direct sampling ion trap mass spectrometry (IT-MS). Organics are purged or otherwise directly introduced into the inlet of the IT-MS. Identification is achieved by monitoring specific ions or by MS-MS. Quantification is conducted by integrating characteristic ions.

Status: Predemonstration; method development needed. This technology is under development at ORNL. It was exported to the Savannah River Laboratory, and it is being considered for Hanford and Energy Systems deployment.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—None

Overall cost—It is application-specific.

Efficacy/strengths—It allows rapid (<5 min) determination of organics, continuous air monitoring, and possible real-time surface analysis. It is field-transportable for on-site analysis because the ion-trap detector is significantly smaller and lighter than other mass detectors. Detection limits, typically sub-ppm.

Science/Technology Needs: Methods need to be developed for specific applications.

Implementation Needs: Capital costs, \$100K; Development, training, and implementation costs, \$200K.

Author: M. R. Guerin/615-574-4862. Reviewed by: J. M. Hiller/615-574-0287

Reference: Personal knowledge as director of IT-MS program.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organics, inorganics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Portable luminescence detection. The detection of surface organic and inorganic chemicals using fluorescence, phosphorescence, and chemiluminescence. Samples are illuminated by a laser or conventional light source. Subsequent luminescence emissions are detected, yielding spectral information about the sample. This may be used to qualitatively identify analytes in a variety of background matrices.

Status: Demonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Not applicable

Applicable contaminant evaluation: Organics (containing conjugated bonding, polychlorinated biphenyls, ...); Hg, U

Waste produced—None if used in situ

Overall cost—\$5/sample

Efficacy/strengths—Luminescence detection can provide extremely sensitive detection and does not require direct contact. Synchronous fluorescence can differentiate compounds in mixtures and can be coupled to fiber optics for remote sensing.

Science/Technology Needs: The technology is mature, but may not provide absolute identification of compounds in complex mixtures. Needs testing on "real" samples for evaluation.

Technical Task Plan OR121201 (FY 1992); relevance: high

System being developed for ER: contact Roy Sheely/615-576-7742

Implementation Needs: Hardware is available at Y-12. Specific techniques need development, and procedures need to be written. Capital costs, >\$250K.

Author: J. M. Storey/615-576-7607. Reviewed by: D. D. Smith/615-574-0917

References:

1. J. D. Ingle, Jr., and S. R. Crouch, *Spectrochemical Analysis*, Prentice Hall, New York, 1988.
2. S. W. Allison et al., "Use of Fiber Optics and Laser-Induced Fluorescence for Remote Measurements in Strong Rotation," K/TS-11, 018, MMES, Oak Ridge Gaseous Diffusion Plant (June 1983). Also published in *Proc. Fifth Workshop on Gases in Strong Rotation*, University of Virginia, June 5-9, 1983.
3. S. W. Allison, G. T. Gillies, M. R. Cates, and B. W. Noel, "Fiber Optic Pulsed Laser Delivery for Remote Measurements," *Opt. Eng.* **26**(6), 538-546, June 1987.
4. I. M. Warner and L. B. McGown, "Molecular Fluorescence, Phosphorescence, and Chemiluminescence Spectroscopy," *Anal. Chem.* **64**(12), June 15, 1992.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Laser ablation organic mass spectrometry. Organic compounds on the surface of an object or a sample are desorbed by laser ablation and are analyzed by mass spectrometry.

Status: Predemonstration; technology under development

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...);

Waste produced—Inconsequential

Overall cost— <\$500/sample

Efficacy/strengths—It can characterize nonvolatile, polar compounds that cannot be detected by other mass spectrometry techniques. A surface analysis (as opposed to bulk analysis) method.

Science/Technology Needs: Development of a sampling methodology (perhaps using a wipe of the surface) and testing on target compounds is needed.

Implementation Needs: Capital costs, \$120K; development cost, \$300K. See CHAR-86-OL.

Author: M. V. Buchanan/615-574-4868. Reviewed by: J. M. Hiller/615-574-0287

References: MMES staff members.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic, organomercury

Reference Requirements: No regulatory requirements need to be met to implement this technology. Some gas chromatography detectors need to be vented to prevent worker exposure to toxic pollutants. Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Alternative: Laboratory methods

Technology: Qualitative and quantitative analysis, using gas chromatography. The detector technologies include flame ionization, electron capture, thermal conductivity, photoionization, flame photometric, and thermionic. Constituents can also be identified by retention time and, in some cases, response by selective detector. Quantify by detector responses. Possible field portable screening use for surface contamination.

Status: Accepted; technology commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, organic forms of mercury, ...)

Waste produced—Minimal; it is only necessary to vent gas chromatographs using nondestructive detectors.

Overall cost—\$5K–\$25K/instrument, depending on needs, plus miscellaneous supplies (carrier goods, etc.)

Efficacy/strengths—It has high efficacy for a very wide variety of organic species, both volatile and semivolatile. It is good for a variety of species, and the analysis time is 10–60 min.

Detection limits for organic forms of mercury: 50 picograms (pg).

Science/Technology Needs: Technology needs are minimal. While improvements can be made, in general, the technology is ready to use.

Implementation Needs: A variety of gas chromatography equipment exists already at ORNL, K-25 Site, and Y-12 Plant.

Author: R. A. Jenkins/615-574-4871. Reviewed by: D. D. Smith/615-574-0917

References:

1. Open literature on the use of gas chromatography for determination of organic contaminants.
2. EPA SW-846 methods.
3. See also CHAR-100-OL for portable gas chromatograph

PHOTON ELECTRON REJECTING ALPHA LIQUID SCINTILLATION

CHAR-97-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: Technical Requirements—DOE Order 5400.5, ANSI N13.12, NRC 5, and NUREG 1.86. Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Photon electron rejecting alpha liquid scintillation (PERALS). A very sensitive (pCi/g) technique for measuring alpha-emitting isotopes.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α)

Waste produced—Spent acid and organic scintillants (1.5 mL/sample)

Overall cost—About \$20K for setup of analytical equipment; about \$50/sample

Efficacy/strengths—It is a very sensitive, isotopically-selective method that is capable of detecting 1 pCi/g of individual isotopes in soil or water. It is ideal for uranium. It has a commercially available reader, and scintillant cocktails are specific to each alpha emitter. It has the lowest detection limits of rapid radiological techniques.

Science/Technology Needs: Scintillation cocktails that are not toxic under RCRA law need to be developed for use in PERALS.

Implementation Needs: A PERALS laboratory is already set up at the ORNL DOSAR facility and at the Y-12 Plant. It can be adapted for rapid "on-line" monitoring of both airborne and loose contamination.

Author: R. B. Gammage/615-574-6256. Reviewed by C. S. Dudley/615-576-2712 and Z. W. Bell/615-574-6120

PHOTON ELECTRON REJECTING ALPHA LIQUID SCINTILLATION

CHAR-97-OY

References: J. R. Cadieux, "Evaluation of a Photoelectron-Rejecting Alpha Liquid-Scintillation (PERALS) Spectrometer for the Measurement of Alpha-Emitting Radionuclides," *Nucl. Instrum. & Methods in Phys. Res.* **A299**(1990), 119-122 (1990).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: PCBs

Reference Requirements: EPA cleanup standard; the most stringent is 10 ppm PCBs by weight. Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: PCB immunoassay kit. Sample wipes are used to collect smear samples from suspected contaminated areas. Wipes are extracted in the field and subjected to test kit screening.

Status: Accepted. Used as a screening method for PCBs in soils and on surfaces. Immunoassay-based screening kits are commercially available for screening of PCBs in soil. Application to sample wipe for oils must be developed and validated.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (Oil, PCBs, VOCs, TCE, ...) Inorganic (Hg, Pb)

Waste produced—Small amounts of reagents (for example, 20 cc methanol sample extract and two disposable plastic tubes per sample wipe).

Overall cost—\$80/test (\$35/kit; 20–30 tests per person per day)

Efficacy/strengths—Thoroughly evaluated in DOE site restoration to minimize false negatives with the commercially available test kit. It is very sensitive (5 ppm).

Science/Technology Needs: Field screening kits for PCBs in soils are commercially available. Methods for the acquisition and validation of the wipe samples must be developed and validated.

Implementation Needs: The technology is ready to apply to soils and should be used for routine analyses at Y-12. Development cost for wipe samples estimated at \$100K.

Author: R. B. Gammage/615-574-6256. Reviewed by: J. M. Hiller/615-574-0287

References:

1. Evaluated in DOE Analytical Field Screening Program. Contact Larry Waters or Dr. Roger Jenkins at ACD-ORNL.
2. USEPA, *Superfund Innovative Technology Evaluation: Technology Profiles, Sixth Edition*, EPA/540/R-93/526, November 1993.

PORTABLE GAS CHROMATOGRAPH/ELECTRON CAPTURE DETECTION

CHAR-100-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic

Reference Requirements: Ten ppb polychlorinated biphenyls (PCBs) in soil is the strictest EPA limit. Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Portable gas chromatograph/electron capture detection (GC-ECD) for analyzing PCBs. PCBs are extracted, from soils and dust for example, with a solvent. The extract is then injected into a field gas chromatograph that separates the sample components and selectively detects halogenated species, including PCBs. Arachlors (PCB mixtures) are identified by their separation pattern and can be quantified using specific chromatographic peaks. Useful for testing around power transformers.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, PCBs, volatile organic compounds, trichloroethylene, ...)

Waste produced—10–50 mL of methanol and hexane extractant/sample

Overall cost—A few dollars per analysis

Efficacy/strengths—Procedure was developed and verified by the EPA. One technician can conduct 20–30 analyses/day. One manager at a Superfund site estimated that on-site data during removal saved \$500K (360 analyses in 8 days). The method is accurate to below 10 ppb.

Science/Technology Needs: Written standard operating procedures are needed.

Implementation Needs: GC/ECD devices, ~\$15K/unit

Author: R. B. Gammage/615-574-6256. Reviewed by: D. D. Smith/615-574-0197

**PORTABLE GAS CHROMATOGRAPH/ELECTRON
CAPTURE DETECTION**

CHAR-100-OY

References:

1. Dr. Tom Spittler, EPA Region I Director. Method description is available. User courses are given regularly.

See CHAR-94-OL for laboratory GC.

SYNCHRONOUS FLUORESCENCE SCREENING FOR POLYCYCLIC AROMATIC HYDROCARBONS

CHAR-101-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organics [polycyclic aromatic hydrocarbons (PAHs)]

Reference Requirements: Ten ppb for general PAHs. Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Synchronous fluorescence screening for polycyclic aromatic hydrocarbons (PAHs). When light of a specific wavelength is directed onto a sample, certain organic compounds (such as PAHs) absorb and re-emit that light (fluoresce) at a higher wavelength. Analytes can be differentiated because they absorb and fluoresce at different wavelengths. Fluorescence intensity is quantitatively proportional to analyte concentration.

Status: Demonstration; instrumentation commercially available.
Predemonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, ...)

Waste produced—Solvent in milliliter quantities/sample

Overall cost—A few dollars per analysis

Efficacy/strengths—An easy concentration step allows detection at drinking water standards. It takes a few minutes per analysis.

Science/Technology Needs: Technology needs to be validated in the EPA program. Numerous situations at ORNL have involved the use of oils and lubricants.

Implementation Needs: Capital costs, \$25K for reader and \$25K for spectrofluorimeter; development costs, \$200K

Author: R. B. Gammage/615-574-6256. Reviewed by W. Fisher/615-574-5042

September 1994
Decontamination and Decommissioning

**SYNCHRONOUS FLUORESCENCE SCREENING
FOR POLYCYCLIC AROMATIC HYDROCARBONS**

CHAR-101-OY

Reference: I. M. Warner and L. B. McGown, "Molecular Fluorescence, Phosphorescence, and Chemiluminescence Spectroscopy," *Anal. Chem.* **64**(12), June 15, 1992.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Sodium iodide-germanium gamma spectroscopy. The NaI detector is used to quantify gamma emitters in items that allow the gammas to penetrate.

Status: Accepted; demonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α , β , γ)

Waste produced—None

Overall cost—Labor for each analysis

Efficacy/strengths—The technology is useful for detection of all gamma emitters. The system can measure radioactivity below the surface. A high-resolution Ge detector may be needed to determine correction factors for attenuation. Sensitivity for ^{235}U = 10 g; for ^{238}U = 500 g through detection of gamma-emitting daughters.

Science/Technology Needs: Correction factor methodology needs to be established.

Implementation Needs: Capital costs, \$20K for detectors

Author: R. C. Hagenhauer/615-574-8835. Reviewed by Z. W. Bell/615-574-6120

References: *Nondestructive Assay Measurements of Gaseous Diffusion Process Equipment*, K/ITP-237.

PROPORTIONAL COUNTER FOR ALPHA AND BETA ACTIVITY

CHAR-108-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Proportional counter for alpha and beta activity. Alpha and beta radiation emitted from the surface contamination is detected and counted.

The device is a gas-filled volume, usually cylindrical, which contains an electrode wire along the cylinder axis. Alpha and beta particles that enter the gas cause gas ionization. The ions drift toward and are collected at the charged electrode wire and thereby counted. The number of ions generated is proportional to the type and energy of the incident radiation.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α , β)

Waste produced—None

Efficacy/strengths—It has sensitivity to 100 dpm/cm². Relatively inexpensive probes are available for wide areas of measurement, or it can be made small to measure inside pipes.

Science/Technology Needs: This is a well-established technology.

Implementation Needs: Normal; capital costs, \$500–\$10K

Author: R. C. Hagenhauer/615-574-8835. Reviewed by: Z. W. Bell/615-574-6120

References: MMES staff members.

FLUORESCENCE DIAGNOSIS OF CONTAMINATED SURFACES

CHAR-110-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Fluorescence diagnosis of contaminated surfaces. Allows identification of areas to sample for quantitative analysis.

Status: Predemonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Fluorescence of UF_6 , U, UO_2F_2 , etc.; inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—None

Overall cost—Depends on the specific application. Equipment, assembly, and testing will comprise the costs.

Efficacy/strengths—It may be used in situ, with or without automation and fiber optics for limited access areas. It can certify when the surface/area is cleaned/decontaminated, which eliminates extra processing. It may eliminate expensive laboratory characterization, some degree of heavy equipment transport, and dismantling. It can monitor the status of processing in real-time. In general, fluorescence is sensitive to ppm for airborne situations.

Science/Technology Needs: Needs separation/speciation lab and field tests

Technical Task Plan OR121201 (FY 1992); relevance: high

Implementation Needs: The required equipment such as a laser (light source), optics, detectors, personal computers (for data acquisition), and interfaces must be purchased. Staff with extensive experience on-site in laser applications and optical design, field testing, and

other appropriate technologies are available. On-site laboratory storage, assembly, and staging are available. The procedures must be written.

Author: S. W. Allison/615-576-2725. Reviewed by: D. D. Smith/615-574-0197

References: Much literature that supports the efficacy of fluorescence-based analytical instrumentation for in situ sampling, measurement, and characterization, including:

1. S. W. Allison et al., "Use of Fiber Optics and Laser-Induced Fluorescence for Remote Measurements in Strong Rotation," K/TS-11, 018, MMES, Oak Ridge Gaseous Diffusion Plant (June 1983) [Also published in *Proc. Fifth Workshop on Gases in Strong Rotation*, (University of Virginia, June 5-9, 1983)].
2. S. W. Allison, G. T. Gillies, M. R. Cates, and B. W. Noel, "Fiber Optic Pulsed Laser Delivery for Remote Measurements," *Opt. Eng.* **26**(6), 538-546 (June 1987).

LASER ABLATION; INDUCTIVELY COUPLED PLASMA; ATOMIC EMISSION SPECTROSCOPY

CHAR-111-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Laser ablation; inductively coupled plasma; atomic emission spectroscopy. Laser ablation is the use of a laser to vaporize a small portion of a sample. This vapor is subsequently transported to an ICP or ICP-MS for qualitative and quantitative analysis.

Status: Demonstration

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (all elements)

Overall cost—Development, \$1M; low cost/sample

Efficacy/strengths—This technology will be accepted by the end of this year (1993) following the Fernald demonstration. It allows multiple elemental analyses.

Science/Technology Needs: Improvement in the robotic process for site-specific conditions (e.g., floor, wall, ceiling) is needed.

Implementation Needs: Instrumentation development is needed. Development costs are estimated at ~\$1M. Integration of laser ablation, ICP, and atomic emission technologies is the issue here.

Author: S. Y. Lee/615-574-6316. Reviewed by T. Ross/615-574-4888

References: Contact Marvin Anderson, Ames Laboratory, Ames, Iowa 50010-6739; 515-294-4580.

ON-LINE SUPERCRITICAL FLUID EXTRACTION— MULTIDETECTOR GAS CHROMATOGRAPHY

CHAR-115-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic

Reference Requirements: Regulations for total petroleum hydrocarbons and polychlorinated biphenyls (PCBs). Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: On-line supercritical fluid extraction—multidetector gas chromatography (SFE-GC). Supercritical fluids extract 1–10 g of soil, and the extracted analytes are accumulated in a cryofocusing unit prior to gas chromatography. Multiple detectors permit the simultaneous analysis of several pollutant types, such as petroleum hydrocarbons, PCBs, and pesticides. The method is much faster than conventional methods and produces no hazardous waste. It may be useful for decontamination processing.

Status: Predemonstration; technology requires final development and demonstration.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk assessments; regulatory

Applicable contaminant evaluation: Organic (oil, PCBs, volatile organic compounds, trichloroethylene, ...)

Waste produced—Only 1–10 g of dry soil; no solvent water

Overall cost—Could be 25% or less than that of separate conventional analyses

Efficacy/strengths—Organic and solvent-contaminated wastes are not generated, as opposed to conventional organic analytical methods. There is also much faster sample turnaround (1–2 h) than with conventional methods (a few days). One commercial instrument is already available for the rapid determination of total petroleum hydrocarbons in soil by on-line SFE-GC. The SFE of PCBs has also been demonstrated. It appears highly likely that the two methods can be combined to allow the rapid and simultaneous analysis of both contaminants and others in soil and other solids. In addition, it shows possible use in decontamination of object/metals, or as an efficient sample extract on technique.

**ON-LINE SUPERCRITICAL FLUID EXTRACTION—
MULTIDETECTOR GAS CHROMATOGRAPHY**

CHAR-115-OY

Science/Technology Needs: The technology requires optimization for the most efficient extraction and chromatography of both total petroleum hydrocarbons and PCBs in a single operation.

Implementation Needs: Capital costs, \$60K; development costs, \$250K. The extraction and analysis conditions must be optimized, and the method validated.

Author: W. H. Griest/615-574-4864. Reviewed by: D. D. Smith/615-574-0197

References: Manufacturer's literature (CCS, Suprex, Dionex).

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium, mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory methods

Technology: High-pressure ashing (HPA) for sample preparation. HPA is useful for the dissolution of organics and other difficult to dissolve materials. HPA involves acid digestion under elevated pressure which permits the use of higher acid temperatures than can be achieved at atmospheric pressure. For example, nitric acid, under pressure at 300°C, becomes a very strong oxidizer. Some development could be applied to field methods.

Status: Demonstration; commercially available but lacks validation to meet QA requirements

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radiochemical and inorganic species in an organic matrix

Waste produced—Depends on sample analyzed but typically small

Efficacy/strengths—Eliminates the need for perchloric acid with most applications

Science/Technology Needs: Commercially available but lacks sufficient validation to meet quality assurance requirements. Some special sample types may be at the development stage.

Implementation Needs: Some equipment and personnel are currently available at ORNL to develop new procedures but needs to be expanded to meet increased work load. Development costs, \$60K–\$120K/year for 2 years.

Author: J. M. Keller/615-574-7063. Reviewed by T. Ross/615-574-4888

References: MMES staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample preparation

Technology: Radioactive sample preparation. Conventional EPA and other sample preparation methods are adapted for the unique requirements of preparing radioactive samples for analysis. Methodology focuses on the DOE ALARA principle and regulatory agency acceptance. Methods minimize waste generation and maximize efficiency in radiochemical hood, glove box, and hot cell work.

Status: Demonstration; current work shows that methods can be adapted to meet these needs.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic; inorganic; radioactive elements; physical properties

Waste produced—One objective of the technology is to reduce the production of secondary laboratory waste.

Overall cost—Determined by the specific procedure and its complexity, but cost minimization is an objective of the technology. Method development costs and duplication of effort among the DOE laboratories will be eliminated.

Efficacy/strengths—Technology development leads to improved radioactive sample preparation methods, which are specifically designed to be conducted in a radiochemical hood, glove box, or hot cell. They will be more efficient, observe the ALARA principle, and are more likely to be accepted by regulators.

Science/Technology Needs: Adaptation of EPA and other methods, and development of new technologies for the safe and efficient preparation of radioactive samples for analysis.

Implementation Needs: Development costs, \$500/year for two years; personnel and facilities are available.

Author: W. H. Griest/615-574-4864. Reviewed by T. Ross/615-574-4888

References:

1. B. A. Tomkins, et al., "Determination of Regulatory Organic Compounds in Radioactive Waste Samples. Volatile Organics in Aqueous Liquids," *Anal. Chem.* **61**, 2751-2756 (1989).
2. B. A. Tomkins, et al., "Determination of Regulatory Organic Compounds in Radioactive Waste Samples. Semivolatile Organics in Aqueous Liquids," *Anal. Chem.* **62**, 253-257 (1990).
3. W. H. Griest and J. L. Botts, "Radioactive Waste Analysis: An Inside Look," *Environ. Lab*, 14-19, April/May, 1992.

ANALYTICAL METHODS FOR CHELATORS AND DECONTAMINATION AGENTS

CHAR-206-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Analytical methods for chelators and decontamination agents. DOE-unique compounds, which are not amenable to analysis by conventional EPA methods, are determined in contaminated samples by chemical derivation and GC, GC-MS, or supercritical fluid chromatography methods.

Status: Demonstration; an existing method shows the technology is promising, but further development is needed. Maybe useful as decontamination process technique. Needs use definition.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technology assessments

Applicable contaminant evaluation: Organic (chelators, decontamination agents)

Waste produced—One mL/sample

Overall cost—\$500–\$1K/sample

Efficacy/strengths—Method will provide information on organic constituents, which affect environmental transport of metals and radionuclides, and also the choice of remediation technologies that cannot be determined using current EPA analytical methods.

Science/Technology Needs: Adapt current methods to the specific constituents and sample matrices at the Y-12 site, conduct method performance validation, and prepare an analytical protocol. ASO development group, at Y-12, has instrumentation and staff.

Implementation Needs: Development costs, \$250K

Author: W. H. Griest/615-574-4864. Reviewed by: D. D. Smith/615-574-0197, N. J. Williams/615-574-0952, and J. C. Franklin/615-574-2284

Reference:

1. A. P. Toste, T. R. Pahl, R. B. Lucke, and R. B. Myers, "Analysis of Complex Mixtures in Nuclear Wastes," pp. 133-150, *Health and Environmental Research on Complex Mixtures*, eds., R. H. Gray et al., Pacific Northwest Laboratory, Richland, Wash., 1987.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organics

Reference Requirements: Refer to the appropriate Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Capillary electrophoresis. A very high resolution separation tool applicable to the determination of charged inorganic or organic species on the basis of electrophoretic mobilities. With micellar mobile phases, neutral species also can be separated by partition. The minimal sample volume requirements (a few nanoliters injected from a few microliters) make it ideal for the analysis of samples with very limited volumes or high radioactivity.

Status: Demonstration; the technology is gaining widespread acceptance in biomedical applications and appears useful for remedial action and waste management applications. Instrumentation commercially available.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic; inorganic; radioactive elements

Waste produced—Minimal, <1 mL

Overall cost—\$300/sample

Efficacy/strengths—Very high resolution method with wide applications, including polar organic degradation products of DOE-unique organic compounds and chelated metals or radionuclides in waste tanks and burial grounds. Absolutely minimal sample volume requirements (a few microliters for nanoliter injections) make the technology ideal for highly limited or very radioactive sample analysis.

Science/Technology Needs: Adaptation and validation for the specific target compounds and sample matrices at the Y-12 site.

Implementation Needs: Hardware costs, \$30K–\$60K; development costs, \$250K

Author: W. H. Griest/615-574-4864

Reference:

1. K. H. Row, W. H. Griest, and M. P. Maskarinec, "Separation of Modified Nucleic Acid Constituents by Micellar Electrokinetic Capillary Chromatography," *J. Chrom.* **409**, 193-203 (1987).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample preparation

Technology: Supercritical fluid extraction of organics. Analytes are efficiently extracted from a sample in an extraction cell under supercritical fluid conditions of high pressure and relatively low temperature. Analyte decomposition is reduced, and recoveries are improved versus those achieved by conventional extraction methods.

Status: Predemonstration; technology requires final development

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technology assessments; regulatory

Applicable contaminant evaluation: Organic; radioactive elements; inorganic

Waste produced—Very little versus that produced by conventional extraction methods (~1 mL)

Overall cost—\$100–\$200/sample

Efficacy/strengths—The method is applicable to both organic analytes and, with the addition of chelators to the extraction fluid, to both metals and radionuclides. It achieves a faster, more efficient extraction than conventional methods, and vastly reduces solvent waste. It can be directly interfaced with an analytical instrument for highly sensitive analyses. It applies particularly in preparing building materials for analysis.

Science/Technology Needs: Extraction conditions need to be optimized for the specific target analytes and matrices at ORNL. If radionuclides and metals are targeted, then the most effective chelators must be selected.

Implementation Needs: Hardware costs, \$30K; development costs, \$300K; automated equipment costs, ~\$100K

Author: W. H. Griest/615-574-4864

References: Instrument manufacturer's data sheets (Suprex, ISCO, Dionex, CCS).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Fissile material

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Fissile material locator/profiler. The ^{252}Cf Source-driven Neutron/Gamma Noise Analysis Method is an absolute method that (1) determines the neutron multiplication constant, k , of fissile systems without the need for calibration at or near the critical state; (2) provides information that can be used for fissile assays and distributions; and (3) because of its high sensitivity to various parameters, such as cross sections, can be used to validate calculations. (See CHAR-44-OL and CHAR-107-OL.)

Status: Approved; ^{252}Cf Neutron/Gamma Noise Analysis Method has been used successfully by Knolls Atomic Power Laboratory, Los Alamos, Hanford and Argonne National Laboratories, and the Oak Ridge Y-12 Plant.

Waste produced—None

Efficacy/strengths—The ^{252}Cf Source-driven Neutron/Gamma Noise Analysis Method is invaluable for fissile systems for which there are criticality safety concerns. It determines the neutron multiplication factor, k , without requiring calibration at or near the critical state, as required by other subcriticality measurement methods. The method is nonintrusive, and measurements can be made accurately and in short periods of time. Fissile assays and distributions studies, as well as system characterizations, can be performed. The data acquisition and processing system has been developed and is available for measurements.

Science/Technology Needs: Although the method has been used successfully to measure the subcriticality of a wide range of fissile configurations, each new configuration needs to be studied to determine the proper positioning of detectors to assure accurate measurements.

Implementation Needs:

Author: John T. Mihalczko/615-574-5577

References:

There are over 200 references by the author covering both liquid and solid fissile systems. The following three references indicate the capability of the measurement method:

1. J. T. Mihalczo et al., "Dynamic Subcriticality Measurements Using the ^{252}Cf -Source Driven Noise Analysis Method," *Nucl. Sci. and Eng.* **104**, 314-338 (1990).
2. J. T. Mihalczo et al., " ^{252}Cf -Source-Driven Neutron Noise Measurements of Subcriticality for an Annular Tank Containing Aqueous Pu-U Nitrate," *Nucl. Tech.* **94**, 336-360 (1991).
3. J. T. Mihalczo et al., " ^{252}Cf -Source-Driven Noise Measurements of Subcriticality for a Slab Tank of Aqueous Pu-U Nitrate," *Nucl. Sci. and Eng.* **107**, 35-57 (1991).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Bubble dosimeters for neutron flux. These dosimeters are an integral part of a field neutron dosimetry system for use where neutron sources and shielding are not well known. They are capable of measuring neutron doses equivalent in low-level fields and providing simple spectral information. This information can be compiled with the response from existing personal thermoluminescence dosimeter detectors to provide appropriate energy correction factors and improve the accuracy of personnel neutron dosimetry.

Status: Accepted; active and passive dose equivalent detectors and passive spectrometer sets. Further development will be needed for use as a passive or active neutron spectrometer in an alarming neutron dose rate meter.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation:

Applicable contaminant evaluation: Radioactive elements (n)

Waste produced—Very little; devices are reusable, some can be zeroed

Overall cost— Nonrecurring costs—imaging equipment, \$2K; commercially available reader, \$50K. Recurring costs— ~\$2-\$3/measurement; ~\$100/passive unit (6/set)

Efficacy/strengths—Limit of detection is about 0.5 mrem. Energy range of spectrometer set is 0.01-20 MeV, nearly the dose equivalent for personal dosimetry units. This system will enhance ALARA practice by providing immediate indication of neutron dose. The technology will be most useful in waste management and remedial action activities involving handling of unknown amounts of ²⁵²Cf or other neutron-emitting radionuclides.

Science/Technology Needs: The measurement principle is well established for measuring neutron flux around personnel. The technique must be evaluated for potential confounding effect in other, less benign, environments. Development of acoustic coupler for applications

requiring real-time measurement of neutron dose rate and a less expensive, automated bubble counter for reliable processing of passive detection results.

Implementation Needs: Normal. Estimated \$200K development costs.

Author: M. A. Buckner/615-574-5859

Reference:

1. *Radiation Protection Dosimetry*, **32**(1), 21-43 (1990).

X-RAY FLUORESCENCE FOR IN SITU MONITORING OF TOXIC HEAVY METALS

CHAR-219-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Detection/measurement-field

Technology: X-ray fluorescence (XRF) for in situ monitoring of toxic heavy metals. An energetic X-ray source is used to irradiate the sample. The emitted X rays are detected and analyzed to identify the element source. This technology can be used for in situ monitoring of toxic heavy metals in paints, on surfaces, and in soils. Portable XRF units are commercially available and have been widely used for screening painted surfaces for lead contamination.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (Pb, Hg, Cr, Tc, U, Th, Ra, etc.)

Waste produced—None

Overall cost—\$50K/unit; each unit could be used for years while making many measurements (5–25) per day (~\$25/measurement for labor costs).

Efficacy/strengths—This technology is already in use in HUD and EPA programs for the detection of lead in paint. Commercially available units are portable and are capable of analyzing homogenized samples for heavy metal contamination. Also, the units can be used to detect metals in situ or on surfaces. The technology was evaluated in the EPA Site Program. Limit of detection for mercury is 9 ppm. For uranium in air, it is 4 $\mu\text{g}/\text{m}^3$. The instrument can detect 50 dpm α inside a painted surface.

Science/Technology Needs: Personnel training in interpretation of results

Implementation Needs: Substrate effects need to be studied. The lower limit of detection for some metals on surfaces needs to be measured (~\$200K).

**X-RAY FLUORESCENCE FOR IN SITU MONITORING
OF TOXIC HEAVY METALS**

CHAR-219-OY

Author: D. L. Wilson/615-576-3208. Reviewed by: J. A. Basford/615-576-4337

References:

1. Scitec Corp. (map spectrum analyzer).
2. HNU Systems, Inc. (SEFA/P portable X-ray fluorescence analyzer).

FRACTALS USED TO SELECT MODELS FOR MATERIAL TRANSPORT IN POROUS MEDIA

CHAR-225-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Data Analysis/Management

Technology: Fractals used to select models for material transport in porous media. Many different computer models exist for calculating material transport rates, flow patterns, and other effects in porous media. Fractal concepts can be used to discriminate, using measurements based on length scales, between flow regimes and characteristics of the media through which flows occur to determine what model assumptions and which approximations are appropriate for a particular application. Fractal concepts should be particularly useful in selecting a candidate from a set of lumped parameter models.

Status: Evolving; one of the early application areas of the mathematical concepts of fractals and fractal geometry has been to flow in porous media. Another is flow control in fluidized beds.

Waste produced—Not applicable

Overall cost—Unknown

Efficacy/strengths—Ability to model and understand material transport mechanisms

Science/Technology Needs: Application of fractal concepts (and chaotic behavior in dynamic systems) to physical systems is a new field. Enough is understood about applying the concepts to problems of flows in porous media to be useful in classifying existing models, if models exist for transport of Hg in porous media. Useful prior to Phase I and II activities.

Implementation Needs: This technology deals with concepts and applications which are expressed in mathematical terms. Hence, hardware development requirements are minimal or nonexistent. Implementation will be almost entirely in terms of software that must be developed and applied to results obtained from other application software or to data. Estimated development cost is \$400K.

Author: John K. Munro, Jr./615-574-0635. Reviewed by: M. W. Sherrill/615-574-2569

September 1994
Decontamination and Decommissioning

**FRACTALS USED TO SELECT MODELS
FOR MATERIAL TRANSPORT IN POROUS MEDIA**

CHAR-225-OY

Reference:

1. D. L. Turcotte, *Fractals and Chaos in Geology and Geophysics*, Cambridge University Press, 1992.

FIBER-OPTIC SYSTEMS FOR MEASURING MULTIPLE PHYSICAL VARIABLES

CHAR-248-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Physical (structural) problems

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Fiber-optic systems for measuring multiple physical variables. Fiber-optic technology provides a medium for transmitting information efficiently, with low noise levels, requiring low (sometimes no) power, and occupying very little space. Optical fibers can be manufactured so that a single fiber with appropriate coatings can be used in the simultaneous measurement (using multiple wavelengths of light) of more than one physical quantity, such as radiation level and temperature. Multiple fibers can be combined for compact sensor arrays that provide spatial information. These and other attributes make this technology an attractive candidate for long-term monitoring applications.

Status: Predemonstration; proof-of-principle of this technology can be demonstrated in the monitoring structural integrity using different types of sensors. Other possible uses include devices suitable for use in underground waste storage tanks. Current development efforts are directed toward extending the range of types of measurements that can be combined into a single device for use in hazardous waste storage monitoring applications.

Efficacy/strengths—This technology can be usefully applied to some combinations of measurements that require no power (passive monitoring). Optical fiber technology can be used very effectively in applications in which limited access paths are a prime consideration. Optical fiber can also provide electrical isolation.

Science/Technology Needs: A range of applications can be developed using this technology.

Implementation Needs: Extensive investments should not be required to set up basic fabrication facilities. This technology should lend itself well to economies of scale in the manufacture of rugged, replaceable devices that should require low (or no) maintenance.

Author: John Munro, Jr./615-574-0635. Reviewed by: J. M. Hiller/615-574-0287

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Data analysis/management

Technology: Analysis of censored data. Analysis of data containing a mixture of censored (less than limits) and observed data to produce mathematically defensible means, estimates, and confidence intervals. The data produced during an environmental investigation usually consists of the amount of various elements found in the sample. Often the amount of an element in the sample is less than the measuring device is able to detect that element, or it is just not there. In such cases the amount of the element indicated in the sample data, is given as less than some amount. As a result, rules-of-thumb have been created to produce estimates of mean levels and confidence bounds, even if the data is of dubious quality. Current literature contains correct and logically sound methods of dealing with this problem. It is assumed that the data may have to be transformed to obtain a usable probability distribution. This proposal is to further adapt these methods of analysis to fit the problems present in the current environmental data. The result would be mathematically defensible estimates and confidence bounds.

Status: Demonstration; some work is available in the literature. The application likely will have to be expanded to meet current needs; thus, some research into working with censored data is probably necessary, as opposed to use of published work.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic; organic; physical

Waste produced—None

Overall cost—Estimated at \$50K to determine methodology for analysis of censored data applicable to Bldg. 9201-4 and set up required software, but may vary according to amount of research to be done.

Efficacy/strengths—This kind of estimation routine will allow for the full use of both censored (less than) and observed data in an orderly way in the data analysis. It will eliminate the need

for "rules of thumb" that are currently used when censored (less than) data are present in the data set.

Science/Technology Needs: Computer work station with access to appropriate data bases and research of existing applications of censored data.

Implementation Needs: Access to appropriate data bases, computer time, mathematical development time, and programming time

Author: W. E. Lever/615-574-3129. Reviewed by: J. M. Hiller/615-574-0287 and M. W. Sherrill/615-574-2569

References: See appropriate JASA and EPA articles.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Data analysis/measurement

Technology: Quality control for measurement processes. Much of the creditability of an experimental study is governed by the creditability of the data used in the study. The quality of the measurement process must be continually evaluated to determine the quality of technical measurements. This evaluation can be done by injecting NIST-type standard samples into the measurement stream, then monitoring the results over time. Use of standard samples requires the development of quality control charts that monitor the mean and variability levels of the measurement devices. In addition to monitoring the consistency of the measurement process, information must be developed that gives limits on the accuracy of the process. This again can be done through the measurement of NIST-type standards.

Status: Accepted. The necessary protocols exist that are applicable to the characterization techniques used for D&D and to develop new protocols where required.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive; inorganic; organic; physical

Waste produced—Not applicable

Overall cost—Cost of evaluating control data are computer and personnel changes; however, if the current QC program in the lab is not capable of providing all standards needed for the application, further expense may be incurred to upgrade.

Efficacy/strengths—Quality Control is practiced by most laboratories and production processes to ensure production of a quality product.

Science/Technology Needs: Data from standards evaluations, which may need additional blind standards for comparison but which will rely primarily on existing protocols used in the Analytical Services Division.

Implementation Needs: Access to Quality Standard measurements. The estimated implementation cost is \$25K to verify.

Author: M. W. Sherrill/615-574-2569. Reviewed by: W. E. Lever/615-574-3129

References: Statistical literature.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sampling design

Technology: Sequential sampling plans. A series of sampling efforts will likely be required in the investigation of previously unexplored waste sites. The location of each set of new samples will depend on the information gained from the previous samples. This procedure will require a sampling plan design, coupled with a sequential type decision procedure that will specify when to continue sampling and where to locate the new sample points. Consultation with a statistician knowledgeable in this area should follow to ensure proper sampling is carried out.

Status: Accepted

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: risk assessment; regulatory

Applicable contaminant evaluation: Radioactive; inorganic; organic; physical

Waste produced—None

Overall cost—Personnel

Efficacy/strengths—Directly applicable to hot spots

Science/Technology Needs: Real experimental site data (which may not be available until actual Phase I D&D activities) is required to determine the appropriate sequential sampling plan. Additional follow-on analysis of data may be required to verify proper techniques are used and are applied as conditions change in D&D activities.

Implementation Needs: Initial planning time and ongoing consulting with project manager and those generating characterization data. Estimated at one week of time per specific application (material and contaminant) requiring sampling.

Author: W. E. Lever/615-574-3129. Reviewed by: J. M. Hiller/615-574-0287 and M. W. Sherrill/615-574-2569

References: Professional literature.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Sampling design

Technology: Spatial sample and data analysis plans. Spatial sampling and data analysis plans are often used to evaluate areas for unknown deposits. Generally these plans are used by mineral and oil explorers to map soil structures and mineral deposits. This type of information will also be needed during the study of waste deposits, so that appropriate decision procedures can be formulated for the further exploration of the site or the clean up of the site.

Status: Accepted. Probably easier to recognize at the early evaluation stages than sequential sampling needs.

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: General

Waste produced—None

Overall cost—Personnel

Efficacy/strengths—Directly applicable to finding hot spots. Spatial sampling plans have been used in geostatistic applications (mining/oil exploration) for a long time. A wealth of recent work has been produced in other areas for the specific purpose of site characterization.

Science/Technology Needs: Personnel and computer time; access to survey data. The actual applicability of this technology to D&D of Alpha-4 is not understood at this time, but as D&D proceeds, this may become important to better characterize Building 9201-4.

Implementation Needs: Time, data, and ongoing consulting with project manager and those generating characterization data. Estimated at one week of time per specific application (material and contaminant) requiring sampling.

Author: W. E. Lever/615-574-3129. Reviewed by: M. W. Sherrill/615-574-2569 and J. M. Hiller/615-574-0287

References: Professional literature.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic, Mercury

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Solid sorbent sampling for mercury and airborne organics. Airborne target species and co-contaminants are collected by drawing air through tubes packed with one or more sorbent materials. Different sorbents may be used for different classes of compounds. The tubes are sealed following sampling and returned to a laboratory for analysis. Conversely, they may be analyzed on-site using field analytical equipment. Sorbed species are usually removed by solvent elution or thermal desorption.

Status: Demonstration; technology is available, but validation is required for particular sampling conditions and target species.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Organics (volatile organic compounds; semivolatile organic compounds)

Waste produced—None to minimal. Some sorbent tubes can be reused, while others cannot. Total waste for nonreusable tubes is ~10 cm³/sample.

Overall cost—\$1–\$50/tube, depending on sorbent

Efficacy/strengths—It permits collection and concentration of vapor phase organic contaminants for subsequent analysis.

Science/Technology Needs: Methods must be developed and validated for specific applications. Reusable sorbent tube technology needs demonstration.

Implementation Needs: Depends on contaminants, development costs ~\$125K

Authors: M. R. Guerin and R. A. Jenkins/615-574-4862. Reviewed by: D. D. Smith/615-574-0197

References:

1. C. E. Higgins, R. A. Jenkins, and M. R. Guerin, "Organic Vapor Phase Composition of Sidestream and Environmental Tobacco Smoke from Cigarettes," pp. 140-145, *Proceedings of the 1987 EPA/APCA Symposium on Measurement of Toxic and Related Air Pollutants*, (1987).
2. R. A. Jenkins, C. E. Higgins, T. M. Gayle, G. W. Allin, and R. R. Smith, "Field experiences with a multisorbent arrayed sampler for the in situ collection of vadose zone volatile organic compounds," presented at the Third International Symposium for Field Screening Methods for Hazardous Wastes and Toxic Chemicals, Las Vegas, February 24-26, 1993.
3. Numerous EPA and OSHA methods.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Alternative: Field methods

Technology: Gas chromatography in the field. Using flame ionization, electron capture, thermal conductivity, photoionization, flame photometric, or thermionic a variety of environmentally important analytes can be determined.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Minimal, it is only necessary to vent gas chromatographs using nondestructive detectors

Overall cost—\$5K–\$25K/instrument, depending on needs, plus miscellaneous supplies (carrier goods, etc.)

Efficacy/strengths—It has high efficacy for a very wide variety of organic species, both volatile and semivolatile organics. It is good for a variety of species, and the analysis time is 10–60 min.

Science/Technology Needs: Technology needs are minimal. While improvements can be made, in general, the technology is ready to use.

Implementation Needs: A variety of gas chromatography equipment exists already at ORNL and may be useful for many needs. Various groups at ORNL are capable of handling large samples (see references).

Author: J. M. Storey/615-576-7607. Reviewed by: D. D. Smith/615-574-0197

References:

1. There is a tremendous amount of open literature on the use of gas chromatography for determination of organic contaminants associated with decontamination and decommissioning activities. Also EPA SW-846 methods.
2. Organic Analytical Group; Analytical Chemistry Division, ORNL.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods/Laboratory methods

Technology: Portable gamma-ray scintillometers. In either a single-channel or multichannel format, they are available commercially. The instrument consists of a sodium or cesium iodide crystal, photomultiplier tube, portable battery operated power supply, pulse height analyzer, and readout. For the single-channel case, the energy window is set appropriately for the isotope of interest, the measurement is made, and the reading can be converted directly into a value for the isotope concentration. When using a multichannel instrument, the isotope spectra are recorded simultaneously and may be permanently stored and analyzed at a future time.

Status: Accepted

Temporal areas of evaluation: Pretreatment; posttreatment

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (γ)

Waste produced—None

Overall cost—\$11K for a complete portable multichannel spectroscopy system

Efficacy/strengths—The application is for quantitative measurements of fixed low-level gamma contamination on surfaces. This technique is not useful for small ($<100 \text{ cm}^2$) or hard-to-access areas. The detection limit is 5–10 mg of surface contamination for thorium and uranium with measurement times of one hour. Good for all gamma emitters.

Science/Technology Needs: Robotic technology is needed for remote control applications.

Implementation Needs: The technology is commercially available. Specialized detector holders may need to be developed for particular applications.

Author: K. E. Meyers/615-574-1504. Reviewed by: Z. W. Bell/615-574-6120

Reference:

1. J. T. Hutton and J. R. Prescott, "Field and Laboratory Measurements of Low-Level Thorium, Uranium, and Potassium," *Nucl. Tracks Radiat. Meas.* **20**, 367-370 (1992).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Organics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Surface-enhanced Raman scattering. Raman spectroscopy is a technique that uses scattered light resulting from photon-molecule collisions to investigate molecular properties. When a monochromatic light beam is incident on systems such as gases, liquids, or solids, most of it is transmitted without change. However, a small portion of the incident light is scattered. Although most of the scattered light has the same wavelength as the incident radiation, a small part of it occurs at different wavelengths. The scattering of light at different wavelengths is called Raman scattering. Surface-enhanced Raman scattering (SERS) is greatly enhanced Raman scattering observed from molecules adsorbed at a roughened metal surface.

Status: Evolving

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—1–100 mL/sample (dependent on the procedure)

Overall cost—Highly variable, \$250K–\$400K

Efficacy/strengths—This technology is a combination of electrochemical and spectroscopic techniques which can yield highly specific information about contaminant identity and quantity in the sampled system.

Weaknesses—Requires sample workup. May have too many variables to be very useful to range of samples expected.

Science/Technology Needs: System development and validation for specific needs

Implementation Needs: Hardware costs, \$10K–\$250K; development costs, ~\$150K

Author: R. D. Shelton/615-574-5042. Reviewed by J. A. Basford/615-576-4337

References: M. M. Carrabola, R. B. Edmonds, and R. D. Rauh, *Anal. Chem.* **59**, 2559-2563 (1987).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium, mercury and other metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory methods

Technology: Neutron activation analysis (NAA). This analytical technique is based on the measurement of sample radioactivity after activity has been induced by irradiation with neutrons. Can use Californium (Cf-252) as neutron source. Neutrons generated interact with ^{235}U or other fissile actinides to cause fission. The delayed neutron ejections from fission are then detected to quantify the fissile content.¹

Status: Accepted; mature technology in laboratory with some development, could be applied to field methods.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganics; total organic halides; fissile material (^{235}U , ^{233}U , ^{239}Pu); long-lived fission products (^{129}I).

Waste produced—Minimal solid waste generated; usually no liquid waste produced. \$50

Overall cost—\$200/sample, if NAA facility already in place. Is at lower end of range for gross fissile analysis of fissile actinides²

Efficacy/strengths—Nondestructive; sample can be archived and reanalyzed; generates minimal waste, and is a mature technology. System may be portable or fixed, for small samples or large. It is possible to screen 55-gal waste drums and detect as little as 10 mg (or less) of fissile material per drum. (Overall cost for barrel/drum: \$800/barrel-analysis.³

Equipment capital costs for most sensitive unit = \$0.5M to \$1.5M.)⁴

Science/Technology Needs: Mature technology; start-up studies need to be done to evaluate possible interferences.

Implementation Needs: Systems for fixed-site installation are commercially available. Some development required to adapt these systems for portable field applications. Instrumentation

and personnel currently exist at ORNL but need to be expanded to meet the expected work load. Estimated cost of upgrade and expansion is \$250K.

Author: J. M. Keller/615-574-7063. Reviewed by: D. E. Beck/615-574-0706 and Z. W. Bell/615-574-6120

References:

1. W. D. Ehmann and D. E. Vance, *Radiochemistry and Nuclear Methods of Analysis*, John Wiley & Sons, Inc. (1991).
2. S. J. Parry, "Activation Spectrometry in Chemical Analysis", *Chemical Analysis Series*, Vol. 119, John Wiley & Sons, Inc., 1991.
3. *Pajarito Scientific Corp.* (505) 662-4377
4. Capability and Limitation Study of the DOT Passive-Active Neutron Waste Assay Instrument, LA-12237-MS.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory methods/Field methods

Technology: Gamma-ray spectrometry. It is used for the measurement of gamma emitting radionuclides. A complete system consists of a detector, amplifier, analog to digital converter, multichannel analyzer (MCA), and computer. Modern detectors are high purity germanium (HPGe) and are available with efficiencies that range from 10% to >100% with typical energy resolution of 1.8-2.0 KeV FWHM at 1332 KeV.

Status: Mature technology

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: All gamma emitters

Waste produced—Minimal waste generated

Efficacy/strengths—Mature and well accepted technology

Science/Technology Needs: The technology is commercially available and mature.

Implementation Needs: Some equipment/personnel are currently available at ORNL but need to be expanded to meet the expected increase in work load. Detector costs range from \$10K-\$50K, depending upon the required efficiency and resolution. The MCA/computer/software requirements for acquiring and processing spectra adds another \$10K to total cost.

Author: J. M. Keller/(615)574-7063. Reviewed by Z. W. Bell/615-574-6120

References:

1. MMES staff members.
2. Literature publications.
3. In-house methods.

SAMPLING INTERFACE SYSTEM FOR SURFACE CONTAMINATION BY ORGANICS

CHAR-271-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Sample collection

Technology: Sampling interface system for surface contamination by organics. The technology consists of a rapid thermal surface heating interface system for direct sampling, ion trap mass spectrometry, allows rapid determination of organics, such as polychlorinated biphenyls and fuel or oil residues, from surfaces such as floors, walls, and even insulation.

Status: Conceptual

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Organics

Waste produced—None

Overall cost—To be determined

Efficacy/strengths—Interface and software will allow rapid and positive determination of organic surface contamination in the field using direct sampling ion trap mass spectrometry.

Science/Technology Needs: Development of rapid heating interface and software for rapid contaminant identification by direct sampling ion trap mass spectrometry are needed.

Implementation Needs: Development costs, \$775K over 3 years

Author: W. H. Griest/615-574-4864. Reviewed by Z. W. Bell/615-574-6120

References:

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Physical (Air Movement Monitoring)

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: 3-dimensional wind gauge measurements. There are two types of technical approaches:

1. Three propeller vanes mounted perpendicular to one another—the mechanical motion of each propeller vane is caused by air movement in the plane that the vane rotates in, with increasing air velocity causing increased propeller movement (higher revolutions per minute).
2. Sonic anemometer that measures the time of flight of sound waves (wave velocity) in air—the wave velocity is sensitive to the air movement, hence the basis for measuring air movement. Sound wave velocity is measured in three orthogonal directions.

Status: Both technologies are commercially available.

Orthogonal Propeller Vanes

Amount of Waste Produced—NA

Efficacy/Strengths—Very robust device that has an excellent low-frequency response. Measurements allow good modeling of air transport to support dispersion modeling.

Weakness—Poor turbulence (high frequency) resolution.

Cost is about \$0.4K/axis and \$2K for data logger for \$3.2K total.

Sonic Anemometer

Amount of Waste Produced—NA

Efficacy/Strengths—Good turbulence resolution, no moving parts, able to detect very low air velocities, reliably measures the vertical air movement component to model surface-to-air flux.

Weakness—More difficult to interpret data output compared with orthogonal vanes technology.

Cost—\$7K to \$50K.

Science/Technology Needs: None

Implementation Needs: Normal

Author: R. L. Fellows/615-576-5632

References:

1. R. P. Hosker, Atmospheric Turbulence and Diffusion Laboratory, 615-576-1248

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: Refer to Volume 1, Chapter 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

To be eligible for exemption from EPA regulation, the maximum concentration of mercury must be less than 50 pg/m³ at the plant property line.

Personnel exposure limits to mercury in air

Contaminant	Time-weighted average		Short-term exposure limit	
	ICGIH	Y-12	ICGIH	Y-12
Mercury alkyls	0.01 mg/m ³	0.005 mg/m ³	0.03 mg/m ³	0.015 mg/m ³
All mercury except alkyls	0.05	0.025	NA	NA
Aryl and inorganic mercury	0.1	0.05	NA	NA

The OSHA air contaminant limit for mercury vapor is 0.05 mg/m³.

Subelement: Characterization

Alternative: Field methods

Technology: Mercury air monitoring. The principal non-routine continuous measurement in D&D of Alpha-4 will be for Hg in air. There are two basic approaches to Hg air monitoring. Area Monitoring can be conducted utilizing direct reading instrumentation (e.g., Jerome Mercury Vapor Analyzer) or by using integrated media sampling (e.g., HYDRAR sampling tubes with calibrated air sampling pumps). Area direct reading instrumentation provides real-time sampling results and is used to conduct semi-quantitative surveys. Integrated sampling methods provide quantitative sampling results and require laboratory sample analysis with a corresponding delay in reported sample results. Integrated sampling can be used to fulfill both area and personal monitoring requirements. Also, see CHAR-312-OY.

Status: Accepted. Direct reading instrumentation uses one of two methods of detection; UV light or gold film. The Jerome Mercury Vapor Analyzer uses the gold film technique for mercury detection while the Bacharach Mercury Vapor Sniffer uses UV. The Y-12 Industrial Hygiene (IH) Department uses the Jerome, because it better suits their needs.

For integrated sampling, the Y-12 IH Department follows NIOSH Method 6009, which utilizes HYDRAR sampling tubes and calibrated air sampling pumps. The only waste produced by this method is a small amount of sampling media and analysis reagents.

Amount of Waste Produced—minimal

Overall Cost—\$10K-\$35K

Efficacy/strengths—Portable direct reading instrumentation allows in-situ real time measurements. Its use in highly contaminated areas poses decontamination problems.

Science/Technology Needs: This is a mature technology but it needs better methods for field calibrations and methods for long-term testing.

Implementation Needs: Telemetry, to PCs, will help establish data bases for local areas without the contamination situations. Depending on the method utilized, implementation requires equipment, sampling media, trained personnel, and access to an approved laboratory.

Author: S. M. Hollenbeck/615-574-9547 and D. D. Smith/615-574-0917

References: EPA-600/4-79-020, Y/DZ-68, vendor literature

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: The Federal Safe Drinking Water Act standard for mercury in drinking water is 2 µg/L, maximum contaminant level (MCL). Refer to Vol. 1, Chap. 8, for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory methods

Technology: Water analysis, for Hg and for other metals of concern will be necessary for secondary waste characterization.

Status: Accepted

Amount of Waste Produced—~25 cc/sample

Overall Cost—\$50K, instrumentation, \$5/sample

Efficacy/Strengths—On-line electrometric monitors are commercially available. Optical methods are also available.

Science/Technology Needs: This is a mature technology but needs demonstration to assess particular methods such as calibrations, ranges, interferences, for on-line (demand) use.

Implementation Needs: Demonstration of reliability of electrode technology and calibration schemes.

Author: D. D. Smith/615-574-0917

References:

1. EPA-600/4-79-020, Y/DZ-68, std. chemical methods, technical and vendor literature.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Physical

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Noise monitoring—continuous noise measurement during D&D operations for occupational safety and health. Noise monitoring is divided into two distinct methodologies. Area noise measurements are conducted with a sound level meter (SLM) that meets the specific requirements of the sampling situation. A type II SLM meets the minimum requirements as set forth by OSHA and ANSI. Depending on the specific application, instruments with different capabilities can be used to measure continuous and/or impulse/impact noise sources. Instruments are also available that can be used to measure specific frequencies to determine engineering control feasibility and applicable noise methods. Personal noise monitoring uses noise dosimeters that may integrate personnel noise exposure over an entire work shift. These instruments must meet minimum specification requirements as set forth by OSHA and ANSI.

Status: Accepted and commercially available. There is a wide variety of noise instrumentation available, depending on the specific application and need.

Amount of Waste Produced—Negligible. These are direct-reading instruments.

Overall Cost—The cost of instrumentation varies widely based on the specific application. The cost of an SLM can range from approximately \$800 to >\$10,000, depending on the specifications requested. Noise dosimeters can cost from \$1500 to \$5000 or more.

Efficacy/Strengths—Both methods of noise measurement are quantifiable if ANSI and OSHA guidelines (e.g., instrumentation specifications, sampling protocol, calibration, etc.) are followed.

Science/Technology Needs: None

Implementation Needs: Noise measurement equipment and trained personnel are required for implementation.

Author: S. M. Hollenbeck/615-574-9547

EM Problem: Decontamination and decommissioning

Y-12 Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: General (Structural Integrity)

Reference Requirements: Refer to Vol. 1, Chap. 10, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field Methods

Technology: Structural sensors; real-time sensors for detecting (and warning of) deflection in the structural members of the building. These sensors would provide continuous real-time data to a centralized data handling and annunciator system.

Status: Previous structural analysis of the Alpha-4 building revealed that some of the floor slabs and beams may not provide sufficient capacity for the movement of heavy forklifts and temporary storage of heavy equipment. Similar structural tests have been performed on structures throughout the world. Critical locations for testing have been identified through a floor load analysis of Alpha-4. The types of sensors and data handling equipment remain to be determined.

Amount of Waste Produced—None

Efficacy/Strengths—NA

Science/Technology Needs: None recognized

Implementation Needs: No unusual needs

Estimated project costs—\$1M which includes \$600K for testing implementation and completion, \$400K for continuous monitoring.

Capital cost—<\$50K

Author: Pam Hoskins/615-576-3369

References:

1. Tests have been performed on the first floor slab of Bldg. 9204-1 (Beta-1). See report Y/EN-611 (1981).

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury in water

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

The Federal Safe Drinking Water Act standard for mercury in drinking water is 2 µg/L, maximum contaminant level (MCL). The preliminary remediation goal for mercury cleanup in Alpha-4, based on EPA equations, is 6.1×10^2 µg/kg soil.¹

Subelement: Characterization

Alternatives: Field analysis

Technology: Method for rapid field analysis of mercury in water, soil, and sediment. A method for analysis of mercury in the field has recently been developed. It uses a chemical pretreatment followed by analysis of the headspace mercury vapor to determine the concentration of mercury in the matrix of interest. A portable, commercially available analyzer is the only equipment needed. The method is rapid, inexpensive, and free of matrix interferences.

Status: Predemonstration. The method was developed for water and expanded to soils and sediments. In the procedure for mercury in water, a small sample is placed in an ordinary polypropylene bottle. A reductant is added to convert all of the mercury in the sample to the elemental state, followed by manual shaking for one minute. The elemental Hg will partition between the solution and the headspace, according to Henry's Law. The headspace vapor is then sampled and analyzed using a portable mercury vapor analyzer (the Jerome Model 411 Gold Film Mercury Analyzer, in these experiments) with an acid gas trap in the train. For soils, two methods are given—one for mercury concentrations >50 µg/g, and one for lower concentrations—each requiring preliminary desorption of particle-bound mercury using a strong acid. After desorption, the reducing agent is added, and sampling and analysis proceed similarly to that for water, except that dilution is necessary.

Amount of Waste Produced—Very little. Method will produce about 100 mL water/sample or 5 mL acid/sample.

Overall Cost—The Jerome portable analyzer costs under \$5000, or it can be rented for approximately \$250/week. The cost of containers and chemicals is trivial (<\$5/sample). This procedure may save money, in the long run, by better defining areas needing lab analysis, thereby eliminating unneeded tests.

Efficacy/Strengths—The preliminary work indicates that a linear response is obtained over

several orders of magnitude in the region of environmental interest, for elemental mercury. The range in water is from 0.1 $\mu\text{g/L}$ to 30 $\mu\text{g/L}$. In soil, the range is about 1.4 $\mu\text{g/g}$ to 66 $\mu\text{g/g}$, and can be extended to higher concentrations by dilution of acid extracts prior to reduction. The vapor analyzer is small, lightweight, easy to use, and produces rapid results. It shows high sensitivity and selectivity, requires only a small sample, and has a low limit of detection. No extensive training is required. This method is intended for locating regions to be sampled for laboratory analysis rather than as a substitute for laboratory analysis. It may also find use in bench-scale water treatment development by providing a rapid means to detect breakthrough in column studies.

Weaknesses—The only potential weakness appears to be reliability of the portable analyzer under heavy use for soil and water analysis. The analyzer was designed for industrial hygiene application in air surveys for mercury vapor. This weakness may be overcome by use of the recommended external acid gas trap and by regular operational checks using a mercury vapor standard (available as an optional calibration kit from the manufacturer).

Science/Technology Needs: The manufacturer of the portable analyzer should consider any modifications to the instrument to improve its reliability in this application.

Implementation Needs: Minimal. Procedure optimization, for soils. Soil field analysis requires several steps more than water, at this point.

Author: R. R. Turner/615-574-7856. Reviewed by: Dianne E. Beck/615-574-0706

References:

1. Mark Stack, Y-12 Risk Assessment Team Leader for Alpha-4, 615-574-8497
2. A. A. Kriger and R. R. Turner, "Fast Field Analyzer for Measuring Mercury in Water, Soil and Sediment Using Static Headspace Analysis", TBP.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Physical

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Coating assayer. An instrument is needed that would provide elemental and spatial information about any coated surface (walls, floors, metal equipment, etc.) and beneath the coated surface (coating). The instrument would operate a cluster of instruments that could reside on an oversized x-y translation stage. As envisioned, the instrument would contain some combination of X-ray fluorescence, X-ray transmission (two sided), neutron activation analysis, and neutron prompt capture gamma. Data would be sent to the master data base.

Status: Preconceptual; no system currently exists that includes these analysis tools.

Amount of Waste Produced—None

Efficacy/Strengths—Complete elemental analysis of wall and floor surface areas.

Science/Technology Needs: Technology integration of these instruments

Implementation Needs: Not evaluated

Author: J. H. Hiller/615-574-0287

References: Author

GAS CHROMATOGRAPH/ELECTRON CAPTURE DETECTION FOR MEASURING ORGANIC MERCURY

CHAR-311-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: The Federal Safe Drinking Water Act standard for mercury in water is 2 µg/L, maximum contaminant level (MCL). For mercury in air, the OSHA contaminant limit is 0.05 mg/m³. For disposal at the Y-12 Sanitary Landfill, contaminated wastes must contain no more than 12 ppm (non-RCRA hazardous waste). Refer to Vol. 1, Chap. 8, for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory methods

Technology: Gas Chromatography with electron capture detection (ECD) is used for separating and indirectly measuring monomethylmercury and other R-Hg-X organic concentrations. In most cases, the ECD is a gas chromatography detector that measures the concentrations of gaseous components by the degree to which they absorb electrons from a ⁶³Ni beta-radiation source. The ECD is particularly sensitive to halogens, such as chloride. Thus, the concentration of monomethylmercury in a sample may be determined by converting the methylmercury ion to a gaseous halide form (such as methylmercury chloride [CH₃HgCl]) and using gas chromatography (GC) separation with electron capture detection.

Status: Accepted

Amount of Waste Produced—10–50 ml methanol and hexane extractant per sample.

Overall Cost—A few dollars per analysis

Efficacy/Strengths—The method is fairly sensitive (in the 50 pg range). It was developed and verified by the EPA for PCBs. It can be made portable (see CHAR-100-OY).

Weaknesses—Since the method is analyzing the halides and not the monomethylmercury directly, it is prone to serious interferences from other halogenated compounds. The success of ECD analysis for monomethylmercury depends on having a large amount of methylmercury forms compared to other similar halides and a good technique on the part of the analyst.

Science/Technology Needs: None, mature technique.

Implementation Needs: ECD devices, ~\$15K/unit.

Author: D. E. Beck/615-574-0706

**GAS CHROMATOGRAPH/ELECTRON CAPTURE DETECTION
FOR MEASURING ORGANIC MERCURY**

CHAR-311-OY

References:

1. K. R. Henke et al., *Critical Review of Mercury Contamination Issues Relevant to Manometers at Natural Gas Industry Sites*, GRI-93/0117, Gas Research Institute, Environment and Safety Research Department, Chicago, Illinois, August 1993.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals, inorganic species in air

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

To be eligible for exemption from EPA regulation, the maximum concentration of mercury in air must be less than 50 picograms/m³ at the plant property line.

Personnel exposure limits to mercury in air

Contaminant	Time-weighted average		Short-term exposure limit	
	ICGIH	Y-12	ICGIH	Y-12
Mercury alkyls	0.01 mg/m ³	0.005 mg/m ³	0.03 mg/m ³	0.015 mg/m ³
All mercury except alkyls	0.05	0.025	NA	NA
Aryl and inorganic mercury	0.1	0.05	NA	NA

The OSHA air contaminant limit for mercury vapor is 0.05 mg/m³.

Subelement: Characterization

Alternatives: Laboratory methods

Technology: Photoacoustic spectrometry (PAS). For mercury detection and quantification, mercury atoms in the vapor are electronically excited by a pulsed 2543.7 nm laser beam. In the presence of a diatomic or polyatomic quenching gas, the excited mercury transfers energy by radiationless transfer (impacts, etc.) to the quenching gas, causing the energy to be converted into vibrational and translational energy. The pulse rate of the laser is consequently converted into a series of pulses of "hot gas" pressure waves that are then detected as sound waves (equivalent to the laser pulse rate) by an acoustic microphone. The intensity of the sound is proportional to the number of quenched atoms per unit volume of gas.

Status: Demonstration. Commercially available for mercury analysis but is new enough to be considered somewhat novel.^{1,4}

Detection limit for Hg: ~10 pg, equivalent to 0.06 micrograms/m³ for 13 s sampling time. An established technology for detection of molecular species in air (ammonia, for example).

Amount of Waste Produced—None

Efficacy/Strengths—Early reports and preliminary investigations (from Frontier Geosciences) indicate that PAS has the potential to be the most sensitive of the analytical techniques for mercury in air, although probably not approaching the sensitivity of cold vapor atomic fluorescence for other media. The laser excitation technique allows very great selectivity for Hg so other potential interferences are eliminated. There is no sample preparation and the technology can run samples in continuous mode. Does not detect organomercury or inorganic (oxidized) Hg(I) or Hg(II).

Weaknesses—Factors limiting the widespread use of PAS include background acoustic noise, dependencies of the signal on carrier gas pressure and flow rate, and the higher cost and complexity of the electronics. Although PAS is much simpler optically than other techniques, advanced electronics are necessary to segregate the signal from the much louder and random acoustical noise that is typically found in a laboratory.

Science/Technology Needs: Possible interferences need to be identified and confirmation of analytical quantitation is necessary over a range of expected Hg concentrations.

Implementation Needs: Development/demonstration cost—\$200K,

Operating cost—Negligible

Capital costs—<\$75K

Authors: D. E. Beck/615-574-0706 and R. L. Fellows/615-576-5632

References:

1. *Threshold Limit Values*, ACGIH (ISBN 0-036712-99-6)
2. Y-12 Standard (1993)
3. K. R. Henke et al., *Critical Review of Mercury Contamination Issues Relevant to Manometers at Natural Gas Industry Sites*, GRI-93/0117, Gas Research Institute, Environment and Safety Research Department, Chicago, Illinois, August 1993.
4. DSIR, Petone, New Zealand.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury in air

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

To be eligible for exemption from EPA regulation, the maximum concentration of mercury must be less than 50 pg/m³ at the plant property line.

Personnel exposure limits to mercury in air

Contaminant	Time-weighted average		Short-term exposure limit	
	ICGIH	Y-12	ICGIH	Y-12
Mercury alkyls	0.01 mg/m ³	0.005 mg/m ³	0.03 mg/m ³	0.015 mg/m ³
All mercury except alkyls	0.05	0.025	NA	NA
Aryl and inorganic mercury	0.1	0.05	NA	NA

The OSHA air contaminant limit for mercury vapor is 0.05 mg/m³.

Subelement: Characterization

Alternatives: Field methods

Technology: A device that detects gaseous forms of mercury with a gold-coated piezoelectric crystal. The vapor pressure of elemental mercury over elemental gold is extremely low and mercury rapidly forms an amalgam with gold. As the gold/mercury amalgam is formed on the gold-plated surface of the piezoelectric, the additional mass causes the crystal oscillation frequency to change and is the basis for detection and quantification.

Status: Predemonstration

Amount of Waste Produced—None

Efficacy/Strengths—The device is very portable.

The device that was tested exhibited detection limits in the microgram (10⁶ pg) range. Interferences will be caused by other materials that will be deposited on gold or the amalgam.

Science/Technology Needs: Interferences need to be identified. Sensitivity increases needed for most applications. Tests for methyl mercury detection need to be performed.

Implementation Needs: Instrument costs: est. <\$10K
Operating costs: est. <\$5/sample
Development costs: est. \$250K

Author: D. E. Beck/615/574-0706. Reviewed by R. L. Fellows/615/576-5632

References:

1. K. R. Henke et al., *Critical Review of Mercury Contamination Issues Relevant to Manometers at Natural Gas Industry Sites*, GRI-93/0117, Gas Research Institute, Environment and Safety Research Department, Chicago, Illinois, August 1993.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury on equipment and building surfaces

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

Maximum acceptable surface contamination for mercury: 100 micrograms/100cm² (Y-12 Industrial Hygiene).

Waste disposal limits: Y-12 landfill—12 mg/kg (12 ppm); Envirocare—4 mg/kg (4 ppm).

Subelement: Characterization

Alternatives: Field methods

Technology: Chemical reaction test kit for mercury. For colorimetric analysis, wipe samples from a surface that are oxidized with a strong oxidant. Subsequent treatment with diphenyl carbazone (which reacts with free Hg²⁺) forms a purple color that can be analyzed colorimetrically.

Status: Conceptual. Procedure needs to be tested and certified. Method is based on a commercially available test for organic contamination that uses Hg²⁺ as a test component. Detection limits: in the microgram (10⁶ pg) range.

Amount of Waste Produced—Minimal. A small quantity of test reagent containing mercury, diphenyl carbazone.

Efficacy/Strengths—Low cost because of the simplicity of the required test kit. Prior to the development of atomic spectroscopy methods, mercury analysis, as with most other metals, was frequently accomplished by using colorimetric techniques. These methods are still in use throughout the developing world and even in many routine testing laboratories in the United States because of their low cost and simplicity. Can be developed into a field test kit. Analysis time is ~10 min/sample.

Weakness—To be determined. Since dyes are not very element specific, interferences by halides may occur.

Science/Technology Needs: Interferences at Y-12 need to be determined.

Implementation Needs: Capital costs: \$0

Operating cost: est. \$10/sample

Demonstration cost: est. <\$250k

Author: R. L. Fellows/615/576-5632

References:

1. Dexsil Corporation, Hamden, CT 06517.

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury in air

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

To be eligible for exemption from EPA regulation, the maximum concentration of mercury must be less than 50 pg/m³ at the plant property line.

Personnel exposure limits to mercury in air

Contaminant	Time-weighted average		Short-term exposure limit	
	ICGIH	Y-12	ICGIH	Y-12
Mercury alkyls	0.01 mg/m ³	0.005 mg/m ³	0.03 mg/m ³	0.015 mg/m ³
All mercury except alkyls	0.05	0.025	NA	NA
Aryl and inorganic mercury	0.1	0.05	NA	NA

The OSHA air contaminant limit for mercury vapor is 0.05 mg/m³.

Subelement: Characterization

Alternatives: Field methods

Technology: Gold amalgam mercury analyzer. Mercury vapor (in air) flowing past a thin gold wire is deposited on the wire and forms a gold amalgam. The resistance of the gold wire, a function of the amount of amalgam present, is monitored to quantify the amount of Hg present. The amalgamated gold is heated to volatilize the Hg and regenerate the gold surface for reuse. Acid gas trap on air input is recommended to improve instrument reliability and gold wire life.

Status: Accepted and in use at Y-12. Instruments are commercially available.

Amount of Waste Produced—Spent soda lime if an acid gas trap is used.

Efficacy/Strengths—Portable units allow in situ real-time measurements on a continuous basis. Detects only elemental mercury. Less prone to interferences than UV detection method.

Weaknesses—Its use in contaminated areas poses decontamination problems. The gold surface is very sensitive to contamination, which permanently degrades the gold detection element (hence instrument) performance. An acid gas trap (soda lime) is sometimes used to

remove potentially damaging contaminants from the air stream prior to introduction into the instrument.

Detection limit: 500 picograms elemental Hg (equivalent to 0.003 mg/m³ for 13 s sampling time). Volatile alkylmercury compounds are not detected.

Science/Technology Needs: The reliability of the technology needs to be improved. In the way it is currently being used at Y-12, there are often unexplained calibration problems leading to a lack of instrument reliability. The types of contamination that degrade or modify the gold film performance should be investigated to improve measurement performance.

Implementation Needs: Instrument cost: <\$5K
Operating cost: estimated at <\$20/sample including supplies and instrument calibration.

Author: R. L. Fellows 615/576-5632, Scott Hollenbeck 615/574-9547

References:

1. K. R. Henke et al., "A Critical Review of Mercury Contamination Issues Relevant to Mercury Manometers at Natural Gas Industry Sites," Gas Research Institute Report GRI-93/0117, August 1993.
2. Arizona Instruments, Model 411 Gold Film Mercury Analyzer (Jerome analyzer). Arizona Instrument Co., Phoenix, AZ 85040.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: The proposed Federal Safe Drinking Water Act standard for natural uranium is 20 µg/L (equivalent to 30 pCi/L). For disposal at the Y-12 Plant Sanitary Landfill, the radioactive waste standard is <32 pCi/gm. Refer to Vol. 1 for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory Analysis

Technology: Thermal emission mass spectrometry. Uranium heated on a tungsten filament produces ions that are separated according to mass- to -charge ratios, and are detected electronically. This technique determines accurate uranium isotopic composition using sub-microgram quantities of uranium.

Status: Accepted; commercially available. In routine use at the Y-12 Plant.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Uranium isotopic abundance. Uranium detection limits: <<1 microgram sample.

Amount of Waste Produced—Variable, depending on type and U concentration

Overall Cost—\$195/sample

Efficacy/Strengths—It is an accepted method for accurate uranium isotopic measurement. Uses microgram amounts of uranium. Unambiguous concentration data are available by isotope dilution mass spectrometry.

Science/Technology Needs: None. Routine laboratory procedure.

Implementation Needs: Hardware costs are \$250K–625K. Instrumentation is available at the Y-12 Plant.

Author: N. J. Williams/615-574-0952. Reviewed by J. C. Franklin/615-574-2284

References: MMES Staff Members

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Lab methods

Technology: Ultra-violet fluorescence spectrometry. The detection and analysis of uranium using ultra-violet excitation and resulting fluorescence from UO_2^{2+} ions. Samples are oxidized, mixed in a salt matrix and illuminated by a ultra-violet light source. Resulting uranium fluorescence emissions in the 400 -500 nm range are usually detected photometrically for quantitative purposes.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Applicable contaminant evaluation: U

Waste produced— small U-contaminated salt pellets

Overall cost—\$75/sample

Efficacy/strengths—Luminescence detection provides extremely sensitive detection. A very well established analytical procedure for U. Detection limits for U: .001 mg/L.

Weakness: procedure very sensitive to fluorescence quenching, therefore quantitation problems. Sample preparation is a laborious and meticulous process.

Science/Technology Needs: The technology is mature. Automation of sample preparation would be a significant advance.

Implementation Needs: Hardware is available at Y-12, K-25, X-10. Capital costs, <\$100K.

Author: R. L. Fellows/615-576-5632

References:

1. K-25 Analytical Services Analysis Procedure ACD-183707.R1 and ACD-173708.R1.

ORGANIC SCINTILLATION DETECTORS FOR GAMMA RAYS

CHAR-326-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: DOE surface decontamination guidelines for natural uranium, ^{235}U , ^{238}U , and associated decay products, are 5,000 dpm/100 cm² average, 15,000 dpm/100 cm² maximum, and 1,000 dpm/100 cm² removable.¹ Refer to Vol. 1 for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be named.

Subelement: Characterization

Alternatives: Field methods

Technology: Organic scintillation detectors for gamma rays. Gamma ray detectors using organic liquid or solid (plastic) viewed by a photomultiplier tube or other optically sensitive device. Scintillator is at least 2.5 cm thick for efficient detection of gamma rays. Instrument includes power supply (110 VAC or battery operated), amplifier, multichannel or single channel analyzer, and readout. Device is useful for survey for radioactive materials but usually cannot be used to identify species.

Status: Accepted. Commercially available.

Applicable contaminant evaluation: Radioactive (gamma)

Amount of Waste Produced—None

Overall Cost—<\$10K for complete instrument

Efficacy/Strengths—If species identification is unimportant, these scintillators are significantly less expensive than inorganic crystals and solid state detectors.

Science/Technology Needs: None, if to be hand-held or used in a laboratory. Robot technology is necessary to carry instrument into areas too contaminated for humans.

Implementation Needs: Technology is commercially available. Instrument may need to be purchased as components, then assembled.

Author: Z. W. Bell/615-574-6120

References: Author

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: Refer to Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

DOE surface decontamination guidelines for natural uranium, ^{235}U , ^{238}U , and associated decay products, are 5,000 dpm/100 cm² average, 15,000 dpm/100 cm² maximum, and 1,000 dpm/100 cm² removable.

Subelement: Characterization

Alternatives: Field methods/Laboratory methods

Technology: Solid-state charged particle detectors. For example, silicon surface barrier detectors. Instrument consists of a detector, power supply, single-channel or multichannel analyzer, and readout device. Device is capable of determining the energy spectrum of alpha or beta particles impinging on the detector and thereby identifying the radioactive species. Device can be used either in a vacuum for greatly improved energy resolution or with a small air gap between source and detector. When surveying objects, this device only examines the surface; it cannot see below layers of paint. Device can be adapted to monitor for airborne alpha/beta emitters.

Status: Accepted. Commercially available.

Applicable contaminant evaluation: Radioactive (alpha and beta)

Amount of Waste Produced—None

Overall Cost—<\$25K for complete instrument

Efficacy/Strengths—Can be used in field on surfaces without vacuum chamber. Can distinguish between different alpha-emitting species. Very low background; not sensitive to gamma- or x-rays; not sensitive to naturally occurring gamma radiation background. Detection limit is as low as 0.05 counts (alpha) per hour per square centimeter of detector surface.

Science/Technology Needs: None, if to be hand-held or used in a laboratory. Robot technology is necessary to carry instrument into areas too contaminated for humans or for use in remote applications.

Implementation Needs: Technology is commercially available. Instrument would probably need to be purchased as components, then assembled.

Author: Z. W. Bell/615-574-6120

References:

1. DOE Order 5400.5, DOE/CH/8901 (Gilbert et al., 1989)
2. EGG Ortec, Oak Ridge, TN.

ALPHA/BETA DETECTION WITH ORGANIC SOLID SCINTILLATORS

CHAR-328-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: DOE surface decontamination guidelines for natural uranium, ^{235}U , ^{238}U , and associated decay products, are 5,000 dpm/100 cm² average, 15,000 dpm/100 cm² maximum, and 1,000 dpm/100 cm² removable.¹ Refer to Vol. 1 for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be named.

Subelement: Characterization

Alternatives: Field methods

Technology: Alpha/beta detection with organic solid scintillators. A thin plastic scintillometer coupled to an optically sensitive device is used to detect alpha and beta particles. The scintillator must have a thin window or be enclosed in a light-tight shroud for the charged particles to be able to penetrate. Device is not sensitive to gamma rays. Device consists of a plastic scintillator (thin plastic foil), optically sensitive device, power supply, amplifier, single-channel or multichannel analyzer, and readout.

Status: Accepted

Applicable contaminant evaluation: Radioactive (alpha and beta)

Amount of Waste Produced—None

Overall Cost—<\$25K for complete instrument

Efficacy/Strengths—Scintillator is inexpensive. Photomultiplier is not necessary; Si diode coupled to a red-emitting plastic is possible. Large area (>100 cm²) possible.

Science/Technology Needs: Testing of response of red-emitting scintillators to alpha and beta radiation.

Implementation Needs: All components are commercially available. Robotic technology is necessary if device is to be deployed in areas too contaminated for entry by humans.

Author: Z. W. Bell/615-574-6120

References:

1. DOE Order 5400.5, DOE/CH/8901 (Gilbert et al., 1989)

ALPHA/BETA DETECTION WITH INORGANIC SCINTILLATORS

CHAR-329-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: DOE surface decontamination guidelines for natural uranium, ^{235}U , ^{238}U , and associated decay products, are 5,000 dpm/100 cm² average, 15,000 dpm/100 cm² maximum, and 1,000 dpm/100 cm² removable.¹ Refer to Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be named.

Subelement: Characterization

Alternatives: Field methods

Technology: Alpha/beta detection with inorganic scintillators. An inorganic crystal (NaI, CsI, BGO, for example) is used to detect alpha and beta particles. Scintillator is coupled to an optically sensitive device such as a photomultiplier tube. Device consists of scintillator, photomultiplier tube, power supply, amplifier, single-channel or multichannel analyzer, and readout device.

Status: Accepted

Applicable Contaminant Evaluation: Radioactive (alpha and beta)

Amount of Waste Produced—None

Overall Cost—<\$25K for complete instrument

Efficacy/Strengths—Device would have more sensitivity to gamma radiation than an organic scintillator. Scintillator must have thin entrance window; this is a concern for hygroscopic crystals such as NaI and CsI, which also must be hermetically sealed. BGO might be useable without a window if enclosed in a light-tight box.

Science/Technology Needs: Probably little. Commercial instruments using NaI with thin entrance windows exist. BGO may need to be investigated.

Implementation Needs: Technology is commercially available. Robotic technology is necessary if device is to be deployed in areas too contaminated for entry by humans.

Author: Z. W. Bell/615-574-6120

References:

1. DOE Order 5400.5, DOE/CH/8901 (Gilbert et al., 1989)

PROMPT FISSION NEUTRON AND GAMMA RAY DETECTION

CHAR-330-OY

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: The proposed Federal Safe Drinking Water Act standard for natural uranium is 20 µg/L (equivalent to 30 pCi/L). DOE surface decontamination guidelines for natural uranium, ^{235}U , ^{238}U , and associated decay products, are 5,000 dpm/100 cm² average, 15,000 dpm/100 cm² maximum, and 1,000 dpm/100 cm² removable.¹ Refer to Vol. 1 for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be applied.

Subelement: Characterization

Alternatives: Field methods/Laboratory methods

Technology: Prompt fission neutron and gamma ray detection. Prompt fast neutrons and/or gamma rays from thermal neutron induced fission of ^{235}U are detected. This technology can conceivably probe through thick materials. Device consists of thermal neutron source, fast neutron detector(s), gamma ray detector(s) (probably Ge), power supplies, amplifiers, multichannel analyzer, and readout device.

Status: Predemonstration. This is a technology integration issue.

Applicable Contaminant Evaluation: Fissile material

Amount of Waste Produced—None

Overall Cost—Probably >\$100K to develop instrument. Probably >\$100K per complete instrument.

Efficacy/Strengths—Fission events with coincident neutrons and characteristic gamma rays are a unique signature of the presence of fissile material. Device would be sensitive to natural background of gamma radiation and possibly naturally occurring uranium.

Science/Technology Needs: No commercial device is known at this time. All components can be purchased and assembled into an instrument. Extensive simulations would probably be required to determine the efficacy of this technology. Calibration studies are necessary.

Implementation Needs: Adequate neutron/gamma shielding to protect personnel from neutron source.

Author: Z. W. Bell/615-574-6120

References:

1. DOE Order 5400.5, DOE/CH/8901 (Gilbert et al., 1989)

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: The proposed Federal Safe Drinking Water Act standard for natural uranium is 20 µg/L (equivalent to 30 pCi/L). DOE surface decontamination guidelines for natural uranium, ^{235}U , ^{238}U , and associated decay products, are 5,000 dpm/100 cm² average, 15,000 dpm/100 cm² maximum, and 1,000 dpm/100 cm² removable.¹ Refer to Vol. 1 for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be named.

Subelement: Characterization

Alternatives: Field methods/Laboratory methods

Technology: Neutron-induced radioactivity. The radioactivity of fission products and ^{239}U generated by the neutron irradiation of a sample containing fissile material is detected. A Ge detector is used to identify gamma rays from the sample after a cool-down period following irradiation. Method is similar to neutron activation analysis because it is applied to trace element analysis. Device consists of a transportable neutron source, Ge detector, power supply, amplifier, multichannel analyzer, and readout device.

Status: Predemonstration

Applicable Contaminant Evaluation: Uranium. Total uranium detection limit: NA.

Amount of Waste Produced—None

Overall Cost—>\$100K for complete instrument

Efficacy/Strengths—Can be very sensitive to trace amounts of fission product and ^{239}U . Can be made insensitive to natural gamma radiation background.

Science/Technology Needs: Sensitivity needs to be determined. All components are commercially available. Instrument is assembled from components. Calibration studies are needed.

Implementation Needs: Adequate shielding required to protect personnel from neutron source.

Author: Z. W. Bell/615-574-6120

References:

1. DOE Order 5400.5, DOE/CH/8901 (Gilbert et al., 1989)

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals, uranium

Reference Requirements: Refer to Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified. The maximum acceptable surface mercury contamination is 100 $\mu\text{g}/100\text{ cm}^2$, according to Y-12 Plant industrial hygiene regulations. DOE surface decontamination guidelines for natural uranium, ^{235}U , ^{238}U , and associated decay products, are 5,000 dpm/100 cm^2 average, 15,000 dpm/100 cm^2 maximum, and 1,000 dpm/100 cm^2 removable.¹

Subelement: Characterization

Alternatives: Field methods/Laboratory methods

Technology: Neutron-induced prompt gamma ray detection. The prompt gamma rays following the capture or scattering of neutrons by the sample are detected. No radioactive element decay is involved in this process. A Ge detector is used to identify gamma rays from the sample during irradiation. Device consists of a neutron source, Ge detector, power supply, amplifier, multichannel analyzer, and readout device.

Status: Predemonstration

Applicable contaminant evaluation: Mercury, uranium

Amount of Waste Produced—None

Overall Cost—>\$100K for a complete instrument.

Efficacy/Strengths—All materials have neutron capture and scattering cross sections and emit characteristic gamma rays on interaction with a neutron. Natural mercury has a capture cross section sufficiently large to make a 3 mm layer opaque to thermal neutrons. It emits a prompt 368 keV gamma ray in 81% of captures. This gamma ray can penetrate pipe and concrete effectively. The device is capable of probing concrete and steel structures to detect mercury hidden from view. Both ^{238}U and ^{235}U have capture cross sections and emit characteristic gamma rays on capture of a neutron.

Science/Technology Needs: No commercial device is known at this time. All components can be purchased and assembled into an instrument. Simulations would probably be required to determine the efficacy of this technology for detecting each material.

Implementation Needs: Adequate neutron/gamma shielding to protect personnel from neutron source.

Author: Z. W. Bell/615-574-6120

References: Author

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals

Reference Requirements: The Federal Safe Drinking Water Act standard for mercury in drinking water is 2 µg/L, maximum contaminant level. The maximum acceptable surface mercury contamination is 100 micrograms/100 cm², according to Y-12 Plant industrial hygiene regulations. The OSHA air contaminant limit for mercury vapor is 0.05 mg/m³. Refer to Vol. 1 for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods/Laboratory methods

Technology: Neutron activation analysis for mercury. Thermal neutrons are captured by a material which then becomes radioactive. The radioactive material emits characteristic gamma rays with a known half-life, as it decays. A Ge detector is used to identify the gamma rays and their diminution with time after irradiation. The device consists of a neutron source, Ge detector, power supply, amplifier, multichannel analyzer, and readout device.

Status: Accepted

Applicable contaminant evaluation: Almost all materials

Amount of Waste Produced—None

Overall Cost—<\$100K for a complete instrument (if using radioactive neutron source), >\$100K if portable, local accelerator-based neutron source is to be developed.

Efficacy/Strengths—Can perform trace analysis. May require sending samples to a reactor and performing analysis there. HFIR at ORNL has been used for this purpose. Depending on material, may be possible to use radioactive neutron source in situ or at site.

Science/Technology Needs: None for detector. Depending on application, may need to develop portable accelerator-based neutron source.

Implementation Needs: Shielding to protect personnel from neutron source.

Author: Z. W. Bell/615-574-6120

References: Author

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Physical (structural) problems

Reference Requirements: Refer to Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: A transmission measurement of a structure is made with neutrons, gamma rays, or X rays. The measured attenuation is related to the amount and variety of materials present in the sample. The device consists of a radiation source, detector, power supply, single channel or multichannel analyzer, and readout device.

Status: Accepted

Applicable Contaminant Evaluation: X rays or gamma rays: metals (especially high-Z metals); neutrons: fissile material, mercury.

Amount of Waste Produced—None

Overall Cost—<\$20K for radioactive X-ray or gamma ray source-based device. Cost increases dramatically for accelerator-based X-ray or gamma ray source. <\$50K for neutron-based device.

Efficacy/Strengths—Inexpensive, well known technology. All components are commercially available. **Weaknesses—**Requires access to opposite sides of a sample.

Science/Technology Needs: None.

Implementation Needs: Shielding is necessary to protect personnel from radiation source. Robotic technology is necessary for areas into which humans may not enter. Devices capable of lifting the instrument and operator are required for overhead work.

Author: Z. W. Bell/615-574-6120

References: Author

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: The proposed Federal Safe Drinking Water Act standard for natural uranium is 20 µg/L (equivalent to 30 pCi/L). DOE surface decontamination guidelines for natural uranium, ²³⁵U, ²³⁸U, and associated decay products, are 5,000 dpm/100 cm² average, 15,000 dpm/100 cm² maximum, and 1,000 dpm/100 cm² removable. Refer to Vol. 1 for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: CdZnTe semiconductor radiation detection. This detector array is used to locate radioactive material. The technology is more efficient than NaI detection; therefore, a smaller sensing head yields equivalent efficiency. Detectors can be fabricated with areas from 1 cm² to 1 mm². Arrays of these detectors can be used in large area applications. Spectroscopy grade detectors can be used for radioactive species identification. Instrument consists of one or more detectors, power supply, amplifier(s), single-channel or multichannel analyzer, and readout device.

Status: Predemonstration. Technology integration is a major factor here.

Applicable Contaminant Evaluation: Radioactive (gamma)

Amount of Waste Produced—None

Overall Cost—<\$25K for a complete instrument.

Efficacy/Strengths—Small size of sensing head. Can be threaded into hard to reach places.

Science/Technology Needs: Efficacy for detection of uranium emissions needs to be determined.

Implementation Needs: Robotic technology is necessary for areas too contaminated for humans.

Author: Z. W. Bell/615-574-6120

References: Author

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Uranium

Reference Requirements: The OSHA air contaminant limits for uranium (as U) are 0.05 mg/m³ for soluble uranium compounds and 0.25 mg/m³ insoluble compounds. Refer to Vol. 1 for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Airborne uranium detection. In this technology, a vacuum pump draws air through a filter. The filter is monitored continuously for alpha activity attributable to uranium.

Status: Accepted. Commercially available.

Applicable Contaminant Evaluation: Radioactivity (airborne alpha emitters)

Amount of Waste Produced—Minimal solid waste (used filter papers)

Overall Cost—<\$15K for a complete instrument.

Efficacy/Strengths—Continuously monitors air in an area.

Science/Technology Needs: None.

Implementation Needs: None. A unit has been acquired for the Y-12 Plant.

Author: Z. W. Bell/615-574-6120

References: Author

EM Problem: Decontamination and Decommissioning (D&D)

Y-12 Plant Problem: Bldg. 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury (Hg) and mercury compounds in water

Reference Requirements: The Federal Safe Drinking Water Act standard for mercury is 2 µg/L, maximum contaminant level (MCL). Refer to the Regulatory Compliance chapter of Vol. 1 for other potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Alternative: Laboratory and Field methods

Technology: Anodic stripping voltammetry. Soluble mercury and mercury compounds in water solution are electrically plated onto a glassy carbon electrode and then stripped off across a linear potential ramp. The measured current is a function of the quantity deposited on the electrode. Microprocessor technology speeds data reduction of mercury analysis.

Status: Demonstration. The instrument is being developed and tested in the Development Division at Y-12. Analytical range is 3–2000 ppb Hg, without pretreatment of water.

Waste produced—Minimal.

Overall cost—Estimated at \$20/sample.

Efficacy/strengths—Analysis time is ~10 min/sample. Instrument is transportable and automated.

Limitations—Thallium will give a positive test result but is not expected to be present in Y-12 samples. Method analyzes for ionic mercury. Elemental mercury must be oxidized prior to analysis. Some organomercury compounds are detected.

Science/Technology Needs: Technology needs include long-term, reliable Hg standard solutions. While improvements can be made, in general, the technology is ready to use.

Implementation Needs: Instrument needs to be field packaged and proven.

Author: D. D. Smith/615-574-0917. Reviewed by R. L. Fellows 615-576-5632.

References: Author

EM Problem: Decontamination and Decommissioning (D&D)

Y-12 Plant Problem: Bldg. 9201-4 (Alpha-4)

Problem Area/Constituents: Organics on concrete, metal equipment, insulation; organics in air.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Alternative: Field method

Technology: Transportable Gas chromatography/ mass spectrometry.

Status: Development. There are at least two manufacturers of "portable" GCMS instruments. They are "transportable" rather than truly "portable". Although gas chromatographs individually are hand portable, in combination with a mass spectrometer the size, mass, and power requirements (a portable generator is necessary) demand vehicular transport. The instruments are typically operated in a mobile laboratory or out of a van or covered pick-up truck. A back-portable GCMS has also been reported but is not commercially available as yet. Commercial transportable GCMS instruments are based on quadropole mass spectrometers rather than ion trap mass spectrometers. Transportable ion trap mass spectrometers have been developed (a direct sampling version was developed at ORNL). They are not yet commercially available but probably will be within about a year.

Waste produced—Minimal.

Efficacy/strengths— Rapid field characterization, with quantitation. Production of more confident results than the GC alone can provide.

Limitations— Size, mass, power requirements. Sample requires preparation before analysis.

Science/Technology Needs: Size minimization of the equipment and power source. Optimization for use in the field. Direct Sampling Ion Trap Mass Spectrometry still requires software and hardware development to produce field instruments with the capabilities of their laboratory-based cousins, and optimization for direct sampling (real-time monitoring) applications. This is, in part, a technology integration issue.

Implementation Needs: TBD

Author: R. L. Fellows/615-576-5632 Reviewed by: M.R. Guerin/615-574-4862 and W.H. Griest/615-574-4864

References: Authors

EM Problem: Decontamination and decommissioning

Y-12 Plant Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Polychlorinated biphenyls (PCBs)

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Cleanup level: PCBs 10 ppb in soils (strictest EPA limit)

Alternative: Field methods

Technology: Chemical reaction test kit for PCBs. The kit functions by: extracting the PCBs from the substrate and dissociating the chlorine by reaction with a proprietary sodium reagent. The resulting chloride ions are then reacted with excess Hg^{2+} to form mercury chloride compounds. Subsequent treatment with diphenyl carbazone (which reacts with free Hg^{2+}) forms a purple color. The greater the PCB quantity in the sample, the less purple the color. Alternately, the Cl^- can be analyzed with a chloride-specific electrode.

Status: Demonstration. Field kits are commercially available. The kit has not been tested on site. Kits were tested under EPA auspices in EPA Region 7 in August 1992, and a final report will be issued in 1994.

Temporal areas of evaluation: Pretreatment, treatment, and posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: polychlorinated biphenyls (PCBs)

Analytical range is 2–2000 ppm PCB.

Waste produced—Minimal. A small quantity of test reagent containing mercury, PCB reaction products, diphenyl carbazone.

Overall cost—\$6–15/sample test.

Efficacy/strengths—Analysis time is ~10 min/sample.

Interferences—Any chlorinated hydrocarbon that reacts with the sodium reagent will give a positive test result.

Science/Technology Needs: Technology needs are minimal. While improvements can be made, in general, the technology is ready to use.

Implementation Needs: N/A

Author: R. L. Fellows/615-576-5632

References:

1. Dexsil Corporation, Hamden, CT 06517. Clor-N-Soil and Clor-N-Oil PCB Screening Kits.
2. SITE Superfund Technology Evaluation, Technology Profiles, Sixth Edition, EPA/540/R-93/526, November 1993.

ULTRAVIOLET ABSORPTION MERCURY VAPOR ANALYZER

CHAR-342-OY

EM Problem: Decontamination and decommissioning

Y-12 Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals in air

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

To be eligible for exemption from EPA regulation, the maximum concentration of mercury must be less than 50 picograms/m³ at the plant property line.

Personnel Exposure Limits to Mercury in Air

Personnel exposure limits to mercury in air

Contaminant	Time-weighted average		Short-term exposure limit	
	ICGIH	Y-12	ICGIH	Y-12
Mercury alkyls	0.01 mg/m ³	0.005 mg/m ³	0.03 mg/m ³	0.015 mg/m ³
All mercury except alkyls	0.05	0.025	NA	NA
Aryl and inorganic mercury	0.1	0.05	NA	NA

The OSHA air contaminant limit for mercury vapor is 0.05 mg/m³.

Subelement: Characterization

Alternatives: Field methods

Technology: Air monitoring using UV light absorption to provide detection of mercury in air. Air sample is drawn into the measurement cell by a small air pump or fan.

Status: Accepted and commercially available

Amount of Waste Produced—none

Efficacy/Strengths—Portable direct reading instrumentation allows in-situ real-time measurements. Rechargeable battery operated unit lasts 4h/charge. It is useful for conducting semi-quantitative area surveys.

Weaknesses—The UV absorption method is prone to interference from other substances that either absorb at the same UV frequency, 239 nm (organics for example) or scatter light (as dust does) resulting in false positive readings. Commercial portable instrument is not

ULTRAVIOLET ABSORPTION MERCURY VAPOR ANALYZER

CHAR-342-OY

recommended to be run continuously over 8 h because of potential for sampling fan overheating.

Measurement range—0.01 to 1.0 mg/m³. Detection limit (sensitivity) 0.01 mg/m³

Science/Technology Needs: Improved Hg-specific response is needed to minimize false positive measurements. More robust fan would allow continuous instrument use.

Implementation Needs: Telemetry to computers will help establish data bases for local areas without the contamination situations.

Instrument Cost—<\$4000.

Operating cost—NA

Authors: S.M. Hollenbeck/615-574-9547 (FAX 6-4595), D. D. Smith/615-574-0917, R. L. Fellows/615-576-5632

References:

1. Bacharach Inc., Pittsburgh, PA 15238.

MERCURY COLLECTION FROM AIR USING HYDRAR OR HOPCALITE TUBES

CHAR-343-OY

EM Problem: Decontamination and decommissioning

Y-12 Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals in air

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

To be eligible for exemption from EPA regulation, the maximum concentration of mercury must be less than 50 picograms/m³ at the plant property line.

Personnel exposure limits to mercury in air

Contaminant	Time-weighted average		Short-term exposure limit	
	ICGIH	Y-12	ICGIH	Y-12
Mercury alkyls	0.01 mg/m ³	0.005 mg/m ³	0.03 mg/m ³	0.015 mg/m ³
All mercury except alkyls	0.05	0.025	NA	NA
Aryl and inorganic mercury	0.1	0.05	NA	NA

The OSHA air contaminant limit for mercury vapor is 0.05 mg/m³.

Subelement: Characterization

Alternatives: Sample Collection

Technology: Mercury sample collection from contaminated air using HYDRAR or hopcalite sampling tubes with calibrated air sampling pumps. This is an integrated media sampling technique. Mercury-contaminated air is drawn through a tube containing a commercially prepared manganese dioxide-based catalyst in particulate form (hopcalite). Mercury (Hg) is oxidized and quantitatively deposits on hopcalite. Analysis is conducted by dissolving loaded hopcalite in HCl/HNO₃, reducing the ionic Hg to elemental Hg with stannous chloride, and analyzing the solution using standard analytical techniques for Hg, flameless atomic absorption for example.

Status: Accepted and in use at Y-12. For integrated sampling, the Y-12 IH Department follows NIOSH Method 6009, which utilizes HYDRAR or hopcalite sampling tubes and calibrated air delivery pumps. Integrated sampling can be used to fulfill both area and personal monitoring requirements.

Waste Produced—0.2–0.5 g hopcalite media and Hg in 100 ml analysis solution.

Efficacy/Strengths—Integrated air contamination analysis over period of sampling. (Direct

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reading, nonintegrating instruments subject to more "sampling error" than integrating method.) Absorbent performance has been > 98% (avg.) recovery of Hg for 1.7 to 130 µg total mercury in air at 0.025 to 1.2 mg/m³ on 0.2 g hopcalite powder.

Weaknesses—Its use in contaminated areas poses decontamination problems for sample removal. Requires laboratory sample analysis with a corresponding delay in reported sample results. "Averaged" results from integration do not identify concentration highs and lows.

Science/Technology Needs: None

Implementation Needs: Mercury analytical instrument cost: as available, probably >\$15K

Air pump—<\$3K

Sample collection—<\$50

Mercury analysis cost: \$130./sample

Authors: S.M. Hollenbeck/615-574-9547, D. D. Smith/615-574-0917, R. L. Fellows/615-576-5632

References:

1. A. O. Rathje and D. H. Marcero, "Improved Hopcalite Procedure for the Determination of Mercury Vapor in Air by Flameless Atomic Absorption," *American Industrial Hygiene Association Journal*, pp 311-314, May 1976
2. Y-12 Report Y/DZ-68

EM Problem: Decontamination and decommissioning

Y-12 Problem: Building 9201-4 (Alpha-4)

Problem Area/Constituents: Mercury and other metals in air

Reference Requirements: Refer to Vol. 1, Chap. 8, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

To be eligible for exemption from EPA regulation, the maximum concentration of mercury must be less than 50 picograms/m³ at the plant property line.

Personnel exposure limits to mercury in air

Contaminant	Time-weighted average		Short-term exposure limit	
	ICGIH	Y-12	ICGIH	Y-12
Mercury alkyls	0.01 mg/m ³	0.005 mg/m ³	0.03 mg/m ³	0.015 mg/m ³
All mercury except alkyls	0.05	0.025	NA	NA
Aryl and inorganic mercury	0.1	0.05	NA	NA

The OSHA air contaminant limit for mercury vapor is 0.05 mg/m³.

Subelement: Characterization

Alternatives: Field Methods

Technology: Ultraviolet light absorption for mercury vapor monitoring. Elemental mercury absorbs light in the ultraviolet region. The 235.7 nm absorption is used to quantify mercury using a spectrophotometer of very long path length, 1600 m (3000 ft) with high intensity UV source.

Status: Demonstration. The instrument is commercially available but its use needs to be demonstrated. An instrument is also being developed at ORNL.

Waste Produced—none

Efficacy/Strengths—Analytical range: 0.008 mg/m³ (1 ppb) to >> 100 mg/m³ (12.2 ppm) Hg. Detection limit: 0.008 mg/m³ (1 ppb) for 1600 m and 2 minute sampling time. Uses same technology as common laboratory analytical analysis method for mercury so is very well understood. Analysis over a broad wavelength range facilitates unambiguous Hg detection. Allows real time monitoring of Hg vapors. Long path length allows monitoring of a very large area. Computer control allows constant surveillance and communication to a central control or network. Instrument can also be used to monitor other UV absorbers such as organics, and some common air pollutants such as SO₂, NO₂, O₃.

Weaknesses—long path length requires stable mounting of instrument components.

Science/Technology Needs: None

Implementation Needs: Instrument cost: >\$ 100K
Operating cost: electricity

Authors: R. L. Fellows/615-576-5632

References:

1. OPSIS Differential Optical Absorption Spectroscopy Monitor. Vendor: ABA Power Plant Controls, Windsor, CT 06095.
2. See CHAR-342 for more portable technology.

DISMANTLEMENT

HIGH-PRESSURE ABRASIVE WATER JET (MASSIVE CONCRETE)

DISM-11-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Massive reinforced concrete structures that are contaminated with low-level uranium, mercury, lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Cutting

Technology: High-pressure abrasive water jet. The abrasive water jet cutting system can cut reinforced concrete using high-pressure water and some sort of abrasive, usually garnet. The garnet is mixed with the high-pressure water in the nozzle to produce a solution that will induce a large impact force. Generally, the system can cut up to 6-in.-thick steel and 4-ft-thick steel-reinforced concrete.

Status: Demonstrated. The abrasive water jet consists of a jet of abrasive-loaded water at pressures up to 50,000 psi which is directed at the workpiece. The basic components of an abrasive water jet cutting system are: high-pressure pumps, abrasive delivery system, abrasive water jet nozzle, traverse system, and a catcher. Pressurized water goes through a sapphire or diamond orifice to produce a high-velocity water jet. The abrasives and water exit the nozzle and perform the cutting. The momentum transfer between the water and abrasive produces a high-velocity, focused stream. This system would be used to cut reinforced concrete above ground level into sections to be taken to a crusher. A recovery system will need to be on the blow-through side of the material being cut. If cutting sections of Building 9201-4's reinforced concrete floor, a recovery system would be hard to design and utilize. A recovery system will need to be able to recirculate the contaminated water, thereby reducing waste. The abrasive water jet is capable of cutting under water.

An intensifier is used to generate the high pressures required. The intensifier pumps require periodic rebuilding (every 1000 h) and constitutes a noise hazard when it is operating (100-110 dBA). The flow rate from the pump is an average of 1.5 gal/min. The pump can be controlled by a microprocessor; therefore, remote control is adaptable.

HIGH-PRESSURE ABRASIVE WATER JET (MASSIVE CONCRETE)

DISM-11-OY

Manipulators are easily adaptable to the cutting system. A 5-axis gantry-type system is commonly used in a stationary system. The cutting system can be portable as well. A common manipulator will cost \$300K.

Airborne and gaseous contamination generated is low. The system also can be remotely operated, if needed. Cutting speed for 2.5-in.-thick carbon steel is 3-4 in./min. The cutting rate of 24-in.-thick reinforced concrete would be 1 in./min. Thicker reinforced concrete requires more power, etc. Abrasive consumption (usually garnet) is 1.5-2.0 lb/min. Also, approximately 1.4 gal/min of liquid is generated. The cost of an abrasive water jet system was \$1M. The mixing tube and orifice of the nozzle, as well as the abrasives, are consumable. The mixing tube is \$230, ceramic balls are \$2/lb, orifices are \$5, and garnet abrasive is \$0.32/lb. DOE has sponsored the development of a deep kerf tool from Quest Integrated, Inc. This tool was built to cut through up to 6-ft-thick concrete. They demonstrated cutting 3-ft-thick concrete. The deep kerf tool has demonstrated cutting rates in thick steel-reinforced concrete up to 10 ft²/hr with greater than 99% spoils recovery.

Science/Technology Needs: A recovery system for the water and recyclable abrasives will need to be developed. Development of a portable system that can position the nozzle on the walls, ceiling, floors, and columns is needed. Development of a method to contain blow-through and the spread of contamination is needed.

Implementation Needs: The ability to separate contamination from the water slurry would have to be demonstrated. The need exists to view videos available from other nuclear facilities and possibly to visit sites to evaluate recovery systems without on-site demonstrations. Currently, at the Y-12 Plant in Oak Ridge, Tennessee, the decontamination and decommissioning program is procuring such a system. A demonstration will be needed to view the portable movement of the system while cutting an I-beam. The demonstration will cost \$250K. The overall assessment of the usefulness of this technology is that it is a high priority. The time required to test the cutting system against specific site problems would be 2 years. The operational cost for an abrasive water jet cutting system is estimated to be \$100/h of cutting.

Author: G. A. Blankenship/615-574-9829 (Y-12)

References:

1. *Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor*, NL-89/31, Argonne National Laboratory, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
2. *Abrasive Water Jet Cutting of Uranium*, FMPC-2118, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
3. *CNC Water Jet Machining and Cutting Center*, KCP-613-4397, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.

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(MASSIVE CONCRETE)**

DISM-11-OY

4. Daren C. Davis, "Robotic Abrasive Water Jet Cutting of Aerostructure Components," MS89-812, Non-Traditional Machining, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
5. Quest Integrated, Inc., personal communication, April 6, 1993.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Massive reinforced concrete structures may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Diamond wire cutting. This technology involves cutting decontaminated concrete into sections to be taken to a crusher for reduction and subsequent use as fill, etc., locally. Diamond wire cutting consists of a continuous cable with replaceable diamond-impregnated sleeves the full length of the cable. Holes are cut through the reinforced concrete, usually by core drilling. Wire is threaded through the holes and around a series of powered and idler sheaves. The drive-sheave mechanism is mounted on a track that maintains tension. The main advantages of this system are the light weight, maneuverability, and ability to nose-in a cut and to cut square holes with no over-cut.

Status: Diamond wire cutting can be used to cut concrete at other nuclear facilities, except at ground-level floors (see Dimas video). Diamond wire cutting is an industry-accepted method but, with heavy, reinforced concrete, will be a high-maintenance item (diamond-impregnated sleeves, cable, and sheaves) and requires water coolant for the cable.

Waste—The waste generated from the coolant will be a slurry that is contaminated. The slurry would be low-level waste. The area would be clean and relatively clear, but positioning the core drilling equipment and the diamond wire cutting machine will be more difficult, because reinforcing bar probably will be exposed. The mass of debris from demolishing a concrete structure is estimated to be 15% of the cubic dimension of the structure.

Cost—Operational costs are estimated to be \$600/yd³.

This technology was used at DOE's Mound in Ohio to cut through 16 ft and 10 ft heavily reinforced concrete walls (rebar 1-2 in.). The technology was able to slice the rebar both perpendicularly and longitudinally. The process had very low maintenance.

Science/Technology Needs: A track system for maneuvering core drilling machine and diamond wire cutting machine may be required. Development and installation of the track system and recovery system for demonstration will cost \$0.5M.

Implementation Needs: A track needs to be developed for demonstrations. Manipulators with vacuum systems need to be able to move in two directions. Vacuum systems will be needed on both sides of the floor being cut. Development priority is high. One year will be required to bring this technology to application. The demonstrations will have to be completed before a cost payback can be evaluated.

Per best engineering estimate, the projected capital cost of this technology is \$1M.

Authors: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Stanley Hydraulic Tools, Division of Stanley Works, Milwaukie, Oregon 97267-5698.
2. Oregon Cutting Systems, Portland, Oregon 97222.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Massive reinforced concrete structures may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Explosive cutting. This technology will be prohibited in areas of mercury contamination. This technology involves the delayed firing of explosives to demolish decontaminated concrete structures. Controlled blasting is a series of blasts set off in a predetermined sequence which reduces vibrations on surrounding structures, controls the direction of material movement, and limits the amount of dust created. Blasting mats can be used to hold down debris and dust. Water may be required to hold down dust. All the concrete structure remaining after decontaminating will be taken to the crusher to be used as fill, etc. locally.

If the decontaminated building can be used as fill, \$17.00/ft³ in disposal costs will be saved. The mass of debris from demolishing concrete structures is estimated to be 15% of the cubic dimension of the structure.

Status: This technology has been demonstrated and used by the demolition industry for years. Reinforcing bars have to be cut after blasting. Contaminated concrete should be removed by scarifying or scabbling. All walls and floors below ground level should not be disturbed until all debris has been removed and water-level tests are complete.

Noncontaminated structures, which will not have to be decontaminated, will be located, and they will be demolished with controlled blasting, monitoring vibrations so that the system can be evaluated before actually being put into use.

Cost—Operational costs are estimated to be \$400/yd³.

Science/Technology Needs: A crane system is needed for moving large sections of decontaminated concrete to the crusher. A remote method of cutting reinforcing bars in large amounts of debris is needed. A method needs to be created for installing lift rings for crane handling of large sections of debris, or other methods need to be developed for moving debris to the crusher. Major components needed would be: a crane, remote reinforcing bar cutting technique, a front-end loader, and a crusher.

Implementation Needs: The need exists to watch and record an actual site being demolished by controlled blasting. The need exists to view videos from demolition companies and explosive manufacturers to see what method industry uses to cut reinforcing bars and remove large amounts of debris.

Before disturbing the walls that are underground or the ground-level floor, a core sampling by a soil engineer is needed to determine the water levels of wet-weather springs. This is to ensure that the dam created by the existing underground walls and floor does not break, creating a pool or stream running through contaminated debris or across contaminated soil beneath the floor that was never exposed before. Some foundations go all the way to bedrock, and some were built on fill over wet-weather springs. If necessary, the soil beneath the floor will have to be decontaminated or stored.

Development priority is low, as much of this technology is already established. One to three years will be required to bring this technology to application. The cost to develop and demonstrate this technology is estimated to be \$2.0M.

Per best engineering estimate, the projected capital cost is \$0.75M.

Authors: D. D. Haskell/615-675-3337 (X-10)
P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Geoff Blast Cleaning Equipment Company, Seminole, Oklahoma 74868.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Massive reinforced concrete structures may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Mechanical saws. This technology will be prohibited in areas of mercury contamination, unless mercury vaporization is contained. Mercury vaporization may be minimized if a coolant is used, but this will impose a recovery system and a containment around the cutting area.

Status: Accepted. Chain saws, hack saws, abrasive wheel saws, etc., can be hand-held (by manipulators) or base- or table-mounted.

Science/Technology Needs: None

Implementation Needs: Adaptation to use by remote manipulation equipment will be required, but this has been done at most hot cell facilities for many years and is considered standard operating procedure. The cost to implement this technology with remote manipulation equipment is about \$250K over 12 months. The operational cost is estimated to be \$30/ft³ of waste generated.

Per best engineering estimate, the projected capital cost of this technology is \$350K.

Author: J. W. Moore/615-574-6389 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Massive reinforced concrete structures may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Removal

Technology: Microwave demolition. This technology involves a robotically manipulated microwave machine that systematically scrabbles the floor, columns, walls, and overhead to remove the contaminated surface. A vacuum system will take the contaminated material to a crusher to be reduced for storage. The microwave scabbling system allows one to start with, work with, and end up with a dry surface. This technology will be prohibited in areas of mercury contamination.

The technology involves massive concrete scabbling using robotically controlled and manipulated microwave machines. Microwave energy is directed at the concrete surface and heats the concrete and free water present in the concrete. (Virtually all concrete, old and new, has some water content.) Continued heating produces steam-pressure-induced mechanical stresses which cause the concrete to burst. The amount of concrete removed in a single pass can be controlled by choosing the frequency, power, and speed of the microwave system.

If the decontaminated building can be used as fill, the \$17/ft³ disposal cost could be saved. The mass of debris from demolishing concrete structures is about 15% of the cubic dimension of the structure.

Status: Microwave scabbling of concrete is in the final stage of Phase 2 of a 4-phase program at ORNL. (See the Concrete Spalling Test 23 video. Note that what appears on the video as dust is actually steam.) Phase 3 is scheduled for completion in mid-1994. Phase 3 will develop improved mobility, remote video control, vacuum waste collection and remote-controlled capabilities. Phase 4 will involve design of vertical and overhead scabbling as well as optimization of the proper methods and configurations for cleaning the off-gas discharged by the vacuum system. All American National Standards Institute and Occupational Safety and Health Act standards will be met or exceeded.

Microwave scabbling was demonstrated by the Japanese Atomic Energy Research Institute in 1987. As much as 3 cm was removed in one pass, but the amount of microwave energy released was not reported.

Wastes generated will be handled by a vacuum system which transfers the material to a crusher for reduction. The crusher may require water to hold down dust but the material can be dried by other microwave systems outlined under Implementation Needs.

The location relative to the surface and grid pattern of the reinforcing bars effects the microwave system, but this is being addressed.

Less than 1% of the debris is less than 1 mm in diameter; therefore, most of the debris should not pose an airborne contamination hazard.

Cracks in the floor may release microwave energy, which will require shielding.

Cost payback will have to be addressed after Phase 3 and possibly after Phase 4 has been completed for microwave scabbling.

Science/Technology Needs: Development already has been funded (see TTP No. OR-3DAA). Installation and demonstration of the Phase 3, advanced-stage microwave machine, robotics, and vacuum system for demonstration will be \$3M. Demonstration costs include characterizing walls and floor, identifying the reinforcing steel grid pattern, building portable containment enclosures, personnel protection, clothing, and container storage but not transportation and burial charges.

Development and installation of the Phase 4 system for demonstration will be \$5M.

Implementation Needs: A track system, if needed, needs to be developed for demonstration. Manipulators with vacuum systems need to be able to move along the floor, around columns, up walls, and overhead.

Per best engineering estimate, the projected capital cost of this technology is \$2M.

Author: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Pentek Corporation, Caraopolis, Pennsylvania 15108-1659.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Massive reinforced concrete structures may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Demolition

Technology: Demolition compounds. This technology involves demolition of concrete structures by using expansive grout. Holes are created in a predetermined pattern in the structure, and an expansive grout is inserted. The grout expands creating cracks in the concrete, allowing the section to be removed. The section removed will be taken to a crusher for reduction in size.

Status: Demonstrated. The technology is effective on nonreinforced or lightly reinforced concrete. Any reinforcing bar will have to be cut by other means. The compound is not considered dangerous.

Cost—The demonstration would cost \$250K. Operational costs are estimated to be \$400/yd³.

Science/Technology Needs: Using a lite or noncontaminated building, a demonstration can be made without scabbling being required. The building would need to be with lite or no reinforced concrete. The crushed decontaminated material could be stored on-site until local use determined.

Size, depth, and pattern of holes would need to be determined. The method of cutting any reinforcing bars needs to be established. The fractured concrete would be removed with a pavement breaker, backhoe, or bucket loader. The dirt beneath the floor will have to be moved, if necessary, and decontaminated or stored.

Implementation Needs: Pattern, size, depth, and location of reinforcing bars need to be established. A means for cutting reinforcing bars and removing fractured sections of concrete needs to be established. A crane facility and a crusher are needed to reduce concrete sections to eliminate any voids in storage. Before disturbing the walls that are underground or the ground-level floor, core sampling by a soil engineer is needed to determine the water level of

wet-weather springs to ensure that the dam created by the existing underground walls does not break, creating a pool or stream running through contaminated rubble or across contaminated soil beneath the floor never exposed before. Some foundations go all the way to bedrock, and some were built on fill over wet-weather springs. If necessary, the dirt beneath the floor will have to be decontaminated or stored.

Development priority is low, as this is a less useful technology for dismantling these types of structures. Development costs are estimated to be \$250K. One year will be required to bring this technology to application.

Per best engineering estimate, the projected capital cost of this technology is \$0.5M.

Authors: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Concrete Cutting Systems, Inc., Knoxville, Tennessee.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Massive reinforced concrete structures may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Demolition

Technology: Conventional demolition. This technology involves using wrecking balls and hydraulic or pneumatic hammers. A wrecking ball is a large-diameter steel ball suspended on a cable by a crane. The ball is dropped or swung and strikes the wall or floor, bursting the concrete.*

Hydraulic or pneumatic hammers: Single head—A hammer with a single, pulsating, wedged-shaped head that can be operated manually or remotely. This hammer can be used to create holes in concrete or to scabble or to break concrete into sections for removal. This hammer has been used to chisel away the outside shell of some reactors.*

Multiple head—A hammer with a series of pulsating, wedged-shaped heads that can be operated manually or remotely. Originally, this hammer was designed to prepare concrete floors for resurfacing, but it has been adapted for scabbling concrete.*

Status: Demonstrated. The wrecking ball is a demolition industry-accepted method but is not recommended for contaminated concrete, such as that existing in most DOE facilities. It is impractical to contain the dust, and the reinforcing bar has to be cut by other means.

Hydraulic or pneumatic hammers

Single-head hammer—An industry-accepted method for creating holes, scabbling, and demolishing concrete on a massive scale, but this hammer is impractical for scabbling or

*This technology will be prohibited in areas of mercury contamination, unless protective measures are taken to prevent and contain mercury vaporization.

destroying large areas. It could be used in corners, etc., that multiple-head machines would be unlikely to access.

Multiple-head hammer—An industry-accepted method for lightly scabbling concrete surfaces. Vacuum systems exist to contain the dust. Machines come in different lengths and capacities.

The dust from the single-head and multiple-head hammers would require a vacuum system with dust filters. The debris would be removed by vacuum and taken to a crusher for reduction in size. Containment of the dust may require starting with a wet floor.

Concrete reinforcing bar will have to be cut by other means when using multiple-head hammers.

Mechanical hammers can drive contamination further down into the concrete. Removing the contaminated surface and assuming that the remainder of the decontaminated building can be crushed and used as fill will save \$17.00/ft³ for disposal. Operational costs are estimated to be \$400/ft².

Science/Technology Needs: Vacuum systems for handling dust and small-to-medium pieces of concrete need to be demonstrated. A crusher to down-size concrete pieces needs to be demonstrated. Development and installation of the vacuum systems to handle both dust and pieces of concrete and a crusher for demonstration would cost \$1.0M.

Implementation Needs: The need exists to view videos available from nuclear facilities and possibly to visit other sites to evaluate multiple-head hammer machines without on-site demonstrations. Demonstrations need to show how the corners and hard-to-reach areas will be handled.

Use of a wrecking ball is not recommended. Hammers can be used to assist other technologies. The cost to develop and demonstrate this technology is estimated to be \$1.0M. One to two years would be required to bring this technology to application.

Per best engineering estimate, the projected capital cost of this technology is \$0.5M.

Authors: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Pentek Corporation, Caraopolis, Pennsylvania 15108-1659.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, that contains: process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Massive reinforced concrete structures may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Demolition

Technology: Grapple and massive shearing. A grapppler is a heavy industrial tool used to crush concrete structures. The technology uses interchangeable jaw mechanisms to apply crushing pressure. Shear jaws can be used to crush concrete into sections, cutting reinforcing bars simultaneously. Sections can be further crushed for use locally as fill. Concrete can be pulverized, sheared, or cracked to accommodate the particular situations. Grappling equipment can crush concrete of much greater density than is possible using conventional methods.

Status: Grapppler machines have been successfully demonstrated on several large-scale projects. Several jaw attachments are in use to provide versatility in dismantlement. The system has reduced schedule lengths by half over conventional jack hammering.

Cost—Operational costs are estimated to be \$100/yd³.

Science/Technology Needs: None

Implementation Needs: The need exists to create a demonstration program to verify applicability of this technology to Y-12 structures. Development priority is high, as this is a relatively inexpensive technology for dismantling large concrete structures. The cost to demonstrate this technology is estimated to be \$500K. One to three years will be required to bring this technology to application.

Per best engineering estimate, the projected capital cost of this technology is \$1M.

Author: D. D. Haskell/615-675-3337 (X-10)
P. N. Hoskins/615-576-3369 (Y-12)

References:

1. La Bounty Manufacturing, Inc., Charlotte, North Carolina 28226.

HIGH-PRESSURE ABRASIVE WATER JET (WALLS)

DISM-19-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Walls, including clay tile and transite siding, may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Cutting

Technology: High-pressure abrasive water jet. The abrasive water jet cutting system can cut the walls using high-pressure water and some sort of abrasive, usually garnet. The garnet is mixed with the high-pressure water in the nozzle to produce a solution that will induce a large impact force. Generally, the system can cut up to 6-in.-thick steel and 4-ft-thick steel-reinforced concrete.

Status: Demonstrated. The abrasive water jet consists of a jet of abrasive-loaded water at pressures up to 50,000 psi which is directed at the wall. The basic components of an abrasive water jet cutting system are: high-pressure pumps, abrasive delivery system, abrasive water jet nozzle, traverse system, and a catcher. Pressurized water goes through a sapphire or diamond orifice to produce a high-velocity water jet. The abrasives and water exit the nozzle and perform the cutting. The momentum transfer between the water and abrasive produces a high-velocity, focused stream. A recovery system will need to be on the blow-through side of the material being cut, if possible. The system may not be able to have a recovery system due to the different types of walls in Building 9201-4. A recovery system would recirculate the contaminated water, thereby reducing waste. The abrasive water jet is capable of cutting under water.

Ferritic and austenitic steel up to 9-in. thick can be cut; other metals also can be cut. An intensifier is used to generate the high pressures required. The intensifier pumps require periodic rebuilding (every 1000 h) and constitutes a noise hazard when it is operating (100-110 dBA). The flow rate from the pump is an average of 1.5 gal/min. The pump can be controlled by a microprocessor; therefore, remote control is adaptable.

Manipulators are easily adaptable to the cutting system. A 5-axis gantry-type system is commonly used in a stationary system. The cutting system would need to be portable for cutting walls. A common manipulator will cost \$300K.

Airborne and gaseous contamination generated is low. Cutting speed for 2.5-in.-thick carbon steel is 3-4 in./min. Abrasive consumption (usually garnet) is 1.5-2.0 lb/min. Also, approximately 1.4 gal/min of liquid is generated. The cost of an abrasive water jet system was \$1M. The mixing tube and orifice of the nozzle, as well as the abrasives, are consumable. The mixing tube is \$230, ceramic balls are \$2/lb, orifices are \$5, and garnet abrasive is \$0.32/lb. This process will not capture surface contamination from the material being cut.

Science/Technology Needs: A recovery system for the water and recyclable abrasives will need to be developed. Development of a portable system that can position the nozzle on the walls, ceiling, floors, and columns is needed. Development of a method to contain blow-through and the spread of contamination is needed.

Implementation Needs: The ability to separate contamination from the water slurry would have to be demonstrated. The need exists to view videos available from other nuclear facilities and possibly to visit sites to evaluate recovery systems without on-site demonstrations. Currently, at the Y-12 Plant in Oak Ridge, Tennessee, the decontamination and decommissioning program is procuring such a system. A demonstration will be needed to view the portable movement of the system while cutting an I-beam. The demonstration and development will cost \$250K. The time required to test the cutting system against specific site problems would be 2 years. The operational cost for an abrasive water jet cutting system is estimated to be \$100/h of cutting.

Author: G. A. Blankenship/615-574-9829 (Y-12)

References:

1. *Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor*, NL-89/31, Argonne National Laboratory, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
2. *Abrasive Water Jet Cutting of Uranium*, FMPC-2118, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
3. *CNC Water Jet Machining and Cutting Center*, KCP-613-4397, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
4. Daren C. Davis, "Robotic Abrasive Water Jet Cutting of Aerostructure Components," MS89-812, Non-Traditional Machining, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
5. Quest Integrated, Inc., personal communication, April 6, 1993.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Walls, including clay tile and transite siding, may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Diamond wire cutting. This technology involves cutting decontaminated concrete into sections to be taken to a crusher for reduction and subsequent use as fill, etc., locally. Diamond wire cutting consists of a continuous cable with replaceable diamond-impregnated sleeves the full length of the cable. Holes are cut through the reinforced concrete, usually by core drilling. Wire is threaded through the holes and around a series of powered and idler sheaves. The drive-sheave mechanism is mounted on a track that maintains tension. The main advantages of this system are the light weight, maneuverability, and ability to nose-in a cut and to cut square holes with no over-cut.

Status: Diamond wire cutting has been used to cut concrete at nuclear facilities, except at ground-level floors (see Dimas video). Diamond wire cutting is an industry-accepted method that requires water coolant for the cable.

Waste—The waste generated will be a slurry that would make the vacuum and recovery system less expensive than when debris has to be handled. The slurry would be low-level waste. The area would be clean and relatively clear.

Cost—Operational costs are estimated to be \$600/yd³.

Science/Technology Needs: A track system for maneuvering core drilling machine and diamond wire cutting machine may be required. Development and installation of the track system and recovery system for demonstration will cost \$0.5M.

Implementation Needs: A track needs to be developed for demonstrations. Manipulators with vacuum systems need to be able to move in two directions. Vacuum systems will be needed on both sides of the section being cut. Development priority is high. Three to six years

will be required to bring this technology to application. Cost to develop and demonstrate this technology is estimated to be \$0.5M. The demonstrations will have to be completed before a cost payback can be evaluated.

Per best engineering estimate, the projected capital cost of this technology is \$1M.

Authors: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Stanley Hydraulic Tools, Division of Stanley Works, Milwaukie, Oregon 97267-5698.
2. Oregon Cutting Systems, Portland, Oregon 97222.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Walls, including clay tile and transite siding, may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Mechanical saws. This technology will be prohibited in areas of mercury contamination. Caution is required when cutting transite siding.

Status: Accepted. Chain saws, hack saws, abrasive wheel saws, etc., can be hand-held (by manipulators) or base- or table-mounted.

Science/Technology Needs: None

Implementation Needs: Adaptation to use by remote manipulation equipment will be required, but this has been done at most hot cell facilities for many years and is considered standard operating procedure. The cost to implement this technology with remote manipulation equipment is about \$250K over 12 months. The operational cost is estimated to be \$20/ft³ of waste generated.

Per best engineering estimate, the projected capital cost of this technology is \$350K.

Author: J. W. Moore/615-574-6389 (X-10)
P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Walls, including clay tile and transite siding, may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Explosive cutting. This technology will be prohibited in areas of mercury contamination. This technology involves the delayed firing of explosives to demolish decontaminated concrete and clay tile structures. Controlled blasting is a series of blasts set off in a predetermined sequence which reduces vibrations on surrounding structures, controls the direction of material movement, and limits the amount of dust created. Blasting mats can be used to hold down debris and dust. Water may be required to hold down dust. The concrete structure will be taken to the crusher to be used as fill, etc., locally.

If the decontaminated building can be used as fill, \$17/ft³ in disposal costs will be saved.

Status: This technology has been demonstrated and used by the demolition industry for years. Reinforcing bars have to be cut after blasting. Contaminated surfaces should be removed by scarfing or scabbling.

Cost—Operational costs are estimated to be \$400/yd³.

Science/Technology Needs: A crane system is needed for moving large sections of decontaminated material to the crusher. A remote method of cutting reinforcing bars in large amounts of debris is needed. A method needs to be created for installing lift rings for crane handling of large sections of debris, or other methods need to be developed for moving debris to the crusher. Major components needed would be: a crane, remote reinforcing bar cutting technique, a front-end loader, and a crusher.

Implementation Needs: This technology is not practical or economical for clay tile walls, which can be demolished by more conventional and less destructive techniques. The need exists to watch and record an actual site being demolished by controlled blasting. The need

exists to view videos from demolition companies and explosive manufacturers to see what method industry uses to cut reinforcing bars and remove large amounts of debris.

Development priority is low, as much of this technology is already established. One to three years will be required to bring this technology to application. The cost to develop and demonstrate this technology is estimated to be \$2.0M.

Per best engineering estimate, the projected capital cost of this technology is \$0.75M.

Authors: D. D. Haskell/615-675-3337 (X-10)
P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Geoff Blast Cleaning Equipment Company, Seminole, Oklahoma 74868.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Walls, including clay tile and transite siding, may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Demolition

Technology: Demolition compounds. This technology involves demolition of clay tile structures by using expansive grout. Holes are created in a predetermined pattern in the structure, and an expansive grout is inserted. The grout expands creating cracks in the clay tile, allowing the section to be removed. The section removed will be taken to a crusher for reduction in size.

Status: The technology is effective on clay tile. Any reinforcing bar will have to be cut by other means. The compound is not considered dangerous.

Cost—The demonstration would cost \$200K. Operational costs are estimated to be \$400/yd³.

Science/Technology Needs: Using a lite or noncontaminated building, a demonstration can be made without scabbling being required. The building would need to be with lite or no reinforced concrete. The crushed decontaminated material could be stored on-site until local use determined.

Size, depth, and pattern of holes would need to be determined. The method of cutting any reinforcing bars needs to be established. The fractured clay tile would be removed with a pavement breaker, backhoe, or bucket loader. The dirt beneath the floor will have to be moved, if necessary, and decontaminated or stored.

Implementation Needs: Pattern, size, depth, and location of reinforcing bars need to be established. A means for cutting reinforcing bars and removing broken sections of clay tile needs to be established. A crane facility and a crusher are needed to reduce sections to eliminate any voids in storage.

Development priority is low, as this is a less useful technology for dismantling these types of structures. Development costs are estimated to be \$250K. One year will be required to bring this technology to application.

Per best engineering estimate, the projected capital cost of this technology is \$0.5M.

Authors: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Concrete Cutting Systems, Inc., Knoxville, Tennessee.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Walls, including clay tile and transite siding, may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Conventional demolition

Technology: Conventional demolition. This technology involves using wrecking balls and hydraulic or pneumatic hammers to demolish masonry walls. A wrecking ball is a large-diameter steel ball suspended on a cable by a crane. The ball is dropped or swung and strikes the wall or floor, bursting the concrete.*

Hydraulic or pneumatic hammers

Single-head hammer—A hammer with a single, pulsating, wedged-shaped head that can be operated manually or remotely. This hammer can be used to create holes in clay tile or to scabble or to break the clay tile into sections for removal. This hammer has been used to chisel away the outside shell of some reactors.*

Multiple-head hammer—A hammer with a series of pulsating, wedged-shaped heads that can be operated manually or remotely. Originally, this hammer was designed to prepare concrete floors for resurfacing, but it has been adapted for scabbling concrete.*

Conventional methods for disassembling/demolishing transite siding includes removing nuts and bolts and sawing using tooth or abrasive blades. Laborers must wear protective clothing and respirators when handling transite siding due to the presence of asbestos.

*This technology will be prohibited in areas of mercury contamination, unless sufficient containment for mercury vaporization is provided.

Hammers can be used to assist other technologies. The cost to develop and demonstrate this technology is estimated to be \$1.0M. One to two years would be required to bring this technology to application.

Per best engineering estimate, the projected capital cost of this technology is \$0.5M.

Authors: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Pentek Corporation, Caraopolis, Pennsylvania 15108-1659.

Hammers can be used to assist other technologies. The cost to develop and demonstrate this technology is estimated to be \$1.0M. One to two years would be required to bring this technology to application.

Per best engineering estimate, the projected capital cost of this technology is \$0.5M.

Authors: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Pentek Corporation, 1026 Fourth Avenue, Caraopolis, Pennsylvania 15108-1659; 412-262-0725.

EM Problem: Decontamination and Decommissioning

Y-12 D&D Problem: Uranium processing facilities, process support facilities, electrical and electrical switch gear, development laboratories, and machining facilities.

Problem Area/Constituents: Dismantlement—This technology will address problems associated with the removal of walls including clay tile and transite siding. The walls may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Demolition

Technology: Grapple and massive shearing. A grapppler is a heavy industrial tool used to crush concrete-like structures. The technology uses interchangeable jaw mechanisms to apply crushing pressure. Shear jaws can be used to crush concrete into sections, cutting reinforcing bars simultaneously. Sections can be further crushed for use locally as fill. Clay tile can be pulverized, sheared, or cracked to accommodate the particular situations. Grappling equipment can crush sections of much greater density than is possible using conventional methods.

Status: Grapppler machines have been successfully demonstrated on several large-scale projects. Several jaw attachments are in use to provide versatility in dismantlement. The system has reduced schedule lengths by half over conventional jack hammering.

Cost—Operational costs are estimated to be \$100/yd³.

Science/Technology Needs: None

Implementation Needs: The need exists to create a demonstration program to verify applicability of this technology to Y-12 structures. Development priority is high, as this is a relatively inexpensive technology for dismantling large concrete structures. The cost to demonstrate this technology is estimated to be \$500K. One to three years will be required to bring this technology to application.

Per best engineering estimate, the projected capital cost for this technology is \$400K per system.

Author: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

References:

1. La Bounty Manufacturing, Inc., Charlotte, North Carolina 28226.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Walls, including clay tile and transite siding, may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Demolition

Technology: Microwave demolition. The technology involves a remotely manipulated microwave machine that systematically scabbles the walls to remove the contaminated surface. The microwave scabbling system allows one to start with, work with, and end up with a dry surface. This technology will be prohibited in areas of mercury contamination.

The technology also involves scabbling using remotely controlled and manipulated microwave machines. Microwave energy is directed at the concrete surface and heats the concrete (or masonry) and free water present in the concrete (virtually all concrete, old and new, has some water content). Continued heating produces steam-pressure-induced mechanical stresses that cause the concrete surface to burst. The amount of concrete removed in a single pass can be controlled by choosing the frequency, power, and speed of the microwave system.

If the decontaminated building can be used as fill, savings of \$17/ft³ disposal costs could be saved.

Status: Microwave scabbling of concrete is in the final stage of Phase 2 of a 4-phase program at ORNL. (See the Concrete Spalling Test 23 video. Note that what appears on the video as dust is actually steam.) Phase 3 is scheduled for completion in mid-1994. Phase 3 will develop improved mobility, remote video control, vacuum waste collection and remote-controlled capabilities. Phase 4 will involve design of vertical and overhead scabbling as well as optimization of the proper methods and configurations for cleaning the off-gas discharged by the vacuum system. All American National Standards Institute and Occupational Safety and Health Act standards will be met or exceeded.

Microwave scabbling was demonstrated by the Japanese Atomic Energy Research Institute in 1987. As much as 3 cm was removed in one pass, but the amount of microwave energy released was not reported.

Wastes generated will be handled by a vacuum system which transfers the material to a crusher for reduction. The crusher may require water to hold down dust but the material can be dried by other microwave systems outlined under Implementation Needs.

The location relative to the surface and grid pattern of the reinforcing bars effects the microwave system, but this is being addressed.

Less than 1% of the debris is less than 1 mm in diameter; therefore, most of the debris should not pose an airborne contamination hazard.

Cracks in the floor may release microwave energy which will require shielding.

Cost payback will have to be addressed after Phase 3 and possibly after Phase 4 has been completed for microwave scabbling.

Science/Technology Needs: Development already has been funded (see TTP No. OR-3DAA). Installation and demonstration of the Phase 3, advanced-stage microwave machine, robotics, and vacuum system for demonstration will be \$3M. Demonstration costs include characterizing walls and floor, identifying the reinforcing steel grid pattern, building portable containment enclosures, personnel protection, clothing, and container storage but not transportation and burial charges.

Development and installation of the Phase 4 system for demonstration will cost \$5M.

Implementation Needs: The need exists to create a demonstration program for the most advanced system of all disciplines, so that a true comparison can be made.

A track system, if needed, needs to be developed for demonstration. Manipulators with vacuum systems need to be able to move along the floor, around columns, up walls, and overhead.

Per best engineering estimate, the projected capital cost of this technology is \$2.0M.

Authors: D. D. Haskell/615-675-3337 (X-10)
P. N. Hoskins/615-576-3369 (Y-12)

References:

1. Pentek Corporation, Caraopolis, Pennsylvania 15108-1659.

LASER CUTTING (STRUCTURAL STEEL)

DISM-27-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Bldg. 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low level Uranium, Mercury, Lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Laser cutting. This technology consists of a laser beam which melts and/or evaporates the metal being cut. An inert gas may be needed to blow away the molten metal to provide a smooth, clean kerf. The temperature produced by the laser can reach more than 20,000°F, and the cutting speed through tough steels can be 20 in./min.

Status: Predemonstration. Any known material can be cut by laser. The laser beam melts and/or evaporates the material (metal) being cut. The contamination would become alloyed in the material being cut because of the extensive heat. The embedded contamination would be a potential problem for decontamination. The kerf and heat-affected zone are smaller than with any other cutting process. The process could easily be adapted to a manipulator for remote control. No waste would be present from the process. Existing laser technology consists of the use of Nd: YAG and CO₂ lasers. Wastes that are present in other cutting systems that produce mixed waste, bulk contaminated waste, etc., are minimized in laser cutting. Cost savings of \$10M would be found in the reduction of labor and protective clothing. A fiber-optic or other waveguide delivery system is preferred and has been demonstrated for Nd: YAG lasers, but appropriate waveguides have not been demonstrated for CO₂ lasers. Some limitations are the capital cost, which is relatively high compared to other cutting methods. Also, laser safety issues such as beam containment need to be addressed to minimize restrictions to collateral activities. An advantage to this system would be that the laser generator remains remote to the contaminated structure, possibly outside the building, thus avoiding being contaminated. The cost of the laser system is estimated to be \$1.5M.

A major disadvantage of this technology for Building 9201-4 is that the heat generated would vaporize the Mercury present, increasing the hazard to workers.

The technology exists in the predemonstration stage at the Penn State Applied Research Laboratory. The U.S. Navy has funded a feasibility demonstration of the technology for dismantlement of submarine hulls. The technology is very likely to work, because laser cutting is common in industry.

Science/Technology Needs: Conclusion of the appropriate power level for the laser for structural steel is needed. A fiber-optic delivery system currently is not viable for some lasers. Development of a system or manipulator that maneuvers the laser in a typical building is needed.

Implementation Needs: A prototype demonstration (full-scale) that shows the applicability and adaptability to supplying a cutting process for structural steel is needed. The cost of a demonstration would be \$2M-\$2.5M. The overall assessment of the usefulness of the technology is that it is a low priority. It would take 4 years to combine the existing technologies to address site-specific problems and to perform tests. The operational cost for a remotely controlled laser cutting system is estimated to be \$900/cut through a 6-in.-diam pipe.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. E.P. Degarmo, J.T. Black, R.A. Kohser, *Materials and Processes in Manufacturing*, 6th ed., Macmillan Publishing Company, New York, New York, 1984.
2. P.E. Denny, Penn State Applied Research Laboratory, personal communication, August 1992.
3. Martin Marietta Energy Systems, Inc., Photonics Research and Development staff.

HIGH-PRESSURE ABRASIVE WATER JET (STRUCTURAL STEEL)

DISM-28-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low-level uranium, mercury, lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Cutting

Technology: High-pressure abrasive water jet. The abrasive water jet cutting system can cut steel using high-pressure water and some sort of abrasive, usually garnet. The garnet is mixed with the high-pressure water in the nozzle to produce a solution that will induce a large impact force. Generally, the system can cut up to 6-in.-thick steel and 4-ft-thick steel-reinforced concrete.

Status: Demonstrated. The abrasive water jet consists of a jet of abrasive-loaded water at pressures exceeding 50,000 psi which is directed at the workpiece. The basic components of an abrasive water jet cutting system are: high-pressure pump, abrasive delivery system, abrasive water jet nozzle, traverse system, and a catcher. Pressurized water goes through a sapphire orifice to produce a high-velocity water jet. The abrasives and water exit the nozzle and perform the cutting. The momentum transfer between the water and abrasive produces a high-velocity, focused stream. A recovery system will need to be on the blow-through side of the material being cut. A recovery system will need to be able to recirculate the contaminated water, thereby reducing waste. The abrasive water jet is capable of cutting under water.

Ferritic and austenitic steel up to 9-in. thick can be cut; other metals also can be cut. An intensifier is used to generate the high pressures required. The intensifier pumps require periodic rebuilding (every 1000 h) and constitutes a noise hazard when it is operating (100-110 dBA). The flow rate from the pump is an average of 1.5 gal/min. The pump can be controlled by a microprocessor; therefore, remote control is adaptable.

Manipulators are easily adaptable to the cutting system. A 5-axis gantry-type system is commonly used in a stationary system. The cutting system can be portable as well. A common manipulator will cost \$300K.

Airborne and gaseous contamination generated is low. The system also can be remotely operated, if needed. Cutting speed for 2.5-in.-thick carbon steel is 3-4 in./min. Abrasive consumption (usually garnet) is 1.5-2.0 lb/min. Also, approximately 1.4 gal/min of liquid is generated. In 1989 dollars, the cost of an abrasive water jet system was \$400K. The mixing tube and orifice of the nozzle, as well as the abrasives, are consumable. The mixing tube is \$230, ceramic balls are \$2/lb, orifices are \$5, and garnet abrasive is \$0.32/lb. This process will not capture surface contamination from the material being cut. Respirators and assorted equipment for worker protection will not be necessary, because the contaminated air particles will be wet, thereby reducing the cost by \$350K.

Science/Technology Needs: A recovery system for the water and recyclable abrasives will need to be developed. Development of a portable system that can position the nozzle on the walls, ceiling, floors, and columns is needed. Development of a method to contain blow-through and the spread of contamination is needed.

Implementation Needs: The ability to separate contamination from the water slurry would have to be demonstrated. The need exists to view videos available from other nuclear facilities and possibly to visit sites to evaluate recovery systems without on-site demonstrations. Currently, at the Y-12 Plant in Oak Ridge, Tennessee, the decontamination and decommissioning program is procuring such a system. A demonstration will be needed to view the portable movement of the system while cutting an I-beam. The demonstration will cost \$250K. The overall assessment of the usefulness of this technology is that it is a high priority. The time required to test the cutting system against specific site problems would be 2 years. The operational cost for an abrasive water jet cutting system is estimated to be \$100/h of cutting.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. *Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor*, NL-89/31, Argonne National Laboratory, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
2. *Abrasive Water Jet Cutting of Uranium*, FMPC-2118, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
3. *CNC Water Jet Machining and Cutting Center*, KCP-613-4397, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
4. Daren C. Davis, "Robotic Abrasive Water Jet Cutting of Aerostructure Components," MS89-812, Non-Traditional Machining, conference paper, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
5. Qwest Integrated, Inc., personal communication, April 6, 1993.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low-level uranium, mercury, lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Cutting

Technology: Plasma arc cutting. This technology uses a high-velocity, high-temperature, ionized gas torch to cut conductive materials. An arc is established between a tungsten electrode and the workpiece in either nitrogen or a mixture of argon and hydrogen. The gas and arc are constricted as they leave the torch nozzle, causing very high current densities and temperatures. This causes the workpiece to melt and the molten metal to be blown out through the cut being made. Jets of water may be used to further constrict the plasma arc and cool the nozzle, thus prolonging its life.

Status: Demonstrated. Typical cutting speed is 13 in./min, and the maximum air depth of a cut in carbon steel is 7 in. Almost any metal can be cut because of the high plasma temperature. Metals resistant to oxy-fuel cutting, such as copper, nickel, magnesium, and titanium, can be cut by plasma arc. Stainless steels require use of a flux to be cut with oxy-fuel, but a flux is not needed with plasma arc. Aluminum is also easily cut by plasma arc. Hearing protection normally is required; noise levels are over 100 DBA near the torch. Airborne contamination will be generated (smoke and particulates), but can be reduced when water jets are used. Torch life is 1-2 h, but is prolonged when water jets are used. Uranium contamination may be alloyed with the structural members being removed, making decontamination nearly impossible when this or any thermal cutting method is used. Complex geometries and layered structures that are not tightly bonded are difficult to cut using plasma arc technology. A plasma arc system will cost \$40K. Nozzle tips are consumable and cost \$2K each. Gas and electric power also are required, as well as electrodes (\$200 each).

A major disadvantage of this technology for Building 9201-4 is that the heat generated would vaporize the mercury present, increasing the hazard to workers.

Science/Technology Needs: Research has been done in Germany whereby the torches have been mounted on a large blade (600-mm diam), but the process is discontinuous, requiring rotation of the blade to be stopped to ignite the torches. The Germans cite the need to make their process continuous and to make the process computer-aided (1989). Cutting under 20 m of water was demonstrated.

Implementation Needs: The particulate generation rate has been determined to be 4-6 lb/h, requiring a high-efficiency, particulate-air-filtered exhaust system and a contained area in which to cut. If water jets are used, 0.5 gal/h is required. The plasma arc torch is operated remotely, but frequent maintenance of the system is necessary, requiring entry into the cutting area. Demonstration will be needed to adapt the process to the different types of structural steel. The overall assessment of the usefulness of plasma arc cutting is that it is a low priority. Four years would be required to test the cutting system on site-specific problems. A demonstration would cost \$250K. The operational cost is estimated to be \$600/cut.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory*, ANL-89/31.
2. *Final report from the Technical University of Hannover to the Department of Research and Technology*, INIS-MF-12032, German Government.
3. E. P. Degarmo, J. T. Black, R. A. Kohser, *Materials and Processes in Manufacturing*, 6th ed., Macmillan Publishing Company, New York, New York, 1984.

OXYACETYLENE CUTTING (STRUCTURAL STEEL)

DISM-30-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low-level uranium, mercury, lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Cutting

Technology: Oxyacetylene cutting. Oxygen and acetylene are run through a torch and ignited. The flame causes rapid exothermic oxidation of the metal. This type of cutting is mostly used on ferrous metals.

Status: Accepted. The process is one of rapid oxidation (burning) of iron at approximately 1600°F. The oxy-fuel is used to raise the temperature to a level at which burning occurs, then oxygen is increased to produce oxidization of the iron. In general, this process is only useful for cutting carbon steels. Highly alloyed steels and nonferrous metals tend to form refractory oxides; these oxides insulate the workpiece from further melting. When cutting carbon steel clad with stainless steel, the stainless can be "gouged" using an electric arc to expose the carbon steel layer beneath. Fluxes also can be used to keep stainless steel from forming oxides. Introducing iron powder into the flame increases flame temperature to aid in cutting alloyed steel. Propane or hydrogen can be used as fuel gases instead of acetylene; use of hydrogen allows cuts to be made under water (metal powder flame enhancers cannot be used under water).

A major disadvantage of this technology for Building 9201-4 is that the heat generated would vaporize the mercury present, increasing the hazard to workers.

Electric arc gouging and introduction of iron powder into the flame allow a wider range of materials to be cut than just mild steel. A torch setup cost around \$2K; oxygen was \$0.92/ft³ and acetylene was \$0.5/ft³.

Science/Technology Needs: Oxyacetylene cutting is a well-developed technology needing no further work.

Implementation Needs: Flame-cutting methods create smoke and metal fumes, so exhaust ventilation is required for personnel in the area. Flame cutting is conducive to mechanization, which tends to produce a more even, neater cut than cutting by hand. Mechanized cutting speeds are 18–30 in./min, attainable in 3–6-in.-thick mild steel. A demonstration would not be necessary. Testing on site-specific problems would take six months. The operational cost of an oxyacetylene cutting system is estimated to be \$150/cut. The overall assessment of the usefulness of oxygen cutting is that it is low priority.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory*, ANL-89/31.
2. E. P. Degarmo, J. T. Black, R. A. Kohser, *Materials and Processes in Manufacturing*, 6th ed., Macmillan Publishing Company, New York, New York, 1984.

THERMITE LANCE (STRUCTURAL STEEL)

DISM-31-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low level Uranium, Mercury, Lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Demolition

Technology: Thermite lance. When iron, aluminum, and magnesium are ignited together, they react ("thermite reaction"), producing temperatures of up to 10,000°F. Oxygen is forced through a lance (consisting of iron pipe packed with aluminum, magnesium, and steel wires); the oxygen and wires then can be lit and the torch directed by the operator. The amount of oxygen controls the flame; the torch is extinguished by closing the oxygen valve. The system is portable, but requires an operator to be close to the cutting. The torch can be used under water.

Status: Predemonstrated. The thermite reaction is well-known and understood, but the thermite lance (an accepted technology) is a gross cutting tool not suitable for toxic materials. Hazards include spattering of hot metal, noise, metal fumes, and dust. In Building 9201-4, the heat generated may vaporize the mercury present and increase the hazard to workers.

Cost—In 1989 dollars, the capital cost for the system was \$650. Lances cost \$6 each; oxygen cost also must be added.

Science/Technology Needs: The thermite reaction needs to be incorporated as a process that can be remotely controlled to be useful in contaminated environments. The time required for commercialization of this technology would be two years.

Implementation Needs: Exhaust ventilation is required with this system, as well as enhanced awareness, because of the fire hazard created by the system. The current technology is not amenable to robotics, because the lance is consumable and the rate of reaction depends on the oxygen flow, which is operator controlled. The lance also must be

placed on the workpiece so that the molten metal continuously washes down out of the cut. The overall assessment of the usefulness of the thermite lance is that it is low priority. The time required for a site-specific test would be three years. A demonstration would cost \$75K. The operational cost for a thermite lance cutting system is estimated to be \$150/cut.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory, NL-89/31.*

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low level Uranium, Mercury, Lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Cutting

Technology: Plasma arc saw. This technology is a process in which a circular saw has a plasma induced on its cutting edge; therefore, any type of steel can be cut. Steel, tubes, banks of tubes, and geometrically complicated components can be cut. This technology can be used under water up to a depth of 65 ft.

Status: Demonstration. Plasma arc saw technology enables thermal cutting of steel plates/walls independent of thickness in a water depth of up to 65 ft. This technology was demonstrated in cutting plates of up to 11.8 in. thick. The maximum permissible metallic wall thickness to be cut depends only on the diameter of the plasma arc saw blade. Emission of dust and aerosol during the process only depends on the melted material. This process can be adapted to remote-control manipulators. Thus, a cost payback of \$800K-\$1M will be realized with the reduction in contaminated clothing, monitoring, etc.

In Y-12 Building 9201-5 (exclusion area), a prototype (experimental stage) arc saw with a water table is available. Although construction of this prototype arc saw is not totally complete, this device still can be used for experimental trials. This arc saw can be operated under water up to a depth of 15 ft. Deeper underwater operations also are possible, but they will require some design and construction changes. The diameter of the saw in this device will determine the maximum possible wall thickness to cut. In general, for these units, a water pool or water table is fixed in one location. The piece to be worked is brought to the machine for processing. Emission of dust and aerosol during the process only depends on the melted material.

PLASMA ARC SAW (STEEL STRUCTURES)

DISM-32-OY

All costs are related to a maximum part-wall-thickness cutting of 6.5 in. (stainless steel). The following partial information was provided by the L-TEC Corporation in South Carolina (803-664-4397).

- The plasma arc cutting system features a standard cutting head:
 - Plasma—approximately \$50K
 - Electric arc—approximately \$25K
- X, Y, Z Table (to be placed in a determined location and not for transportation to field operations):
 - Plasma—up to \$150K (depending on sophistication)
 - Electric arc—approximately up to \$150K (depending on sophistication).
- Water table:
 - Plasma—approximately \$60K-\$80K
 - Electric arc—approximately \$60K-\$80K (This arc cutting device with carbon-electrode is not recommended for underwater operations.)
- Air treatment system—This system features a filter device, hoods, snorkel device, etc., to be applied in atmospheric and underwater operations:
 - Plasma—approximately \$20K-\$50K (depending on sophistication)
 - Electric arc—approximately \$20K-\$50K (depending on sophistication)

If the cutting equipment is made "transportable" to field operation directly upon installation:

- Cutting head—approximately \$50K
- Portable "rig," "carrier"—approximately \$20K-\$50K
- Hydraulic arm (moveable, displaceable) up to about 10-12 ft high—approximately \$40K-\$60K.

For an arc with a carbon-electrode, this "transportable" system will not be recommended because of the multiple passes required to perform a metallic cut. In general, when field operations are desired, the cutting operation should be as simple and as fast as possible, especially when physical obstructions are present in the specific area of cutting. The cutting depth (directly in the cutting kerf) is approximately 3/8 to 5/8 in. for the "first pass."

In general, two persons are required to operate these systems, especially during set-up of the system. Labor rate: \$70/h each. A steel pipe with an outer diameter of 10 in. with a wall thickness of 1 in. can be cut. The cutting speed of the process is 30-60 in./min, after the pipe has been brought to the cutting head. The time necessary to cut the pipe is about 1 min. The approximate cost of this system with a remote-control manipulator is \$1.2M-\$1.4M.

The cutting of metals through electric-arc or plasma generate dust, aerosol, and particles. Therefore, an air-filtration system is necessary (for atmospheric and underwater operations). These particles clog the filter very often. The heat generated could vaporize the Mercury present increasing the hazard to workers. the water used would be contaminated and must be treated as a waste.

Science/Technology Needs: Development of a large saw to saw through a thick steel wall is needed. Development of a remote-control manipulator to maneuver the saw in and out of the cutting position also is needed. A time period of two years would be required for commercialization of this technology.

Implementation Needs: Requires transfer from development stages to broad industrial application. The technology is available on a commercial basis. Because of the intrinsic condition of the cutting operations, a computer-controlled process is required. A remote-control operation can be implemented without difficulty, making this technology very suitable for underwater operations. A demonstration should be prepared to show the applicability of the remote-control manipulator using the plasma arc saw on an I-beam. The demonstration is estimated to cost \$1M-\$1.5M. Developing and demonstrating this technology is a low priority. Two years would be required to test this technology against specific site problems. The operational cost is estimated to be \$1100/cut.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

Reference:

1. *Final Report from the Technical University of Hannover to the Department of Research and Technology*, INIS-MF-12032, German Government.

THERMAL ARC WATER JET (STRUCTURAL STEEL)

DISM-33-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4 which contains: process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low level Uranium, Mercury, Lithium compounds, PCB's, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Cutting

Technology: Thermal arc water jet. The cutting process involves creation of an electric arc between the wire electrode and metal sheet which melts the metal in the workpiece. The water jet around the wire is used to "wash away" melted material from the cutting kerf. The wire is consumed because of the high current. The wire has to be fed so that the process can work continuously. With this device, steels with a wall thickness of up to 3.95 in. can be cut under water up to depths of 65 ft.

Status: Demonstrated. In general, these devices are directed by a computer numeric controller. With additional tooling support, cutting in several axes of operation will be possible. Hole piercing of up to a wall thickness of 1.2 in. also can be done. Cutting in vertical and horizontal motion of pipes, bank of pipes, and geometrically complicated components is possible.

This process can be adapted to remote-control manipulators. Thus, a cost payback of \$800K-\$1M per building will be found with the reduction in contaminated clothing, monitoring, etc.

All costs are related to a maximum part-wall-thickness cutting of 6.5 in. (stainless steel). The following partial cost information was provided by the L-TEC Corporation in South Carolina (803-664-4397).

- The electric arc cutting system features a standard cutting head
 - Plasma—approximately \$50K
 - Electric arc—approximately \$25K
 - X, Y, Z table (to be placed in a determined location, not for transportation to field operations).
 - Plasma—up to \$150K (depending on sophistication)
 - Electric arc—up to \$150K (depending on sophistication)
- Water table:
 - Plasma—approximately \$60K–\$80K
 - Electric arc—approximately \$60K–\$80K (This arc-cutting device with carbon electrode is not recommended for underwater operations.)
- Air treatment system—This system features a filter device, hoods, snorkel device, etc., to be applied in atmospheric and underwater operations:
 - Plasma—approximately \$20K–\$50K (depending on sophistication)
 - Electric arc—approximately \$20K–\$50K (depending on sophistication)
- If the cutting equipment is made “transportable” to field operation directly on the installation:
 - Cutting head—approximately \$50K
 - Portable “rig,” “carrier”—approximately \$20K–\$50K
 - Hydraulic arm, moveable, displaceable up to 10–12 ft high—approximately \$40K–\$60K.

For an arc with a carbon electrode, this “transportable” system will not be recommended, because of the multiple passes required to perform a metallic cut. In general, when field operations are desired, the cutting operation should be as simple and as fast as possible, especially when physical obstructions are present in the specific area of cutting. Cutting depth (directly in the cutting kerf) is approximately 3/8 to 5/8 in. for the “first pass.”

In general, two persons are required to operate these systems, especially during setup of the system. Labor rate: \$70/h each. A steel pipe with an outer diameter of 10 in. with a wall thickness of 1 in. can be cut. The cutting speed of the process is 30–60 in./min, after the pipe has been brought to the cutting head. The time necessary to cut the pipe was approximately 1 min.

The cutting of metals through electric arc or plasma generates dust, aerosol, and particles. Therefore, an air filtration system is necessary (for atmospheric and underwater operations). These particles clog the filter very often. The heat generated would vaporize the Mercury present, increasing the hazard to workers.

The approximate cost of this system with a remote-control manipulator is \$1M–\$1.2M, plus a labor rate of \$70/h each for two operators.

THERMAL ARC WATER JET (STRUCTURAL STEEL)

DISM-33-OY

Science/Technology needs: Development of a remote-control manipulator to maneuver the system around the workpiece is needed. Two years will be required for the technology to reach a mature application.

Implementation Needs: In general, no major changes to the cutter device are needed. This is commercially available technology. The process can be adapted to a machine with more axes for diversity of operation. A remote-control operation can be implemented, allowing this process to be very acceptable for underwater operation. A demonstration of the system would be desirable to show the applicability and adaptability to cutting structural steel. The demonstration would cost \$1M-\$1.5M. Testing on the specific site problems will require two years. Developing and demonstrating this technology would be a low priority. The operational cost is estimated to be \$1000/cut.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

Reference:

1. *Final Report from the Technical University of Hannover to the Department of Research and Technology*, INIS-MF-12032, German Government.

EXPLOSIVE CUTTING (STRUCTURAL STEEL)

DISM-34-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low level Uranium, Mercury, Lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Demolition

Technology: Explosive cutting. This technology consists of an explosive core contained in a metal or hard plastic casing. The cutter is chevron shaped, so it can be directed at the workpiece.

Status: Demonstrated. This technology is accepted as a means of gross cutting. This technique can be used either in air or under water; immersion in water helps to dampen the sound of the explosion. This technique is typically used only where two or more cuts must be made simultaneously or where cutting by other means is impractical. Cutting speed is a function of how fast the charges can be placed; this process can cut metals up to roughly 6-in.-thick.

Cost—Capital cost of this system is \$116K. Charges and cutters are consumable; charges cost \$175/ft and cutters cost \$9280 each. Containment of the contaminants (if any) will be required, costing \$25K. To eliminate this problem, the technology could be used under water, such as in canals and pools, to meet the requirements for contamination control.

Science/Technology Needs: A means of buffering the shock wave and its associated noise is needed. A method to contain the contamination that explodes from the material is needed.

Implementation Needs: Charges can be placed remotely. The need exists to research technology and to visit other nuclear facilities to find alternatives regarding the explosive process. Overall assessment for this technology is that it is medium priority. To demonstrate the technology on a pilot scale and to perform site-specific tests would take 3 years and cost \$200K. The operational cost is estimated to be \$10K/cut.

Author: G. A. Blankenship/615-574-9829 (Y-12)

**EXPLOSIVE CUTTING
(STRUCTURAL STEEL)**

DISM-34-OY

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory, ANL-89/31.*

LIQUIFIED CRYOGENIC GAS CUTTING (STRUCTURAL STEEL)

DISM-35-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low-level uranium, mercury, lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Liquified cryogenic gas cutting. Cryogenic liquified gas would be used like water jet cutting.

Status: Evolving technology. The advantage to such a system would be like CO₂ blasting in that removed or cut materials would be lifted from the surfaces involved by the evaporating gas with very little surface abrasion to trap contamination. Another advantage may be achieved because of the low temperatures involved. Cutting below the embrittlement temperature for metals may be advantageous. Contamination will not be alloyed to the material being cut using this process. This process would provide a means to cut material contaminated with a hazardous material that has a low vaporization temperature (i.e., mercury). A remote control would be needed to manipulate the cutting system; therefore, worker exposure would be minimized. Elimination of the cryogenic gas from the operator breathing air is an issue which must be addressed.

Cost—The approximate cost of the system is \$3M–\$3.5M. Cost payback would be \$500K–\$750K, if contaminated clothes and equipment were minimized. Cost advantages would be realized in cutting equipment, where criticality safety is a major issue. Any reduction in criticality safety considerations could mean major savings.

Science Technology Needs: A cooperative effort with commercial suppliers of jet cutting and blasting equipment must be initiated to investigate this technology. Development of a manipulator that would supply the cutting head and the process in which to use cryogenics to cut is needed. Mercury vaporization caused by cryogenic gas cutting needs to be quantified.

LIQUIFIED CRYOGENIC GAS CUTTING (STRUCTURAL STEEL)

DISM-35-OY

Implementation Needs: Full engineering and development is needed. The cost to demonstrate this technology is estimated to be \$10M. An overall assessment of the usefulness of the technology would be high. To obtain a pilot-scale demonstration and a test of the exact site problems will take four years. The operational costs are estimated to be \$2000/cut.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. Martin Marietta Energy Systems, Inc., Engineering staff.

CONVENTIONAL DISASSEMBLY (STRUCTURAL STEEL)

DISM-36-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low-level uranium, mercury, lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Demolition

Technology: Conventional disassembly. This technology includes dismantling by removing nuts and bolts and sawing using tooth or abrasive blades. Dismantling by removing fasteners creates no extra waste and, if the dismantled pieces are clean, they can be reused in many instances. Labor will be used to do the dismantlement; therefore, manipulators and robotics will not be a cost factor. However, dismantling by removing fasteners is slow and labor intensive.

Status: Accepted. Conventional dismantlement will largely be done by labor and use of small, inexpensive equipment to remove fasteners. Total cost for conventional dismantlement by a labor force will be inexpensive (\$50K-\$100K). The process will be limited only to the clean areas or areas that have low-level contamination. Respiratory protection against lead-based paints, airborne mercury, and asbestos may be needed.

Conventional sawing such as tooth or abrasive blades can be used, but considerable attention should be focused on the spread of contamination through the kerf. Unlike the thermal sawing processes, sawing with tooth or abrasive blades will not cause contaminants to melt into the workpiece. Cutting can be done in air or under a liquid, using power or hand tools. Very soft and very hard materials are most difficult to cut. Very soft material sticks on the saw blade, while the teeth or abrasive on the blade must be harder than the workpiece for cutting to occur. The cost of conventional saw and accessories would be \$75K. Not using robotics and manipulators will provide a cost payback of \$500K.

Science/Technology Needs: These needs depend on the particular method chosen. A demonstration will be needed to adapt and improve the process and to maximize worker protection.

Implementation Needs: The need exists to view videos from other nuclear facilities and possibly to visit other sites to evaluate dismantlement equipment and procedures. Methods of addressing the issue of the spread of contamination through the kerf produced by the sawing process are needed. Containment will be applied to the contamination for the process. The overall assessment of the usefulness of the conventional disassembly is that it is essential priority. The time required for combining existing technologies to meet specific requirements and to perform tests pertaining to specific site problems would be one year. The demonstration will cost \$200K. The operational cost is estimated to be \$10/bolt and \$300/cut.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. Martin Marietta Energy Systems, Inc., Engineering staff.

GRAPPLE AND MASSIVE SHEARING (STRUCTURAL STEEL)

DISM-37-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of steel structural materials that are contaminated with low-level uranium, mercury, lithium compounds, PCBs, oil, and lead base paint.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Demolition

Technology: Grapple and massive shearing. An excavator-mounted shear uses the hydraulic power of an excavator to operate a shear on the excavator arm. The shear can cut steel beams and concrete. The excavator-mounted grapple, similar to the shear, can be used to handle scrap, tear, and pull to help demolish buildings. The operator is protected inside the cab of the excavator, 30-50 ft from the shearing site.

Status: Demonstrated. The shear is an accepted technology. A "medium shear" which can cut up to 16-in. steel beams costs roughly \$120K (excluding excavator). An excavator of 50K-65K lb would cost \$250K. The head of this shear rotates to allow shearing at different angles. Consideration of floor loading and available space to operate the excavator should be addressed while sizing the excavator. Rental of excavators is a common practice, if the job is not large enough to justify procurement of one.

Disadvantages include limited use due to space and floor loading limitations in Building 9201-4, and the potential for scattering contaminated debris.

Science/Technology Needs: The excavator-mounted shear is a commercially available technology.

Implementation Needs: The excavator-mounted shear can only be used in areas large enough to accommodate the excavator. Spread of contamination when cutting contaminated metals would be minimal because the shearing takes place in the ambient temperatures, and no shavings or swarf is generated. However, working in a contaminated area might contaminate the excavator. The excavator can be modified to operate remotely, removing the operator from the work area. The overall assessment of the usefulness of this technology is

GRAPPLE AND MASSIVE SHEARING (STRUCTURAL STEEL)

DISM-37-OY

that it is essential priority. The time required to perform site-specific tests would be one year. The operational cost is estimated to be \$150/cut.

Author: G. A. Blankenship/615-574-9829 (Y-12)

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. LaBounty Mfg., Inc.
2. LaBounty Mfg., Inc., literature pertaining to shears and grapples.
3. John Deere, Inc., and Caterpillar, Inc., videotapes of excavators.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of asbestos materials that are contaminated with low level uranium, mercury, lithium compounds, and PCBs.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Removal.

Technology: Conventional removal. Manual removal of asbestos utilizing manpower. Personnel enter the area in disposable clothing and respirators. They rip out the asbestos with hand tools and bag it for disposal. This process is very slow and cumbersome.

Status: Accepted. This technology is widely used at this time. This is a very labor-intensive, costly, lengthy process. The time and cost of removing asbestos in a project of this size would be better used in development of automated processes.

Cost—The operational cost is estimated to be \$200/ft².

Science/Technology Needs: None

Implementation Needs: None. This is a low priority, because of high costs and manpower availability. To complete the removal of asbestos, it is estimated to take 2 years using 3 crews of 10 people working 2 shifts. There would be no cost to develop this technology, because it is proven.

Author: E. C. Strange/615-675-3337

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References: None

CONVENTIONAL/AUTOMATED REMOVAL WITH VACUUM SYSTEM (ASBESTOS)

DISM-39-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of asbestos materials that are contaminated with low-level uranium, mercury, lithium compounds, and PCBs.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Removal

Technology: Conventional/automated with vacuum system. The technology involves manual removal of asbestos with the aid of a high-volume vacuum system. The vacuum system will be remote and will draw asbestos from inside the building to a mobile vacuum system outside the building. At this point, the asbestos will be bagged and disposed.

The vacuum system is self-contained and mounted on a towable trailer. The system includes a hopper, bagging port, high-efficiency particulate air filter, self-powered vacuum system, and large-diameter suction hose. The hose is routed to the asbestos removal area and transports the asbestos to the hopper outside for bagging. The distance from the hopper to the removal point can be up to 1000 ft.

Status: Accepted. The technology is currently available and in use at the Oak Ridge Y-12 Plant.

Cost—This system would save about 250% in the cost of materials and labor over the conventional removal and glove-bag operation. An example of cost savings: an area requiring 11 laborers and 4000 bags using the conventional method would require 4 laborers and 1500 bags using the proposed automated method. The operational cost is estimated to be \$60/ft²

Science/Technology Needs: None required. However this could be integrated with alternative, highly automated systems, in which case, it would require additional engineering design support.

Implementation Needs: Operator training on system setup and operation is required. This is a medium priority, based on cost savings over the conventional methods. It is estimated

**CONVENTIONAL/AUTOMATED REMOVAL
WITH VACUUM SYSTEM (ASBESTOS)**

DISM-39-OY

to take 1 year to develop and test this technology. The cost of development would be \$200K for a small demo.

Authors: E. C. Strange/615-675-3337

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. Vacuum Engineering Corporation, Milwaukee, Wisconsin.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of asbestos materials that are contaminated with low level uranium, mercury, lithium compounds, and PCBs.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Removal

Technology: CO₂ blasting. This technology consists of ultrahigh-pressure CO₂ that is forced through a small-diameter nozzle which creates a spray that cuts away the surface of material. The contaminated removed surface will be handled as waste. Then, the remaining pipe can be cut up by other methods and recycled, reused, or disposed locally. The technology is currently available but has not been demonstrated in Building 9201-4.

Removal: This involves a robotically manipulated CO₂ blasting machine which systematically removes the exterior asbestos of the pipe overhead and on the walls. This system would encircle the pipe using a clamshell mechanism inside a shroud with a vacuum recovery system that would collect contaminated debris. Pipe hangers, elbows, valves, and pipes located close to walls must be addressed differently. All piping will be free of exterior radioactive contaminants before removal.

Asbestos-covered walls are cleaned using a directional nozzle mounted on a robotic manipulator with a vacuum recovery system. The robot is operated remotely using optics to direct the CO₂ blast. The asbestos is removed to the bare concrete or block wall, and the vacuum system recovers the asbestos after removal.

Status: Demonstration. This technology is a DOE-sponsored development. Programmable robotic manipulators have been developed. High maintenance items include nozzles, hoses, and pumps.

By removing the contaminated surfaces, which will be bagged and disposed, the remainder of the decontaminated pipe can be recycled or reused, saving \$17/ft³ in disposal costs.

Demonstrations of removal need to be completed before cost payback can be evaluated. The CO₂ systems that require no water and simplify the recovery system would be well suited for contaminated piping.

Cost—The operational cost for this technology is estimated to be \$20/ft².

Science/Technology Needs: A vacuum recovery system linked to a robotically controlled CO₂ blaster needs to be demonstrated. Development of this equipment, manipulators for tracking pipe during removal, remotely operated robotic manipulators, and an integrated vacuum system for demonstration would cost \$3.5M. Demonstration costs include personnel protection, clothing, and container storage but not transportation and burial charges.

Implementation Needs: The need exists to view videos available from other nuclear facilities and possibly to visit sites to evaluate recovery systems without on-site demonstrations. The need exists to determine what robotics have been developed using in-house seminars from vendors on the latest and future technologies. Robotic manipulators with a recovery system need to be able to move around on the floor, up and around concrete columns, and overhead (the underside of the floor above). Methods of addressing removal of asbestos from valves in piping, piping elbows, and piping very close to walls are needed. This is a high priority in asbestos removal, as the personnel required to operate this system is minimal and it removes the worker from the environment. The estimated time to implement this technology is from 4 to 5 years. The cost to develop the integrated system is estimated to be \$3.5M. The operational cost of this system is estimated to be \$20/ft², which is a substantial savings over the conventional method.

Authors: E. C. Strange/615-675-3337

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. Alpheus Cleaning Tech. Corp., Rancho Cucamonga, California.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of asbestos materials that are contaminated with low level uranium, mercury, lithium compounds, and PCBs.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Removal

Technology: Sodium bicarbonate blasting. This technology uses a sodium bicarbonate slurry as the blasting abrasive in a high-pressure water jet. The abrasive is nontoxic, non-sparking, and environmentally sound. The residue is water soluble. No air supplied respirators are required for the operator. A portable self-contained vacuum system will remove residue and water to a collection tank for recycling or disposal.

Status: Demonstration. The technology has not been demonstrated at Y-12.

Efficacy—Medium. It will remove asbestos from a surface without damaging the surface. Production rate is 2 ft²/min.

Waste—100 lbs per hour of sodium bicarbonate and 0.5 gpm of water.

Science/Technology Needs: Science Development—Recyclable blast media and a recovery system for the abrasives and water. Technology Improvement—Longer lasting nozzles, hoses, and pumps.

Implementation Needs: Personnel training. Implementation of a remote controlled manipulator.

The following costs represent the author's best engineering estimate:

Development cost: \$300K
Capital cost: \$200K/system
Operating cost: \$100/hour

Authors: R. L. Whaley/615-574-2271 (Y-12)

References:

1. Corrosion Specialties Incorporated, Tucker, Georgia.
2. CDS Group, Princeton, New Jersey.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of asbestos materials that are contaminated with low level uranium, mercury, lithium compounds, and PCBs.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Removal

Technology: Ice blasting. This technology delivers a high-velocity stream of solid CO₂ pellets (dry ice) to clean or strip a surface. The pellets are non-toxic, sublime to the atmosphere on impact, and require no disposal. The system requires a liquid CO₂ supply and often requires a separate air compressor/dryer. Possible use of 600 lbs/hour of CO₂ in enclosed spaces may require breathing air for the operator.

Status: Demonstration. Not yet demonstrated at Y-12.

Efficacy—High. It will remove asbestos from a surface without harming the surface.

Waste—Minimal.

Science/Technology Needs: Technology Improvement—Longer lasting nozzles and hoses.

Implementation Needs: Personnel training

The following costs represent the author's best engineering estimate:

Development cost: \$100K

Capital cost: \$25K/system

Operating cost: \$100/hour

Authors: R. L. Whaley/615-574-2271 (Y-12)

References:

1. Cold Jet, Inc., Loveland, Ohio.

2. Environmental Alternatives, Inc., West Chesterfield, New Hampshire.
3. Alpheus Cleaning Technologies Corp., Rancho Cucamonga, California.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of asbestos materials that are contaminated with low level uranium, mercury, lithium compounds, and PCBs.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: High-pressure water jet. This technology uses high-pressure water to provide the cutting force. No abrasive is used to cut the asbestos. A self-contained vacuum system will recover the water.

Status: Demonstration—not yet demonstrated at Y-12.

Efficacy—High. It will remove asbestos from surface and minimize the airborne contaminants.

Waste—1.0 gpm of water. No abrasive exists to be collected.

Science/Technology Needs: Science development—A recovery system for the water. Technology improvement—Longer lasting nozzles, hoses, and pumps.

Implementation Needs: Personnel training

The following costs represent the author's best engineering estimate.

Development costs: \$300K
Capital cost: \$350K per system
Operating cost: \$110/hour

Authors: R. L. Whaley/615-574-2271 (Y-12)

References:

None

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of asbestos materials that are contaminated with low level uranium, mercury, lithium compounds, and PCBs.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Laser cutting. Removal—The technology involves a robotically manipulated laser cutting machine which systematically holds and cuts the transite asbestos walls around equipment and outer building walls and stacks these on a transfer cart for removal and disposal.

Laser cutting is accomplished with a laser beam which thermally sears through the asbestos and cuts it into pieces that are easily handled for disposal. This method would be used to cut transite panels from around the equipment. The laser manipulator could include either grippers or suction cups to safely remove and stack pieces during and after they have been cut.

Status: Predemonstration. This technology is a DOE-sponsored development. Programmable robotic manipulators have been developed. Laser cutting of asbestos has been demonstrated for laboratory feasibility. Preliminary results show that cutting of material results in essentially no dispersement of fibers and leaves the asbestos-cut interface cauterized, thus helping to seal the surface and to prevent dispersement of fibers during handling. Nd:YAG-type lasers should have sufficient power and can be coupled with a fiber-optic delivery system for ease of adaption to automated systems and for improved safety.

A disadvantage of this technology for Building 9201-4 is that the heat generated could vaporize the mercury present increasing the hazard to workers.

Cost payback: Elimination of waste, surface preparation, and man interface could save \$50M-\$100M during displacement operations. The system is potentially useful for cutting other hazardous materials such as PCBs, volatile organic compounds, etc.

Science/Technology Needs: The need exists for confirmation of negligible asbestos dispersement and cut cauterization. Beam containment, laser safety, optics protection from flaming, etc., are issues to be addressed during development. The key issue is to substantiate that fusion of fibers occurs and does not create any new, unrecognized waste control or disposal problems.

Development of this equipment, a manipulator track for the laser, and grippers or holding devices for the cut material (for demonstration) would cost \$3.5M. Demonstration costs include building a portable containment enclosure, personnel protection, and clothing and container storage but not transportation and burial charges. Operational costs are \$900/cut.

Implementation Needs: The need exists to view videos available from other nuclear facilities and possibly to visit sites to evaluate recovery systems without on-site demonstrations. The need exists to determine what robotics have been developed using in-house seminars from vendors on the latest and future technologies. Robotic manipulators with a recovery system need to be able to move around on the floor, up and around concrete columns, and overhead (the underside of the floor above). Methods of addressing cracks in concrete; blow-through when cutting; containerization of contaminated material; water and possibly abrasives; and removal of asbestos from valves in piping, piping elbows, and piping very near walls are needed. This is a medium priority. It is estimated to take 3 to 6 years to develop and test this concept. The cost of development is estimated to be \$3.5M.

Authors: E. C. Strange/615-675-3337

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. Laser Materials Processing Manufacturing Science Department, Penn State University, Henry E. Watson; 814-865-6345.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of asbestos materials that are contaminated with low-level uranium, mercury, lithium compounds, and PCBs.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: High-pressure abrasive water jet. Removal: Involves a robotically manipulated, high-pressure water jet machine which systematically removes the exterior asbestos of the pipe overhead. This system would encircle the pipe using a clamshell mechanism inside a shroud, with a vacuum recovery system that would collect contaminated slurry and recycle the water and possibly the abrasives, if used. Pipe hangers, elbows, valves, and pipes located near walls must be addressed differently. All piping will be free of exterior radioactive contaminants before removal. Cutting: Involves a robotically manipulated, high-pressure water jet machine. The machine will be mounted, and manipulators will grip two ends of the pipe to support it inside the cutting area. After cutting, the manipulators will lower the section of pipe and load it onto a pallet, so that the cut sections can be cycled through a remote water jet system which can strip the asbestos from the exterior using a feed system which rotates the pipe as it travels through a series of water jets positioned at different angles around the diameter of the pipe. All piping will be free of exterior and interior radioactive contaminants before removal.

Abrasive water jet removal is ultrahigh-pressure water with and without abrasive that is forced through a small-diameter nozzle which creates a spray that cuts away the surface of material. The contaminated surface removed will be handled as waste, with the contaminated abrasives and water to be recycled. The remaining pipe can then be cut up by water jet or other methods and be recycled, reused, or disposed locally. The technology is currently available but has not been demonstrated in Building 9201-4.

Abrasive water jet cutting is ultrahigh-pressure water with abrasive that is forced through a small-diameter nozzle, creating a stream that cuts through steel piping with one pass. This method would be used to cut process piping after asbestos has been removed, or with asbestos covering still intact, into sections for disposal or remote removal of the asbestos.

Status: This technology is a DOE-sponsored development; programmable robotic manipulators have been developed, and the water can be recycled. Concepts exist for abrasive recycling with 95% of the spoils recoverable. High-maintenance items include nozzles, hoses, and pumps when abrasives are used. Metal cutting with high-pressure water jets has been demonstrated.

A high-efficiency recovery system is needed for removal, to keep contaminated runoff to a minimum. Cracks in concrete will be a problem, because contamination will still be present and will have to be addressed, but no one system will be ideal for every situation.

A high-pressure water jet cutting recovery system will need to be present on both sides of the section being cut because of blow-through. The recovery system opposite the machine will have to withstand the pressure of blow-through.

By removing the contaminated surfaces (which will be microwave-dried and disposed), the remainder of the decontaminated pipe can be recycled or reused, saving \$17/ft³ in disposal costs.

Demonstrations for the removing and cutting processes need to be completed before cost payback can be evaluated. The lower-pressure systems that require less water and simplify the recovery system would be best suited for contaminated piping. The low-pressure system works at a slower rate, but the simpler recovery system would justify it. The operational cost is estimated to be \$1.25/ft².

Microwave drying being developed at ORNL could be used to consolidate and immobilize liquid wastes inside containers or bags for ultimate waste disposal but this would require demonstrations.

Science/Technology Needs: A recovery system with recyclable water and abrasives needs to be demonstrated. This will require a portable facility, if available, or pools with necessary equipment to separate and possibly decontaminate the water and abrasive for reuse.

Development of this equipment, manipulators for tracking pipe during removal, holding pipe during cutting, lowering pipe after cutting, and cleaning pools for demonstration would cost \$3.5M. The demonstration costs include building a portable containment enclosure, personnel protection, and clothing and container storage but not transportation and burial charges.

Implementation Needs: The need exists to view videos available from other nuclear facilities and possibly to visit sites to evaluate recovery systems without on-site demonstrations. The need exists to determine what robotics have been developed using in-house seminars from vendors on the latest and future technologies. Robotic manipulators with a recovery system need to be able to move around on the floor, up and around concrete columns, and overhead (the underside of the floor above). Methods of addressing cracks in concrete; blow-through when cutting; containerization of contaminated material, water, and possibly abrasives; and

removal of asbestos from valves in piping, piping elbows, and piping very near walls are needed. This is a high priority in asbestos removal, because of the cost savings, the fact that no heat is generated, and the fact that it is an available technology. The estimated time to implement this technology is 2-3 years. Cost to develop and demonstrate this integrated system is estimated to be \$3.5M. The operational cost is estimated to be \$1.25/ft².

Authors: E. C. Strange/615-675-3337

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. Quest Integrated, Inc., Kent, Washington.

LIQUIFIED CRYOGENIC GAS CUTTING (ASBESTOS)

DISM-46-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Removal of asbestos materials that are contaminated with low level uranium, mercury, lithium compounds, and PCBs.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Liquified cryogenic gas cutting

Status: Evolving technology. In this system liquified gas is used in a manner similar to the way water is used in water jet cutting.

Potential advantages—There will be no liquid effluent to collect and decontaminate. The low temperatures involved may allow cutting at temperatures below the embrittlement temperature for metals, and avoid vaporization of mercury. Cost advantages would be realized in cutting equipment where criticality safety is a major issue; this technique could save 20% of the cost over abrasive water jet cutting but probably would not produce any savings when compared to the more conventional cutting techniques such as laser cutting.

Potential disadvantage—Because of relatively large volumes of gas being generated by evaporation of the liquid, significant air filtration may be required. Adequate breathing air for operators is an issue.

Science/Technology Needs: Implementation requires that provisions be provided for collection and treatment of gas generated by liquid evaporation and the definition of the interface between the system and the remote manipulation deployment system.

Implementation Needs: Cost to implement is estimated to be \$10M, and the time to develop is estimated to be 6–10 years. The operational cost is estimated to be \$60/ft³ of waste generated. This technology is medium priority. Mercury vaporization needs to be quantified for asbestos being cut using this technology.

Author: J. W. Moore/615-574-6389 (Y-12)

**LIQUIFIED CRYOGENIC GAS CUTTING
(ASBESTOS)**

DISM-46-OY

Reviewer: R. L. Whaley/615-574-2271 (Y-12)

References:

1. *The Hanford Model: Environmental Cleanup Problems, Science and Technology Needs, Facility Managements*, September 1991.

HIGH-PRESSURE ABRASIVE WATER JET (EQUIPMENT REMOVAL)

DISM-47-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: High-pressure abrasive water jet. Abrasive water jet cutting uses ultrahigh-pressure water (50,000 psi), an abrasive material, and a small-diameter nozzle, creating a high-energy, small-diameter stream that can cut through metal (up to 9 in. of stainless steel), concrete, etc. The blow-through will have to be contained and collected using (1) shrouds attached to a high-efficiency vacuum system and (2) a containment pool for collecting over-spray, runoff, etc. Shrouds and containment pools will be designed for each specific application, when necessary. Abrasives and water to be separated from the parent material will be treated to remove excessive contamination and debris and reused. The parent material removed will be handled as radiological or mixed waste, when required.

Status: Demonstration. Abrasive water jet cutting is a DOE-sponsored development. Programmable robotic manipulators have been developed. A disadvantage of this method is the high noise level (approx. 115 db) which is present during cutting. This problem can be eliminated by proper shrouding which reduces the noise to acceptable levels (<85 db). Water and abrasives can be recycled with 95% spoils recoverable, saving about \$20/ft³ in disposal costs for low-level waste and greater than \$20/ft³ for transuranic waste.

Science/Technology Needs: The utilization of this technology for cutting equipment in place such as pipe/tanks is dependent on the development of flexible enclosures and recovery systems.

Implementation Needs: Abrasive water jet cutting technology exists, but a high-efficiency vacuum recovery and mobile containment system will need to be further developed with the shrouds, etc., designed for a specific application in a demonstration. Because of the equipment, remote manipulation using video viewing may be required to deploy the water jet to prevent unacceptable operator exposure. This system needs to be demonstrated in a

HIGH-PRESSURE ABRASIVE WATER JET (EQUIPMENT REMOVAL)

DISM-47-OY

mockup facility to ensure adequate system functionality and to provide for operator training. A state-of-the-art demonstration would cost about \$2M and would not include transportation or burial charges. The demonstration/development effort will last 3-5 years. The operational cost is estimated to be \$40/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: L. M. Woodard/615-574-1861, Bldg. 9998 (Y-12)

References:

1. *Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor*, NL-89/31, Argonne National Laboratory.
2. *Abrasive Water Jet Cutting of Uranium*, FMPC-2118.
3. *CNC Water Jet Machining and Cutting Center*, KCP-613-4397.

OXYACETYLENE CUTTING (EQUIPMENT REMOVAL)

DISM-48-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Cutting

Technology: Oxygen cutting. Oxygen and acetylene are run through a torch and ignited. The flame causes rapid exothermic oxidation of the metal. This type of cutting is mostly used on ferrous metals.

Status: Accepted. The process is one of rapid oxidation (burning) of iron at approximately 1600°F. The oxy-fuel is used to raise the temperature to a level at which burning occurs, then oxygen is increased to produce oxidization of the iron. In general, this process is only useful for cutting carbon steels. Highly alloyed steels and nonferrous metals tend to form refractory oxides; these oxides insulate the workpiece from further melting. When cutting carbon steel clad with stainless steel, the stainless can be "gouged" using an electric arc to expose the carbon steel layer beneath. Fluxes also can be used to keep stainless steel from forming oxides. Introducing iron powder into the flame increases flame temperature to aid in cutting alloyed steel. Propane or hydrogen can be used as fuel gases instead of acetylene; use of hydrogen allows cuts to be made under water (metal powder flame enhancers cannot be used under water).

Radiological contamination may be alloyed with the material being cut, making decontamination nearly impossible.

Electric arc gouging and introduction of iron powder into the flame allow a wider range of materials to be cut than just mild steel. A torch setup cost around \$2K; oxygen was \$0.92/ft³ and acetylene was \$0.5/ft³.

This method of cutting would be most feasible in areas of Alpha 4 where mercury contamination was low. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits.

Science/Technology Needs: Application of this technology would be enhanced by the development of a ventilated shroud or enclosure which would isolate the immediate work zone. Mercury vapor generated during the cut could then be vented away from the work area where it could be removed by filtering. Use of this type of isolation system however, would require longer times between cuts since ventilation would be needed till the material near the cut was cool.

Implementation Needs: Flame-cutting methods create smoke and metal fumes, so exhaust ventilation is required for personnel in the area. Flame cutting is conducive to mechanization, which tends to produce a more even, neater cut than cutting by hand. Mechanized cutting speeds are 18-30 in./min, attainable in 3-6-in.-thick mild steel. A demonstration would not be necessary. Testing on site-specific problems would take six months. The operational cost of an oxygen cutting system is estimated to be \$5/ft³ of waste generated. Capital costs: \$10K excluding remote operations capability. Development costs for remote operations capability: \$500K

Author: G. A. Blankenship/615-574-9829

Reviewer: L. M. Woodard/615-574-1861, Bldg. 9998 (Y-12)

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory*, ANL-89/31.
2. E. P. Degarmo, J. T. Elack, R. A. Kohser, *Materials and Processes in Manufacturing*, 6th ed., Macmillan Publishing Company, New York, New York, 1984.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Abrasive wire cutting

Status: Demonstration. Abrasive wire cutting is a proven method in general industry. A continuous cable with replaceable abrasive-impregnated sleeves is used to cut through metal items such as pipes and plates. Water is required for washing away the fines.

Science/Technology Needs: None

Implementation Needs: Adaptation and demonstration in a remotely manipulated environment is required; estimated cost is \$1M-\$2M over 2-4 years. The operational cost is estimated to be \$40/ft³ of waste generated.

Capital costs: \$10K excluding remote operations equipment. **Development costs:** \$500K

Author: J. W. Moore/615-574-6389

Reviewer: F. J. Roettger/615-574-1841 (Y-12)

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Mechanical saws

Status: Accepted. Chain saws, hack saws, abrasive wheel saws, etc., can be hand-held (by manipulators) or base- or table-mounted.

Science/Technology Needs: Application of this technology would be enhanced by the development of a ventilated shroud or enclosure which would isolate the immediate work zone. Mercury vapor generated during the cut could then be vented away from the work area where it could be removed by filtering. Use of this type of isolation system however, would require longer times between cuts since ventilation would be needed till the material near the cut was cool.

Implementation Needs: Adaptation to use by remote manipulation equipment will be required, but this has been done at many facilities for many years and is considered standard operating procedure. The cost to implement this technology with remote manipulation equipment is about \$250K over 12 months. The operational cost is estimated to be \$20/ft³ of waste generated. The capital cost is estimated to be \$10K not including remote manipulation provisions.

Author: J. W. Moore/615-574-6389

Reviewer: F. J. Roettger/615-574-1841 (Y-12)

References:

1. Martin Marietta Energy Systems, Inc., staff members.

**ADVANCED AUTOMATIC FIXTURES, BUG-O, ETC.
(EQUIPMENT REMOVAL)**

DISM-51-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Advanced automatic fixtures, Bug-O, etc.

Status: Accepted. Automated positioning tooling for cutting and welding is commercially available. Deployment via remote means will be required. This method could be highly beneficial for cutting round cross-section items such as piping, tubing, etc. Careful attention will need to be paid to shrouding the area where the cut is taking place to avoid the spread of airborne contamination. The technology can achieve increased efficiency of manpower utilization and still maintain safe operations.

Cost savings of 50%–70% could be achieved over that required per manual cut. Safety of operators would be improved, compared to manual methods. A significant reduction of waste in the form of disposed safety clothing would be realized over manual techniques.

Science/Technology Needs: None

Implementation Needs: A full-scale demonstration will be required in an enclosed environment. The demonstration would define an acceptable way to deploy, power, and control the tooling in a remote operating mode.

Approximately 1 staff-year of design would be required to design a prototype (\$90K). The total hardware cost would be approximately \$100K, in 1992 dollars. No significant software is required, although interlocking with a remote manipulation system would be necessary and may require about 0.5 staff-years to design. No facilities are needed beyond those existing in Oak Ridge.

**ADVANCED AUTOMATIC FIXTURES, BUG-O, ETC.
(EQUIPMENT REMOVAL)**

DISM-51-OY

The total cost of a prototype demonstration is estimated to be about \$1M-\$2M and take 2-4 years. The tooling then would be duplicated. Testing for acceptability for several different sizes of pipe/tubing would be required. The operational costs are estimated to be \$30/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: F. J. Roettger/615-574-1841

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation program standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Split Frame Cutoff Machine

Status: Demonstration. Split frame cutoff machines for cutting and welding are commercially available. A modification of installing a cutoff wheel to separate pipe sections will be required. This system will produce very little waste from the pipe cutting operation. Deployment via remote means will be required. This method could be highly beneficial for cutting round cross-section items such as piping, tubing, etc. Careful attention will need to be paid to shrouding the area where the cut is taking place to avoid the spread of airborne mercury contamination. The technology can achieve increased efficiency of manpower utilization and still maintain safe operations.

Cost savings of approximately 50%–70% could be achieved over that required per manual cut. Safety of operators would be improved, compared to manual methods. A significant reduction of waste in the form of disposed safety clothing would be realized over manual techniques.

Science/Technology Needs: None

Implementation Needs: A full-scale demonstration will be required in an enclosed environment. The demonstration would define an acceptable way to deploy, power, and control the tooling in a remote operating mode.

The total cost of a prototype demonstration is estimated to be about \$1M–\$2M and take 2–4 years. The tooling would then be duplicated. Testing for acceptability for several different sizes of pipe/tubing would be required. Operational costs are estimated to be \$100 per cut; capital cost would be \$200K, not including remote manipulation equipment.

Author: F. J. Roettger/615-574-1841

References:

1. Martin Marietta Energy Systems, Inc., staff members

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Laser cutting

Status: Predemonstration. Technology exists in the predemonstration stage at the Penn State Applied Research Laboratory. The U.S. Navy has funded a feasibility demonstration of the technology for dismantlement of submarine hulls. The technology is very likely to work, because laser cutting is common in industry. Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used. This method of cutting would be most feasible in areas of Alpha 4 where mercury contamination was low. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits. Following is a list of potential advantages and disadvantages of CO₂ laser cutting technology.

Efficacy

Advantages: Cost savings may be realized because of the reduction of labor and protective clothing. The laser generator can remain remote to the contaminated equipment, possibly outside the cell or building, thus avoiding being contaminated. The potential exists for localized destruction of organic contaminants such as oils and PCBs, thus eliminating their removal from any waste generated.

Disadvantages: A smaller bulk amount of contaminated waste will result—small, relative to what was introduced in past equipment removal by oxyacetylene cutting. A fiber-optic or other waveguide delivery system is preferred but has not been demonstrated. Laser safety issues such as beam containment need to be addressed to minimize restrictions to collateral activities. First cost is high.

Science/Technology Needs: Document. Laser cutting using a laser carried through a fiber-optic cable or waveguide requires development and demonstration. Current fiber-optic cables cannot efficiently transmit the wavelengths generated by a CO₂ laser.

Application of this technology would be enhanced by the development of a ventilated shroud or enclosure which would isolate the immediate work zone. Mercury vapor generated during the cut could then be vented away from the work area where it could be removed by filtering. Use of this type of isolation system however, would require longer times between cuts since ventilation would be needed until the material near the cut was cool.

Implementation Needs: Document. A fixture to interface the laser cutting head with a remotely controlled delivery system needs to be designed and demonstrated. Demonstration of a complete laser cutting system is required. Cost is estimated to be \$3M-\$5M and implementation is expected to take 4-6 years. The operational cost is estimated to be \$50/ft³ of waste generated. Capital costs would be \$200K excluding remote handling equipment.

Author: J. W. Moore/615-574-6389

Reviewer: L. M. Woodard/615-574-1861

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Plasma arc cutting. This technology uses a high-velocity, high-temperature, ionized gas torch to cut conductive materials. An arc is established between a tungsten electrode and the workpiece either in nitrogen or in a mixture of argon and hydrogen. The gas and arc are constricted as they leave the torch nozzle, causing very high current densities and temperatures. This causes the workpiece to melt and the molten metal to be blown out through the cut being made. Jets of water may be used to further constrict the plasma arc and to cool the nozzle, thus prolonging its life.

Status: Demonstration. Typical cutting speed is 13 in./min, and the maximum in-air cut of carbon steel is 7-in. thick. Almost any metal can be cut because of the high plasma temperature. Metals resistant to oxy-fuel cutting, such as copper, nickel, magnesium, and titanium, can be cut by plasma arc. Stainless steels require use of a flux to be cut with oxy-fuel, but a flux is not needed with plasma arc. Aluminum also is easily cut by plasma arc. Hearing protection normally is required; noise levels are over 100 dB near the torch. Airborne contamination will be generated (smoke and particulates), but these can be reduced by using water jets. Torch life is 1-2 h, but can be longer, if water jets are used. Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used. This method of cutting would be most feasible in areas of Alpha 4 where mercury contamination was low. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits. Complex geometries and layered structures that are not tightly bonded are difficult to cut using plasma arc technology. In 1989 dollars, a plasma arc system costs \$40K; nozzle tips are consumable and cost \$1K each. Gas and electric power also are required as well as electrodes (\$100 each).

Science/Technology Needs: Application of this technology would be enhanced by the development of a ventilated shroud of enclosure which would isolate the immediate work zone. Mercury vapor generated during the cut could then be vented away from the work area where it could be removed by filtering. Use of this type of isolation system, however, would require longer times between cuts since ventilation would be needed until the material near the cut was cool.

Implementation Needs: Deployment of the plasma arc torch will require remote manipulation equipment and remote maintenance. A demonstration will be required to establish operating parameters and for operator training. The particulate generation rate has been determined to be 4–6 lb/h. An effective airborne particulate confinement, collection, and exhaust system will be required which contains high-efficiency particulate air filters. In addition, containment, collection, and treatment of liquids will be required. Demonstration cost is estimated to be \$2M–\$3.5M over 4–6 years. The operational cost is estimated to be \$50/ft³ of waste generated. Capital cost would be \$200K excluding remote handling capability.

Author: J. W. Moore/615-574-6389

Reviewer: L. M. Woodard/615-574-1861

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory*, ANL-89/31.
2. *Final Report from the Technical University of Hannover to the Department of Research and Technology*, INIS-MF-12032, German Government.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Advanced (Nd: YAG and CO₂) laser cutting

Status: Predemonstration. CO₂ laser cutting technology exists in the predemonstration stage at the Penn State Applied Research Laboratory. The U.S. Navy has funded a feasibility demonstration of the technology for dismantlement of submarine hulls. The technology is very likely to work because laser cutting is common in industry. New laser technologies becoming available in the 1993 to 1998 time frame will provide the same advantages as CO₂ laser cutting but also can provide additional advantages to laser use as a means of precise thermal cutting. Advantages of smaller units, smaller power requirements, easier deployment, and greater efficiency are expected. Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used. Following is a list of potential advantages and disadvantages of advanced laser cutting technology.

Efficacy

Potential advantages: Reduced quantities of contaminated waste, mixed waste, etc., relative to other cutting techniques (e.g., plasma arc torch, arc saw, etc.). Cost savings of \$200M-\$300M in reduction of labor and protective clothing. The laser generator can remain remote to the contaminated equipment, possibly outside the building, thus avoiding being contaminated. Potential exists for the localized destruction of organic contaminants such as oils and PCBs, thus eliminating their removal from any waste generated. Operating and waste disposal costs relative to other systems are potentially low.

This method of cutting would be most feasible in areas of Alpha 4 where mercury contamination was low. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits.

Potential disadvantages: A smaller bulk amount of contaminated waste will result—small, relative to what would be produced during equipment removal using oxyacetylene cutting. A fiber-optic or other waveguide delivery system is preferred but has not been demonstrated. Laser safety issues such as beam containment need to be addressed to minimize restrictions to collateral activities. High capital cost. Implementation in hot cells will be difficult.

Science/Technology Needs: Scaling of laser powers to required levels is needed. An advanced laser delivery system needs to be developed. Application of this technology would be enhanced by the development of a ventilated shroud or enclosure which would isolate the immediate work zone. Mercury vapor generated during the cut could then be vented away from the work area where it could be removed by filtering. Use of this type of isolation system, however, would require longer times between cuts since ventilation would be needed until the material near the cut was cool.

Implementation Needs: A demonstration using a less-than-full-scale system to determine system feasibility is needed (\$400K–\$600K). The cost, including full-scale prototype system, is \$800K–\$1M. Development of a prototype of a full-scale system is needed, including deployment system requirements. The deployment system will need to incorporate remote operation capabilities, costing about \$1M–\$2M. This technology is 4–8 years from being ready. A demonstration of system economics is needed. The operational cost is estimated to be \$50/ft³ of generated waste. Capital cost would be \$250K excluding remote handling equipment.

Author: J. W. Moore/615-574-6389

Reviewer: L. M. Woodard/615-574-1861

References:

1. Martin Marietta Energy Systems, Inc., Photonics Research and Development staff.
2. Technology briefing, P.E. Denny, Penn State Applied Research Laboratory, April 15, 1992.
3. Ibid., personal communication, W.S. Key, August 1992.
4. Ibid., personal communication, W.S. Key, January 4, 1993.
5. *American National Standards Institute Standard 136.1-1992.*
6. *R&D Magazine*, May 1992.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Explosive cutting. This technology consists of an explosive charge contained in a metal or hard plastic casing. The cutter is chevron shaped, so it can be directed at the workpiece. This technique can be used either in air or under water; immersion in water helps to dampen the sound of the explosion. This technique typically is used only where two or more cuts must be made simultaneously or where cutting by other means is impractical. Cutting speed is a function of how fast the charges can be placed; this process can cut metals up to 6 in. thick. Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used.

Status: Demonstration. This technology is accepted as a means of gross cutting. Capital cost of this system, in 1989 dollars, was \$100. Charges and cutters are consumable; charges cost \$150/ft and cutters cost \$8K each.

Science/Technology Needs: A means of buffering the shock wave and its associated noise is needed. Application of this technology would be enhanced by the development of a ventilated shroud or enclosure which would isolate the immediate work zone. Mercury vapor generated during the cut could then be vented away from the work area where it could be removed by filtering.

Implementation Needs: This process is not recommended for contaminated metals, because it would be extremely difficult to control the spread of airborne contaminants. The development and demonstration costs are \$1.5M.

This method of cutting would be most feasible in areas of Alpha 4 where mercury contamination was low. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits.

Author: J. W. Moore/615-574-6389

Reviewer: F. J. Roettger/615-574-1841

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory, ANL-89/31.*

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Plasma arc saw cutting

Status: Demonstration. The technology is available on a commercial basis. The plasma arc saw system, which is controlled by computers, allows thermal cutting of steel with wall thickness up to 300 mm, tubes, banks of tubes, and geometrically complicated components. Also, this technology can be used under water to a depth of 20 m. The maximum permissible material thickness that can be cut is determined by the diameter of the saw blade. The quantity and character of dust and aerosol generated during cutting could be a significant concern and will be contingent on the material being melted. Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used.

Science/Technology Needs: Saw design for wall thickness greater than 100 mm will require development. Application of this technology would be enhanced by the development of a ventilated shroud or enclosure which would isolate the immediate work zone. Mercury vapor generated during the cut could then be vented away from the work area where it could be removed by filtering. Use of this type of isolation system, however, would require longer times between cuts since ventilation would be needed until the material near the cut was cool.

Implementation Needs: Transfer from the development stages (prototype-1990) to broad industrial application is needed. Because of the mercury contaminated environment in which much of the cutting operations occur, remote manipulation will be required for deployment. Debris containment and collection (including airborne particulates) will need to be defined and demonstrated. This method of cutting would be most feasible in areas of Alpha 4 where mercury contamination was low. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits. The estimated cost for

implementing this technology is \$3M-\$4M over 4-6 years of development/demonstration activity. The operational cost is estimated to be \$50/ft³ of waste generated. Capital costs would be \$250K excluding remote handling capability.

Author: J. W. Moore/615-574-6389

Reviewer: F. J. Roettger/615-574-1841

References:

1. *Final Report from the Technical University of Hannover to the Department of Research and Technology*, INIS-MF-12032, German Government.

THERMAL ARC WATER JET CUTTING (EQUIPMENT REMOVAL)

DISM-58-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Thermal arc water jet cutting

Status: Demonstration. With the existing technology (at least in Germany), thermal arc water jet cutting can cut metal items up to 100 mm thick when submerged in up to 20 m of water. The cutting process occurs by establishing an electric arc between the wire electrode and metal sheet, thereby heating the metal to melting temperatures. A water jet around the wire is used to "wash" the melted material away from the cutting kerf. The electrode is consumed because of the high current and is continuously fed during operation. The diameter of the "saw" in this device will determine the maximum possible part wall thickness to cut. These thermal arc water jet cuts are, in general, directed by a computer numeric controller. With additional tooling support, cutting in several axes of operation will be possible. Hole piercing up to a wall thickness of 30 mm also can be accomplished. Cutting is possible in vertical and horizontal orientations, banks of pipe, and geometrically complicated components.

In Y-12 Building 9201-5 (Oak Ridge Y-12 Plant, Mr. A. Wood/4-2079; Mr. J. Turley/4-2492) a prototype of an arc saw with a water table is available. Construction of this prototype arc saw is not yet complete, but it is available for experimental trials. This arc saw can be operated under water up to 15 ft deep. Deeper underwater operations also are possible, but these will require some design and construction changes.

Science/Technology Needs: None

THERMAL ARC WATER JET CUTTING (EQUIPMENT REMOVAL)

DISM-58-OY

Implementation Needs: In general, these units are fixed in one location (not portable). The item to be reduced in size is brought to the machine for processing. A demonstration will be required to determine operating parameters and requirements such as space requirements, ventilation system requirements, water treatment/decontamination system needs, debris separation system requirements, remote manipulation system interfaces, controls, etc. Several of these requirements are a direct result of working in a contaminated/radioactive environment on contaminated equipment. A development effort costing \$2M-\$3M and lasting 3-4 years is needed. The price of this unit is estimated to be \$1M-\$1.2M. The operational cost is estimated to be \$40/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: F. J. Roettger/615-574-1841

References:

1. *Final Report from the Technical University Hannover to the Department of Research and Technology*, INIS-MF-12019, German Government.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Thermite lance cutting. When iron, aluminum, and magnesium are ignited together, they react (in a thermite reaction), producing temperatures up to 10,000°F. Oxygen is forced through a lance consisting of iron pipe packed with aluminum, magnesium, and steel wires; the oxygen and wires then can be lit and the torch directed by the operator. The amount of oxygen controls the flame. The torch is extinguished by closing the oxygen valve. The system is portable, but it requires an operator to be near the cutting. The torch can be used under water.

Status: Predemonstration. The thermite reaction is well known and understood, but the thermite lance (an accepted technology) is a gross cutting tool unsuitable for toxic materials. Hazards include spattering of hot metal, noise, metal fumes, and dust. In 1989 dollars, capital cost for the system was \$555. Lances cost \$5 each; oxygen costs must also be added. Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used.

Science/Technology Needs: Application of this technology would be enhanced by the development of a ventilated shroud or enclosure which would isolate the immediate work zone. Mercury vapor generated during the cut could then be vented away from the work area where it could be removed by filtering. Use of this type of isolation system, however, would require longer times between cuts since ventilation would be needed until the material near the cut was cool.

Implementation Needs: Exhaust ventilation is required with this system as well as enhanced safety awareness because of the fire hazard created by the system. This method of cutting would be most feasible in areas of Alpha 4 where mercury contamination was low. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond

allowable personnel exposure limits. The thermite reaction needs to be incorporated into a process that can be remotely controlled to be useful in contaminated environments. A demonstration is required, which is estimated to cost \$500K and to take 1-2 years to complete. The operational cost is estimated to be \$10/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: F. J. Roettger/615-574-1841

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory*, NL-89/31.

LIQUIFIED CRYOGENIC GAS CUTTING (EQUIPMENT REMOVAL)

DISM-60-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Liquified cryogenic gas cutting

Status: Evolving technology. In this system liquified gas is used in a manner similar to the way water is used in water jet cutting.

Efficacy

Advantages: There will be no liquid effluent to collect and decontaminate; the low temperatures involved may allow cutting at temperatures below the embrittlement temperature for metals. Cost advantages would be realized in cutting equipment where criticality safety is a major issue; this technique could save 20% of the cost over abrasive water jet cutting but probably would not produce any savings when compared to the more conventional cutting techniques such as laser cutting.

Disadvantage: Because of relatively large volumes of gas being generated by evaporation of the liquid, significant air filtration may be required. Providing clean breathing air to the cutting operators is an important issue.

Science/Technology Needs: A significant development and demonstration effort will be necessary in order to make this system a serious contender for use in the Y-12 D&D program. Quest Integrated, Inc., is currently developing this technology. Mercury vaporization by the cutting process is an important area to evaluate.

Implementation Needs: Implementation requires that provisions be provided for collection and treatment of gas generated by liquid evaporation and the definition of the interface

between the system and the remote manipulation deployment system. Cost to implement is estimated to be \$10M, and the time to develop is estimated to be 6–10 years. The operational cost is estimated to be \$60/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: L. M. Woodard/615-574-1861

References:

1. *The Hanford Model: Environmental Cleanup Problems, Science and Technology Needs, Facility Managements*, September 1991.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: High-pressure water jet

Status: Accepted. High-pressure water jet systems are fully developed which use water pressures of 30K-60K psi. This method is used for cutting many nonmetallic materials and can be used for cutting thin-gauge metals.

Science/Technology Needs: None

Implementation Needs: Water jet cutting technology exists, but a high-efficiency vacuum recovery and a mobile containment system need to be developed further, with the shrouds, etc., designed for a specific application for a demonstration. This system needs to be demonstrated in a mockup facility to ensure adequate system functionality and to provide for operator training. A state-of-the-art demonstration would cost about \$1M-\$2M over 1-2 years and would not include transportation or burial charges. The operational cost is estimated to be \$30/ft³ of waste generated. Capital costs would be \$200K, not including remote manipulation provisions.

Application of this technology would be enhanced by the development of a ventilated shroud or enclosure which would isolate the immediate work zone. Mercury vapor generated during the cut could then be vented away from the work area where it could be removed by filtering.

Author: J. W. Moore/615-574-6389

Reviewer: L. M. Woodard/615-574-1861

References:

1. Martin Marietta Energy Systems, Inc., staff members.

CONVENTIONAL DISASSEMBLY (EQUIPMENT REMOVAL)

DISM-62-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Disassembly

Technology: Conventional disassembly

Status: Accepted. Cost depends on the equipment chosen for the job, but most equipment is inexpensive. Conventional disassembly includes sawing with tooth or abrasive blades and dismantling by removing fasteners. Dismantling by removing fasteners creates no extra waste, and if the dismantled pieces are clean, they can, in many instances, be reused. Dismantling by removing fasteners is, however, slow and labor intensive. Unlike the thermal sawing processes, sawing with tooth or abrasive blades will not cause contaminants to melt into the workpiece. There is, also, little danger of electrical shock compared to the arc processes. Cutting can be done in air or under a liquid, using power or hand tools. Very soft and very hard materials are most difficult to cut: very soft material sticks on the saw blade, while hard materials may require special, hardened blades. Due to the heat and vibration from conventional cutting techniques in air, there is a potential for mercury vapor levels to rise beyond allowable personnel exposure limits.

Science/Technology Needs: None

Implementation Needs: Adaption to use by remote manipulation equipment will be required, but this has been done at most hot cell facilities for many years and is considered standard operating procedure. Demonstration of this technology would cost about \$500K-\$1M and would take 2-3 years. The operational cost is estimated to be \$40/ft³ of waste generated. Capital cost would be \$250K, not including remote handling equipment.

Author: J. W. Moore/615-574-6389

**CONVENTIONAL DISASSEMBLY
(EQUIPMENT REMOVAL)**

DISM-62-OY

Reviewer: L. M. Woodard/615-574-1861

References:

1. Martin Marietta Energy Systems, Inc., staff members.

GRAPPLE AND MASSIVE SHEARING (EQUIPMENT REMOVAL)

DISM-63-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Process equipment and utility support structures contaminated with mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Automated Conventional Disassembly

Technology: Grapple and massive shearing.

Status: Demonstration. Commercially available technology exists which uses large hydraulic shearing jaws and grappling devices to reduce the size of metal components. Deployment of this equipment would be remote and would have to be provided.

Efficacy

Potential advantages: The shear can accept a wide range of sizes of components. The same deployment system could be used to remove piping, equipment, etc., after size reduction. Cost savings would be in the range of 10-75% on labor to disassemble components.

Potential disadvantages: Control and containment of airborne contamination will be difficult. Additional work will be required in the component disassembly area to recover from any mangling of components during major dismantlement.

Science/Technology Needs: None

Implementation Needs: A major demonstration of this technology will be required to determine remote manipulation requirements and the extent of airborne contamination generated during cutting. Cost of such a demonstration will be \$1M-\$2M and will take 2-4 years. Cost may be shared with a demonstration for asbestos, structural steel, and massive concrete. The operational cost is estimated to be \$30/ft³ of waste generated. Capital cost: \$250K.

**GRAPPLE AND MASSIVE SHEARING
(EQUIPMENT REMOVAL)**

DISM-63-OY

Author: J. W. Moore/615-574-6389

Reviewer: L. M. Woodard/615-574-1861

References:

1. Martin Marietta Energy Systems, Inc., staff members.
2. LaBounty Mfg., Inc.

HIGH-PRESSURE ABRASIVE WATER JET (EQUIPMENT DISASSEMBLY)

DISM-64-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: High-pressure abrasive water jet. Abrasive water jet cutting uses ultrahigh-pressure water (50,000 psi), an abrasive material, and a small-diameter nozzle, creating a high-energy, small-diameter stream that can cut through metal (up to 9 in. of stainless steel), concrete, etc. The blow-through will have to be contained and collected using (1) shrouds attached to a high-efficiency vacuum system and (2) a containment pool for collecting over-spray, runoff, etc. Shrouds and containment pools will be designed for each specific application, when necessary. Abrasives and water to be separated from the parent material will be treated to remove excessive contamination and debris and reused. The parent material removed will be handled as radiological or mixed waste, when required.

Status: Demonstration. Abrasive water jet cutting is a DOE-sponsored development. Programmable robotic manipulators have been developed. A disadvantage of this method is the high noise level (approximately 115 db) which is present during cutting. This problem can be eliminated by proper shrouding which reduces the noise to acceptable level (<85 db). Water and abrasives can be recycled with 95% spoils recoverable, saving about \$20/ft³ in disposal costs for low-level waste and greater than \$20/ft³ for transuranic waste.

Efficacy—Technology has high potential. DOE sponsored development with robotics developed.

Waste—Water and abrasives recycled with 95% spoils recovery.

HIGH-PRESSURE ABRASIVE WATER JET (EQUIPMENT DISASSEMBLY)

DISM-64-OY

Science/Technology Needs: High efficiency water recovery and recycle system with mobil containment system for site specific must be developed. Improvement of wear on nozzles, hoses, and pumps.

Implementation Needs: Abrasive water jet cutting technology exists, but a high-efficiency vacuum recovery and mobile containment system will need to be further developed with the shrouds, etc., designed for a specific application in a demonstration. Because of the radioactive nature of the equipment and the environment, remote manipulation using video viewing will be required to deploy the water jet to prevent unacceptable operator exposure. This system needs to be demonstrated in a mockup facility to ensure adequate system functionality and to provide for operator training. A state-of-the-art demonstration would cost about \$2M-\$3M and would not include transportation or burial charges. The demonstration/development effort will last 4-6 years. Capital equipment costs are \$1.1M. The operational cost is estimated to be \$40/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: T. Barnes/615-675-3337

References:

1. *Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor*, NL-89/31, Argonne National Laboratory.
2. *Abrasive Water Jet Cutting of Uranium*, FMPC-2118.
3. *CNC Water Jet Machining and Cutting Center*, KCP-613-4397.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Abrasive wire cutting

Status: Demonstration. Abrasive wire cutting is a proven method in general industry. A continuous cable with replaceable abrasive-impregnated sleeves is used to cut through metal items such as pipes and plates. Water is required for washing away the fines and will have to be collected and recycled with the fines removed and decontaminated or handled as mixed waste.

Efficacy—Medium. Technology accepted and has excellent potential in most areas.

Waste—Water to be recycled with the fines to be decontaminated at least to the point they will be handled as low level waste.

Science/Technology Needs: System for recycling the water and removing and decontaminating the fines. Remote manipulator needs to be developed.

Implementation Needs: Adaptation and demonstration in a remotely manipulated environment is required; estimated cost is \$2M–\$3M over 2–4 years. Capital equipment costs are \$50K not including remote manipulators. The operational cost is estimated to be \$40/ft³ of waste generated.

Author: F. J. Roettger/615-574-1861

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Oxygen cutting. Oxygen and acetylene are run through a torch and ignited. The flame causes rapid exothermic oxidation of the metal. This type of cutting is mostly used on ferrous metals.

Status: Accepted. The process is one of rapid oxidation (burning) of iron at approximately 1600°F. The oxy-fuel is used to raise the temperature to a level at which burning occurs, then oxygen is increased to produce oxidation of the iron. In general, this process is only useful for cutting carbon steels. Highly alloyed steels and nonferrous metals tend to form refractory oxides; these oxides insulate the workpiece from further melting. When cutting carbon steel clad with stainless steel, the stainless can be "gouged" using an electric arc to expose the carbon steel layer beneath. Fluxes also can be used to keep stainless steel from forming oxides. Introducing iron powder into the flame increases flame temperature to aid in cutting alloyed steel. Propane or hydrogen can be used as fuel gases instead of acetylene; use of hydrogen allows cuts to be made under water (metal powder flame enhancers cannot be used under water).

Electric arc gouging and introduction of iron powder into the flame allow a wider range of materials to be cut than just mild steel. A torch setup cost around \$2K; oxygen was \$0.92/ft³, and acetylene was \$0.5/ft³.

Efficacy—Low. Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used.

This method of cutting could only be used in areas of Alpha 4 that were free of mercury contamination. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits.

Waste—Waste created by thermal cutting would need to be decontaminated or handled as low-level waste.

Science/Technology Needs: Remote manipulators need developed.

Implementation Needs: Deployment of the oxyacetylene torch will require remote manipulation equipment. A demonstration will be required to establish operating parameters and for operator training, with a total estimated cost of \$500K over 12–15 months. Capital equipment costs are \$10K not including remote manipulators. The operational cost is estimated to be \$5/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Mechanical saws; handheld or remote operated.

Status: Accepted. Chain saws, hack saws, abrasive wheel saws, etc., can be hand-held (by manipulators) or base- or table-mounted.

Efficacy—High. This technology will work in most areas, particularly cutting small parts.

Waste—The fines created by sawing will be decontaminated or handled as low-level waste.

Science/Technology Needs: Create remote manipulators.

Implementation Needs: Adaptation to use by remote manipulation equipment will be required, but this has been done at most hot cell facilities for many years and is considered standard operating procedure. The cost to implement this technology with remote manipulation equipment is about \$250K over 12 months. Capital equipment costs are \$10K not including remote manipulators. The operational cost is estimated to be \$20/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

ADVANCED AUTOMATIC FIXTURES (EQUIPMENT DISASSEMBLY)

DISM-68-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Advanced automatic fixtures, Bug-O, etc.

Status: Accepted. Automated positioning tooling for cutting and welding is commercially available. Deployment via remote means will be required. This method could be highly beneficial for cutting round cross-section items such as piping, tubing, etc. Careful attention will need to be paid to shrouding the area where the cut is taking place to avoid the spread of airborne contamination. The technology can achieve increased efficiency of manpower utilization and still maintain safe operations.

Efficacy—High. This technology has excellent potential, especially in highly contaminated or dangerous areas.

Waste—No waste created.

Cost—Cost savings of 50%–70% could be achieved over that required per manual cut. Safety of operators would be improved, compared to manual methods. No waste specific to this technology would be generated, although a significant reduction of waste in the form of disposed safety clothing would be realized over manual techniques.

Science/Technology Needs: Adapt known technology to specific needs. Develop remote manipulators.

ADVANCED AUTOMATIC FIXTURES (EQUIPMENT DISASSEMBLY)

DISM-68-OY

Implementation Needs: A full-scale demonstration will be required in an enclosed environment. The demonstration would define an acceptable way to deploy, power, and control the tooling in a remote operating mode.

Approximately 1 staff-year of design would be required to design a prototype (\$100K). The total hardware cost would be approximately \$100K, in 1992 dollars. No significant software is required, although interlocking with a remote manipulation system would be necessary and may require about 0.5 staff-years to design. No facilities are needed beyond those existing in Oak Ridge.

The total cost of a prototype demonstration is estimated to be about \$1M-\$2M and take 2-4 years. The tooling then would be duplicated. Testing for acceptability for several different sizes of pipe/tubing would be required. The operational costs are estimated to be \$30/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

SPLIT FRAME CUTOFF MACHINE (EQUIPMENT DISASSEMBLY)

DISM-69-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Split Frame Cutoff Machine

Status: Demonstration. Split frame cutoff machines for cutting and welding are commercially available. A modification of installing a cutoff wheel to separate pipe sections will be required. This system will produce very little waste from the pipe cutting operation. Deployment via remote means will be required. This method could be highly beneficial for cutting round cross-section items such as piping, tubing, etc. Careful attention will need to be paid to shrouding the area where the cut is taking place to avoid the spread of airborne mercury contamination. The technology can achieve increased efficiency of manpower utilization and still maintain safe operations.

Efficacy—High. Existing technology will work after being adapted to specific needs.

Waste—No waste created.

Cost—Cost savings of approximately 50%–70% could be achieved over that required per manual cut. Safety of operators would be improved, compared to manual methods. A significant reduction of waste in the form of disposed safety clothing would be realized over manual techniques.

Science/Technology Needs: Develop remote manipulators.

SPLIT FRAME CUTOFF MACHINE (EQUIPMENT DISASSEMBLY)

DISM-69-OY

Implementation Needs: A full-scale demonstration will be required in an enclosed environment. The demonstration would define an acceptable way to deploy, power, and control the tooling in a remote operating mode.

The total cost of a prototype demonstration is estimated to be about \$1M-\$2M and take 2-4 years. Capital equipment costs are \$200K not including remote manipulators. The tooling would then be duplicated. Testing for acceptability for several different sizes of pipe/tubing would be required. Operational costs are estimated to be \$100/cut.

Author: F. J. Roettger/615-574-1841

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Laser cutting

Status: Predemonstration. Technology exists in the predemonstration stage at the Penn State Applied Research Laboratory. The U.S. Navy has funded a feasibility demonstration of the technology for dismantlement of submarine hulls.

Efficacy—Medium. The technology is very likely to work, because laser cutting is common in industry.

Potential advantages of CO₂ laser cutting technology: Cost savings may be realized because of the reduction of labor and protective clothing. The laser generator can remain remote to the contaminated equipment, possibly outside the building, thus avoiding being contaminated. The potential exists for localized destruction of organic contaminants such as oils and PCBs, thus eliminating their removal from any waste generated.

Potential disadvantages of CO₂ laser cutting technology: A smaller bulk amount of contaminated waste will result—small, relative to what was introduced in past equipment removal by oxyacetylene cutting. A fiber-optic or other waveguide delivery system is preferred but has not been demonstrated. Laser safety issues such as beam containment need to be addressed to minimize restrictions to collateral activities. First cost is high.

This method of cutting could only be used in areas of Alpha 4 that were free of mercury contamination. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits.

Waste—Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used. The waste created by cutting will be handled as low-level waste.

Science/Technology Needs: Document. Laser cutting using a laser carried through a fiber-optic cable or waveguide requires development and demonstration. Current fiber-optic cables cannot efficiently transmit the wavelengths generated by a CO₂ laser.

Implementation Needs: Document. A fixture to interface the laser cutting head with a remotely controlled delivery system needs to be designed and demonstrated. Demonstration of a complete laser cutting system is required. Cost is estimated to be \$3M–\$5M and implementation is expected to take 4–6 years. Capital costs are \$200K not including remote manipulators. The operational cost is estimated to be \$50/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items contaminated with lithium compounds, PCBs, and low-level uranium that are to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Plasma arc cutting. This technology uses a high-velocity, high-temperature, ionized gas torch to cut conductive materials. An arc is established between a tungsten electrode and the workpiece either in nitrogen or in a mixture of argon and hydrogen. The gas and arc are constricted as they leave the torch nozzle, causing very high current densities and temperatures. This causes the workpiece to melt and the molten metal to be blown out through the cut being made. Jets of water may be used to further constrict the plasma arc and to cool the nozzle, thus prolonging its life.

Status: Demonstration. An accepted technology. Typical cutting speed is 13 in./min, and the maximum in-air cut of carbon steel is 7-in. thick. Almost any metal can be cut because of the high plasma temperature. Metals resistant to oxy-fuel cutting, such as copper, nickel, magnesium, and titanium, can be cut by plasma arc. Stainless steels require use of a flux to be cut with oxy-fuel, but a flux is not needed with plasma arc. Aluminum also is easily cut by plasma arc. Hearing protection normally is required; noise levels are over 100 dB near the torch. Airborne contamination will be generated (smoke and particulates), but these can be reduced by using water jets. Torch life is 1-2 h, but can be longer, if water jets are used. This method of cutting could only be used in areas of Alpha 4 that were free of mercury contamination. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits.

Efficacy—Low. Radiological contamination may be alloyed with the equipment or structural members being cut, making decontamination nearly impossible when this or any thermal

cutting method is used. Complex geometries and layered structures that are not tightly bonded are difficult to cut using plasma arc technology.

Waste—The material being blown through by cutting will have to be handled as low-level waste and if water is used as a coolant it will need to be cleaned and recycled.

Cost—In 1989 dollars, a plasma arc system costs \$40K; nozzle tips are consumable and cost \$1K each. Gas and electric power also are required as well as electrodes (\$100 each).

Science/Technology Needs: Saw designed for 100 mm and remote manipulators.

Implementation Needs: Deployment of the plasma arc torch will require remote manipulation equipment and remote maintenance. A demonstration will be required to establish operating parameters and for operator training. The particulate generation rate has been determined to be 4–6 lb/h. An effective airborne particulate confinement, collection, and exhaust system will be required which contains high-efficiency particulate air filters. In addition, containment, collection, and treatment of liquids will be required. Demonstration cost is estimated to be \$2M–\$4M over 4–6 years. Capital costs are \$200K not including remote manipulators. The operational cost is estimated to be \$50/ft³ of waste generated.

Author: L. M. Woodard/615-574-1861

Reviewer: T. Barnes/615-675-3337

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory*, ANL-89/31.
2. *Final Report from the Technical University of Hannover to the Department of Research and Technology*, INIS-MF-12032, German Government.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Advanced (Nd: YAG and CO₂) laser cutting

Status: Predemonstration. CO₂ laser cutting technology exists in the predemonstration stage at the Penn State Applied Research Laboratory. The U.S. Navy has funded a feasibility demonstration of the technology for dismantlement of submarine hulls. The technology is very likely to work because laser cutting is common in industry. New laser technologies becoming available in the 1993 to 1998 time frame will provide the same advantages as CO₂ laser cutting but also can provide additional advantages to laser use as a means of precise thermal cutting. Advantages of smaller units, smaller power requirements, easier deployment, and greater efficiency are expected.

This method of cutting could only be used in areas of Alpha 4 that were free of mercury contamination. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits.

Efficacy—Low.

Potential advantages of advanced laser cutting technology: Reduced quantities of contaminated waste, mixed waste, etc., relative to other cutting techniques (e.g., plasma arc torch, arc saw, etc.). Cost savings of \$200M-\$300M in reduction of labor and protective clothing. The laser generator can remain remote to the contaminated equipment, possibly

outside the building, thus avoiding being contaminated. Potential exists for the localized destruction of organic contaminants such as oils and PCBs, thus eliminating their removal from any waste generated. Operating and waste disposal costs relative to other systems are potentially low.

Potential disadvantages of advanced laser cutting technology: A smaller bulk amount of contaminated waste will result—small, relative to what would be produced during equipment removal using oxyacetylene cutting. A fiber-optic or other waveguide delivery system is preferred but has not been demonstrated. Laser safety issues such as beam containment need to be addressed to minimize restrictions to collateral activities. High capital cost.

Waste—The waste created by cutting will be handled as low-level waste. Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used.

Science/Technology Needs: Scaling of laser powers to required levels is needed. An advanced laser delivery system needs to be developed.

Implementation Needs: A demonstration using a less-than-full-scale system to determine system feasibility is needed (\$400K–\$600K). The cost, including full-scale prototype system, is \$800K–\$1M. Development of a prototype of a full-scale system is needed, including deployment system requirements. The deployment system will need to incorporate remote operation capabilities, costing about \$2M–\$3M. Capital equipment costs are \$250K not including remote manipulators. This technology is 4–8 years from being ready. A demonstration of system economics is needed. The operational cost is estimated to be \$50/ft³ of generated waste.

Author: L. M. Woodard/615-574-1861

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., Photonics Research and Development staff.
2. Technology briefing, P.E. Denny, Penn State Applied Research Laboratory, April 15, 1992.
3. Ibid., personal communication, W.S. Key, August 1992.
4. Ibid., personal communication, W.S. Key, January 4, 1993.
5. *American National Standards Institute Standard 136.1-1992.*
6. *R&D Magazine*, May 1992.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Plasma arc saw cutting

Status: Demonstration. The plasma arc saw system, which is controlled by computers, allows thermal cutting of steel with wall thickness up to 300 mm, tubes, banks of tubes, and geometrically complicated components. Also, this technology can be used under water to a depth of 20 m. The maximum permissible material thickness that can be cut is determined by the diameter of the saw blade. The quantity and character of dust and aerosol generated during cutting could be a significant concern and will be contingent on the material being melted.

This method of cutting could only be used in areas of Alpha 4 that were free of mercury contamination. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits.

Efficacy—Medium. Industry proven technology.

Waste—Radiological contamination may be alloyed with the equipment or structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used. The waste created by cutting will be handled as low-level waste.

Science/Technology Needs: Saw design for wall thickness greater than 100 mm will require development. Design remote manipulators.

Implementation Needs: Transfer from the development stages (prototype-1990) to broad industrial application is needed. The technology is available on a commercial basis. Because of the radiological environment in which much of the cutting operations occur, remote manipulation will be required for deployment. Debris containment and collection (including airborne particulates) will need to be defined and demonstrated. The estimated cost for implementing this technology is \$3M-\$4M over 4-6 years of development/demonstration activity. Capital costs are \$250K not including remote manipulators. The operational cost is estimated to be \$50/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: T. Barnes/615-675-3337

References:

1. *Final Report from the Technical University of Hannover to the Department of Research and Technology*, INIS-MF-12032, German Government.

THERMAL ARC WATER JET CUTTING (EQUIPMENT DISASSEMBLY)

DISM-74-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Thermal arc water jet cutting

Status: Demonstration. With the existing technology (at least in Germany), thermal arc water jet cutting can cut metal items up to 100 mm thick. The cutting process occurs by establishing an electric arc between the wire electrode and metal sheet, thereby heating the metal to melting temperatures. A water jet around the wire is used to "wash" the melted material away from the cutting kerf. The electrode is consumed because of the high current and is continuously fed during operation. The diameter of the "saw" in this device will determine the maximum possible part wall thickness to cut. These thermal arc water jet cuts are, in general, directed by a computer numeric controller. With additional tooling support, cutting in several axes of operation will be possible. Hole piercing up to a wall thickness of 30 mm also can be accomplished. Cutting is possible in vertical and horizontal orientations, banks of pipe, and geometrically complicated components. Cutting can also occur under water and has been demonstrated when submerged in up to 20 m of water.

This method of cutting could only be used in areas of Alpha 4 that were free of mercury contamination. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits. If the system were set up under water it should be highly effective in preventing mercury vaporization. It would then be useful to size-reduce pipe etc. at a fixed location station.

Efficacy—Proven technology in Germany. Tested and proven in prototype at Y-12. In Y-12 Building 9201-5 (Oak Ridge Y-12 Plant, Mr. A. Wood/4-2079; Mr. J. Turley/4-2492) a

THERMAL ARC WATER JET CUTTING (EQUIPMENT DISASSEMBLY)

DISM-74-OY

prototype of an arc saw with a water table is available. Construction of this prototype arc saw is not yet complete, but it is available for experimental trials. This arc saw can be operated under water up to 15 ft deep. Deeper underwater operations also are possible, but these will require some design and construction changes.

Waste—The water coming in contact with the contaminant will be recycled. The waste created by the cut will be handled as mixed waste or decontaminated. The waste escaping after the cut will be contained and disposed of.

Science/Technology Needs: Unknown

Implementation Needs: In general, these units are fixed in one location (not portable). The item to be reduced in size is brought to the machine for processing. A demonstration will be required to determine operating parameters and requirements such as space requirements, ventilation system requirements, water treatment/decontamination system needs, debris separation system requirements, remote manipulation system interfaces, controls, etc. Several of these requirements are a direct result of working in a contaminated/radioactive environment on contaminated equipment. A development effort costing \$2M–\$3M and lasting 3–4 years is needed. The price of this unit is estimated to be \$1M–\$1.2M. The operational cost is estimated to be \$40/ft³ of waste generated.

Author: L. M. Woodard/615-574-1861; FAX 576-7649

Reviewer: T. Barnes/615-675-3337

References:

1. *Final Report from the Technical University Hannover to the Department of Research and Technology*, INIS-MF-12019, German Government.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Thermite lance cutting. When iron, aluminum, and magnesium are ignited together, they react (in a thermite reaction), producing temperatures up to 10,000°F. Oxygen is forced through a lance consisting of iron pipe packed with aluminum, magnesium, and steel wires; the oxygen and wires then can be lit and the torch directed by the operator. The amount of oxygen controls the flame. The torch is extinguished by closing the oxygen valve. The system is portable, but it requires an operator to be near the cutting. The torch can be used under water.

Status: Predemonstration. The thermite reaction is well known and understood.

Efficacy—Medium. The thermite lance (an accepted technology) is a gross cutting tool unsuitable for toxic materials. Hazards include spattering of hot metal, noise, metal fumes, and dust. In 1989 dollars, capital cost for the system was \$555. Lances cost \$5 each; oxygen costs must also be added. Radiological contamination may be alloyed with the structural members being cut, making decontamination nearly impossible when this or any thermal cutting method is used.

Waste—The waste created by the cut will be handled as mixed waste or decontaminated. The waste escaping after the cut will be contained and disposed of. This method of cutting could only be used in areas of Alpha 4 that were free of mercury contamination. Hot cutting in mercury contaminated areas would elevate mercury vapor levels beyond allowable personnel exposure limits.

Science/Technology Needs: Remote manipulators.

Implementation Needs: Exhaust ventilation is required with this system as well as enhanced safety awareness because of the fire hazard created by the system. The thermite reaction needs to be incorporated into a process that can be remotely controlled to be useful in contaminated environments. A demonstration is required, which is estimated to cost \$500K and to take 1-2 years to complete. Capital costs are \$10K not including remote manipulators. The operational cost is estimated to be \$10/ft³ of waste generated.

Author: J. W. Moore/615-574-6389

Reviewer: T. Barnes/615-675-3337

References:

1. *An Evaluation of Alternative Reactor Vessel Cutting Technologies for the Experimental Boiling Water Reactor at Argonne National Laboratory*, NL-89/31.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds. The technology is applicable to equipment removal and disassembly, size, reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: High-pressure water jet

Status: Accepted. High-pressure water jet systems are fully developed which use water pressures (non-abrasive) of 30K-60K psi and can cut non-metallic material, clean concrete, remove paint, etc.

Efficacy—Low. DOE-sponsored development with robotics developed.

Waste—Water recycled with 95% spoils recovery.

Science/Technology Needs: High efficiency water recovery and recycle system with mobil containment system for site specific must be developed.

Implementation Needs: Water jet cutting technology exists, but a high-efficiency vacuum recovery and a mobile containment system need to be developed further, with the shrouds, etc., designed for a specific application for a demonstration. Because of the radioactive nature of the equipment and the environment, remote manipulation using video viewing will be required to deploy the water jet to prevent unacceptable operator exposure. This system needs to be demonstrated in a mockup facility to ensure adequate system functionality and to provide for operator training. A state-of-the-art demonstration would cost about \$2M-\$4M over 4-6 years and would not include transportation or burial charges. Capital costs are \$1.1M. The operational cost is estimated to be \$40/ft³ of waste generated.

Author: L. M. Woodard/615-574-1861

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

LIQUIFIED CRYOGENIC GAS CUTTING (EQUIPMENT DISASSEMBLY)

DISM-77-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Cutting

Technology: Liquified cryogenic gas cutting

Status: Evolving technology. This technology is included in the Hanford Model Wiring Diagram. In this system liquified gas is used in a manner similar to the way water is used in water jet cutting (author's opinion).

Efficacy—High.

Advantages: There will be no liquid effluent to collect and decontaminate. The low temperatures involved may allow cutting at temperatures below the embrittlement temperature for metals. This technique could save 20% of the cost over abrasive water jet cutting but probably would not produce any savings when compared to the more conventional cutting techniques such as laser cutting.

Disadvantage: Because of relatively large volumes of gas being generated by evaporation of the liquid, significant air filtration may be required.

Waste—The waste created by the cut will be handled as mixed waste or decontaminated. The waste escaping after the cut will be contained and disposed of.

Science/Technology Needs: A significant development and demonstration effort will be necessary in order to make this system a serious contender for use in the D&D Alpha 4 program. The Hanford Model Wiring Diagram states that there is "no known program," but

LIQUIFIED CRYOGENIC GAS CUTTING (EQUIPMENT DISASSEMBLY)

DISM-77-OY

Quest Integrated Inc., is currently performing research and development on this technology (sponsored by DOE).

Implementation Needs: Implementation requires that provisions be provided for collection and treatment of gas generated by liquid evaporation and the definition of the interface between the system and the remote manipulation deployment system. Cost to implement is estimated to be \$10M, and the time to develop is estimated to be 6-10 years. Capital costs are \$10M not including remote manipulators. The operational cost is estimated to be \$60/ft³ of waste generated.

Author: L. M. Woodard/615-574-1861. Reviewed by: T. Barnes 615/675-3337

References:

1. *The Hanford Model: Environmental Cleanup Problems, Science and Technology Needs, Facility Managements*, September 1991.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds. The technology is applicable to equipment removal and disassembly, size, reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement/Disassembly

Alternative: Cutting

Technology: Mechanical Shears

Status: Accepted. Mechanical shears provide a conventional means for quickly reducing the size of metal components. Most have automatic systems which feed the work into the shear.

Efficacy—High.

Advantages: Speed of operation and relatively low maintenance requirements. The cutting action on mercury contaminated metal does not cause the mercury to vaporize.

Disadvantages: Equipment such as pipe would be more difficult to decontaminate due to the deformation of the pipe from shearing. Also the equipment to be sheared must be configured so that it will fit into the machine.

Waste—Materials would be segregated and decontaminated. All metal not decontaminated would be compressed and baled for storage. The contaminants coming out of the pipes and machinery will have to be contained and sheltered from the elements and accumulated for disposal.

Science/Technology Needs: Develop a system to contain the mercury vaporization from the cutting area.

Implementation Needs: In general, these units are fixed in one location (not portable). The item to be reduced in size is brought to the machine for processing. A demonstration will be

needed to determine requirements such as necessary space, ventilation system requirements, remote manipulation system interfaces, controls, etc. Several of these requirements are a direct result of working in a contaminated environment on contaminated equipment. The price of this 640-ton shear is estimated to be \$750K. The development cost of the containment system is \$250K. The operational cost is estimated to be \$50/cut.

Author: L. M. Woodard/615-574-1861

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members

CONVENTIONAL DISASSEMBLY (EQUIPMENT DISASSEMBLY)

DISM-79-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds. This technology is applicable to equipment removal and disassembly, size reduction, and packaging of items to be stored or decontaminated.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Disassembly

Technology: Conventional disassembly

Status: In-use. Conventional disassembly includes sawing with tooth or abrasive blades and dismantling by removing fasteners.

Efficacy—High. Dismantling by removing fasteners is, however, slow and labor intensive. Unlike the thermal sawing processes, sawing with tooth or abrasive blades will not cause contaminants to melt into the workpiece. There is, also, little danger of electrical shock compared to the arc processes. Cutting can be done in air or under a liquid, using power or hand tools. Very soft and very hard materials are most difficult to cut: very soft material sticks on the saw blade, while hard materials may require special, hardened blades.

Waste—Dismantling by removing fasteners creates no extra waste, and if the dismantled pieces are clean, they can, in many instances, be reused.

Cost—Cost depends on the equipment chosen for the job, but most equipment is inexpensive.

Science/Technology Needs: None

Implementation Needs: Adaption to use by remote manipulation equipment may be required, but this has been done at most hot cell facilities for many years and is considered standard operating procedure. Demonstration of this technology would cost about

**CONVENTIONAL DISASSEMBLY
(EQUIPMENT DISASSEMBLY)**

DISM-79-OY

\$500K-\$1M and would take 2-3 years. Capital costs are \$1K not including remote manipulators. The operational cost is estimated to be \$40/ft³ of waste generated.

Author: L. M. Woodard/615-574-1861

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities or underground utilities to be permanently or temporarily abandoned in place. The technologies may apply to known contaminated soils area depending upon the type of contaminants. Contaminants to be addressed are low-level uranium, mercury, lithium, PCBs, and oils of various types. An example of this would be filling an abandoned storm sewer or sanitary sewer line under or near a facility to be decontaminated and decommissioned.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Entombment

Technology: Thermoset polymer/thermal plastic stabilization. Using resinous material to physically restrict mass transfer of waste.

Status: Demonstration technology. Has been widely used at other sites. Examples are Westinghouse, Hanford (WA), Beatty (NV), and Barnwell (SC). Although these materials do not significantly interact chemically with waste species and therefore encapsulate by solidification only, their leachability index (LI) is 11-12 compared to 6-9 for the best concrete-based grouts. This means waste leachate is subject to diffusive, rather than advective, flow. An LI of 13-15 means for all practical purposes no leaking occurs. These materials have lower viscosity and surface tension values than water. They are therefore an excellent encapsulation material for rubble because of their natural ability to flow into nooks and crannies without forming air pockets. Voids are completely eliminated without needing to premix solid waste with solidifier before pouring. This process, called vinyl ester resin in-situ (VERI), has been used to encase lead, cadmium, and circuit boards. The vinyl ester styrene (VES) process has been used to solidify ion-exchange resins and liquid wastes. Solid, granular waste can be wet. If wet, waste not granular (like incinerator ash) then must be sludge solidified. In the VES process, liquid waste is mixed with the base material in a high-speed mixer to create an emulsion. Fifteen minutes after the promoter is added the mixture is plasticized. In both cases a benzoyl peroxide catalyst creates an oxygen radical that allows polymerization to occur. Having a high percentage of waste present optimizes the reaction by

acting as a heat sink for the energy that is evolved. The base material for both processes has been approved by the NRC for use with Class A, B, and C wastes. The resulting waste form has passed the EPA Toxicity Characteristic Leaching Procedure (TCLP) test found in 10 CFR Part 61 Waste Form Qualification Testing which includes compressive strength and biological challenge tests. If cured correctly (at temperatures not exceeding 200°F) no cracking or crazing will occur. During squeeze testing the middle will bulge and fine surface cracks will appear but they do not penetrate. It will support 2000–7000 lbs/in.². Usually 1–3 in. of left-over binder is poured on top but technically a cap is unnecessary. Although the promoter is hazardous it is consumed by the curing process and the polymerized form is harmless. This technique has not been tested by the NRC for homogeneous mixing but solidification will not occur under conditions of nonhomogeneity. Styrene is present in nonsignificant amounts. Some organics may interfere with the setting process. The polymerization material costs \$25/gal. Operating costs are about 10% of the material costs. For a volume of 100,000 ft³ (100 ft × 100 ft × 10 ft) filled with baseball-sized pieces of rubble one might assume 30%–40% void space which would roughly equal 75,000 gal of bulk material costing \$1.8M. However, for this large a volume a vendor is likely to reduce this to \$1M, resulting in a total cost of \$1.1M.

Efficacy—This technology is more effective than specialty grouts in reducing waste leachate by three orders of magnitude. EPA experts estimate this technology to endure more than 300 years. This technology is expensive but may be cheaper than a highly tailored grout for a complex waste species. Low porosity.

Waste—No waste would be produced with this technology except protective clothing or equipment that might be needed for operators. The cost would be about \$1.1M for a 100,000 ft³ volume with 60%–70% waste loading.

Additional comments: Charring and surface carbonization occur at 2000°F but there is no known melting temperature for set polymers. EPA experts expect polymerized waste forms to maintain solidification performance beyond 300 years.

Science/Technology Needs: Some wastes may present a problem by interfering with polymerization. In this case a grout or other solidification/stabilization should be used. May want to test for presence of promoter remaining after polymerization since unused promoter is hazardous.

Implementation Needs: Development priorities low but depend on waste. For entombment an in-line mixer and tanker cars of bulk material would likely be used. Solidification and transfer system can be purchased or leased. If purchased, would be a capital equipment cost of \$70K–\$80K. Decreasing waste size increases waste loading while lessening solidification expenses since less polymer is needed. Source I or Source II code would have to be modified for entombment and VERI performance characteristics entered in. Homogenous mixing must occur for success. Pumping may require preparation work depending on location. Estimated

time to maturity is on the order of weeks/months with the most likely determining factor being Source code modification.

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References:

1. Diversified Technologies, Knoxville, Tenn. 37931.
2. Roger Spence, 615-574-6782; personal communication.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities or underground utilities to be permanently or temporarily abandoned in place. The technologies may apply to known contaminated soils area depending upon the type of contaminants. Contaminants to be addressed are low-level uranium, mercury, lithium, PCBs, and oils of various types. An example of this would be filling an abandoned storm sewer or sanitary sewer line under or near a facility to be decontaminated and decommissioned.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Entombment

Technology: Groundwater diversion. Using French drain, biopolymer drain, or horizontal well drainage systems to lower the diffusivity coefficient of soil surrounding the entombment structure.

Status: Accepted technology. French drains are narrow, vertical trenches lined with slotted, plastic pipe and filled with porous backfill. They connect to a sump pump or a storm drain system. Any diversion which occurs in a drain-enclosed region is due to interception of moisture having a horizontal flow component. French drains would not ensure diversion under a basement floor if its foundation is below the water table. This method works best in hillside or hilltop locations. Preexisting underground utilities can complicate installation. Deep French drains have been successfully constructed in SWSA 6 and along Lagoon Road at ORNL.

Accepted technology. Biopolymer drains are French drains which are installed using a biodegradable slurry for side-wall support. Use of the biopolymer installation method enables a narrow, vertical trench to be excavated without shoring, backfilled with a porous stone fill, and converted into a high-transmissivity interceptor trench. This technique is especially useful in locations of unstable or saturated soils which are likely to collapse if excavated vertically. It is available for use in soils or loose rock materials which can be excavated with conventional equipment. Geo-Con, Inc., of Pittsburgh, Pennsylvania, has installed biopolymer

trench drains at the Portsmouth Gaseous Diffusion Plant as part of two site remediation projects.

Demonstration technology. Horizontal wells/directional drilling has been demonstrated by Sandia National Laboratory and Lawrence Berkeley Laboratory. They were found to improve efficiency of remediation by increasing the amount of surface area available for reaction and accessing areas of the subsurface otherwise inaccessible, such as under existing facilities. By the beginning of FY 94, four directional drilling technologies/systems will have been demonstrated. The overall capabilities, limitations, efficiency, and cost effectiveness will be compared for utilization in environmental remedial applications. Formation of a users group to assist with the technology transfer and information exchange effort will be a primary goal. WELLPACK horizontal wells are slotted-pipe-cased wells backfilled with gravel, typically 3-12 in. in diameter and located 8-10 ft apart. The filter packing is achieved by pulling back a casing while pneumatically stowing graded sand around the well screen, which is centrally located within the casing. They are installed horizontally or with directional drilling techniques for the purpose of isolating a site from groundwater infiltration and can range from 10-50 ft deep over a 1000-ft length. This technology is commercially available and has been extensively used in highway applications. Directional drilling is widely used in oil-field applications. Horizontal wells are optimum for flat or near water-table locations. They can be installed below utilities, avoiding complications. A new application for this technology is using horizontal or directional drilling for the installation of groundwater interceptor wells to extract volatile organic compounds from soil surrounding hazardous waste sites. All monitoring and drilling can be done from one wellhead center (multiple drill head), lowering the probability of encountering operational difficulties due to location or surrounding structures. This is possible because the well drills can be curve steered. Drill units range from \$25K-\$100K depending on the type. Nonmagnetic drill rods run \$30-\$50/ft. Encapsulated instrumentation packages containing pressure gauges, lysimeters (leachate collectors), and other detectors can be easily installed and removed for leak detection and monitoring groundwater behavior. Wells with these instrumentation packages (SEAMIST) cost approximately \$20/ft with lysimeters every 10-15 ft.

Efficacy—Medium efficacy depending on technique, location, soil composition, and handling of preexisting underground utilities. Cost effective construction of French drains is limited to rippable materials, i.e., soil and rock which can be excavated without blasting, jackhammering, etc. French or biopolymer drains offer only a small cross-section of well at a given elevation. In comparison, a horizontal well can have hundreds of feet of cased length at a key elevation. One horizontal well would be a much more effective groundwater interceptor than a series of vertical wells. Of the three technologies listed, only horizontal wells can actively divert groundwater below the building foundation or be successful for sub-water-table applications. Horizontal well drilling may offer a strategic operational advantage in areas close to other buildings and inaccessible for crane and/or backhoe installation. A dry, down-the-hole motor drilling technique is under conceptual development. It would enclose contaminated cuttings without the presence of a liquid transport mechanism, thus increasing worker safety during contaminated soil drilling.

Waste—Amount of waste produced varies depending on whether drill cuttings are contaminated and whether protective clothing or equipment is needed for operators.

Cost—\$203K for 1400 ft of installed horizontal/directional wells.

Additional comments: The curve steering ability of horizontal/directional drilling appears promising for an entombment scenario since both horizontal and vertical flow component interception is possible and diversion can take place beneath the water table. An added benefit is the ability to extract volatile organic compounds from contaminated soil. An optimal scenario might include supplementary French drains.

Science/Technology Needs: French drains—The need exists for cost-effective techniques for French drain installation in hard rock.

Biopolymer drains—Although biopolymer drains are a mature technology, there may be opportunities to apply it in new applications or with different construction equipment.

Horizontal/directional drilling—Although excellent in hard-rock applications, horizontal well demonstrations need to focus on the technical feasibility of drilling long distances in bedded and interbedded shales and limestone; however long-distance drilling may be unnecessary for entombment applications. The hard-rock drill has problems in mud seams. The effective distance between wells for groundwater interception should be investigated. Preliminary calculations for an isotropic, homogeneous deposit indicate that a single horizontal well is hydraulically equivalent to 5 vertical wells in sandy soil or 25 vertical wells in clay soil. Cost evaluation would consider permitting required for single versus multiple wells. Analytical techniques can evaluate the degree of filter pack perviousness required for a perfect drain. Installation techniques may require using water-jetting tools to cut away the smear zone along the borehole prior to well screen installation. Vacuum cleaning of cuttings or fines in the borehole may also be required due to the clayey nature of the saprolite.

Implementation Needs: An economic feasibility study of each drain type using computer modeling of site-specific scenarios for Building 9201-4 is required. Computer software for transient and steady-state seepage of water for unconfined flow, incompressible soil, and anisotropic conductivities. Cost effectiveness of each drainage method would be determined.

French drains—Developing/demonstrating priorities for French drain installation in hard rock are low to medium depending on the building conditions. Drains less than 10 ft deep could be installed in a 1-ft-wide slot. A 2.5–3-ft-wide hole to accommodate a backhoe would be needed for drains deeper than 10 ft. Only limited construction equipment sizes are available. Estimated time to maturity for hard-rock French drain installation is 3–5 years.

Horizontal/directional drilling—Studies published by Los Alamos National Laboratory indicate that a horizontal air stripping system costs approximately 40% less for volatile organic compound (VOC) extraction when compared to conventional soil vapor extraction. A major cost reduction factor is related to the higher efficiency of a horizontal well to remove

VOCs. Perform field test to evaluate the operational problems of installing a filter-packed horizontal well. A building 100 ft² is estimated to require 10-12 wells. For a 50-ft-deep, 400-ft-long well at \$90-\$100/ft, this would come to about \$400K-\$500K. Estimated time to maturity for long-distance drilling in bedded and interbedded shale and limestone is 5-10 years. Estimated time to maturity for general horizontal drilling is dictated by how many leachate collections are needed to characterize the site (1 month/collection cycle) which is customer driven. Time to drill 1 well is 1-2 days, maximum. Production rate is 400-600 ft/10-h shift.

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(Some text taken directly or paraphrased from remedial action input documents authored by Bill Barton and Joe Kauschinger.)

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References:

1. Bill Barton, personal communication; 615-576-0519.
2. Bill Barton, Remedial Action Input Documents, REMA-43-OL, REMA-44-OL, and REMA-45-OL.
3. Bill Key, personal communication; 615-576-0278.
4. Jensen Drilling Company, Alcoa, Tennessee. Vendor literature on horizontal well drilling and installing.
5. Ground Engineering Services. Remedial Action Input Document.
6. Office of Technology Development Technical Task Plan Summary, "SRS Integrated Demonstration; Directional Drilling," TTP No. SR121101, Rev. 2, November 9, 1992.

TEMPORARY ENTOMBMENT/CLAY FILL (ENTOMBMENT)

DISM-82-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities or underground utilities to be permanently or temporarily abandoned in place. The technologies may apply to known contaminated soils area depending upon the type of contaminants. Contaminants to be addressed are low-level uranium, mercury, lithium, PCBs, and oils of various types. An example of this would be filling an abandoned storm sewer or sanitary sewer line under or near a facility to be decontaminated and decommissioned.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Entombment

Technology: Temporary entombment/clay fill. The technology involves use of clay fill as a void eliminator and waste solidifier in an entombment structure.

Status: Evolving technology—conceptual. Although clay fill has been used at other sites and is proposed for use at the ORNL graphite reactor transfer trench it has not yet been used in preexisting subsurface structural entombment. Rubble or other waste must be homogeneously mixed with clay to achieve a monolithic (solid block) structure. Like permanent entombment, the limitation of this technology is leachability of contaminants or waste through clay fill and subsurface wall structure into surrounding environment. Legal and regulatory decisions must be made regarding acceptable levels of moisture diffusivity. The variation in diffusivity coefficients of different species through clay would require strict attention to hydrologic isolation specifications. Since solutes in the leachate would diffuse under the influence of chemical gradients, clay would only retard the movement of contaminants. In order to provide a measure of additional safety, the use of geomembranes as primary liners has been recommended by the EPA for hazardous waste facilities. Monitoring of hydrologic isolation and/or waste leachate via embedded sensors or instrumentation packages installed in horizontal wells would help assure entombment integrity. Clay fill would necessitate aboveground capping. Due to the problem of desiccation the capping barrier would have to maintain the fill internal humidity while isolating it from

TEMPORARY ENTOMBMENT/CLAY FILL (ENTOMBMENT)

DISM-82-OY

external sources of moisture. Wet clay is "self-healing" in nature and will spontaneously move to fill in any cracks or voids that may occur over time.

Efficacy—Long-term effectiveness unknown without demonstration but ranked low to high depending on type of waste, waste loading ratio, fill type, and hydrologic isolation techniques used. Waste is physically contained, containment integrity is thought to endure at least 50-100 years depending on hydrologic isolation success, clay fill needs little or no development as a solidification material (i.e., is well known and characterized), and is inexpensive. Limitations are the need to produce a monolithic structure (solid block of clay/waste mix), the problem of desiccation, capping and sealing effectiveness in maintaining internal moisture, and the ability of hydrologic isolation and monitoring methods to prevent untimely degradation of containment integrity.

Waste—Volume increase of waste varies depending on calculated waste loading, but no additional waste is generated by the entombment process. It is possible that adding enough clay to a small amount of waste could dilute the contamination to acceptable levels if waste form/size renders it easily dispersible. Some additional waste may be generated by need for protective clothing or equipment for operators.

Cost—Could range from \$300K-\$2M/building (100 ft x 100 ft x 10 ft) depending on location, structural complexity, and issues described under Science/Technology Needs.

Additional comments: An acceptable diffusivity limit is the determining factor in evaluating available hydrologic isolation techniques and identifying the best candidates or combination thereof.

Science/Technology Needs: Similar to those of permanent entombment minus solidification/stabilization process development since waste is physically restricted by clay fill. Research and development for hydrologic isolation of subsurface building structure depending on: (1) type and amount of structural contamination present, (2) type of waste stored within the structure, and (3) what level of moisture flow into the surrounding soil is environmentally acceptable. It is reasonable to assume that temporary entombment is not expected to endure as long as permanent entombment, but it may be possible to extend predicted lifetime based on judicious (and likely more expensive) choice of hydrologic isolation methods. Research and development for detecting waste leachate and monitoring hydrologic isolation of the entombed structure if sensors are used to accomplish this. Application-specific demonstrations of capping, hydrologic isolation, containment monitoring, and waste leachate detection are needed.

Implementation Needs: Developing/demonstrating priority is high. None of the capping or hydrologic isolation technologies have been previously applied to entombment. Therefore, characterization of waste, site location, and structural contamination are crucial in evaluating and identifying an optimal solution. Depending on the characterization results and the issues described under Science/Technology Needs, solution could range from a simple

TEMPORARY ENTOMBMENT/CLAY FILL (ENTOMBMENT)

DISM-82-OY

clay/sand/soil mixing and filling operation with French drains to hydrologic isolation via external subsurface structural sealing and prototype development of waste detectors and hydrologic isolation monitoring sensors. A complete performance/assessment analysis is required by DOE, necessitating modification of existing Source II code for an entombment scenario. Aboveground building dismantlement, removal, decontamination, rubblization, and worker protection from hazardous/toxic/radiological wastes need to be addressed. Estimated time to maturity is about 4-5 years.

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References:

1. Diversified Technologies.
2. Bill Key, 615-576-0278; personal communication.
3. Bill Barton, 615-576-0519; personal communication.
4. Roger Spence, 615-574-6782; personal communication.
5. Catherine Mattus, 615-574-6793; personal communication.
6. Hal Adair, 615-574-5900; personal communication.
7. Earl McDaniel, 615-574-0439; personal communication.
8. Southern Constructors, Inc.
9. Herschel Godbee, 615-576-2198; personal communication.
10. Ingold, T.S., Editor, "Liquid Conduction Tests for Geomembranes," a paper submitted to *Geotextiles and Geomembranes*, April 20, 1991, available from Gundle Lining Systems, Inc.; 1-800-435-2008.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities and utilities abandoned in place as the last step of dismantlement after other decontamination and decommissioning steps have been completed. An example of this would be the filling of basement structures of a facility with impermeable material (concrete) to affix or immobilize remaining contamination or filling "abandon-in-place" utility lines.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Entombment

Technology: Permanent entombment. Macroencapsulation of solidified and stabilized waste in existing, subsurface structures modified for monitored hydrologic isolation.

Status: Evolving technology—conceptual. The basis for this technology exists but hasn't been implemented or tested. Permanent entombment is similar in concept to tumulus construction, an accepted technology, but differs in practice. Permanent entombment involves removing the aboveground portion of a building and using the remaining basement structure as a container for waste. Should contaminated pipes, substructures, or equipment remain they should be individually sealed by encapsulation before subsequent, total void elimination. Appropriately prepared hazardous, toxic, or radioactive waste can be used to fill void space. Depending on the solidification/stabilization process used, the waste can be converted to rubble and mixed with a cement-based grout or simply surrounded with a thermoset polymer or thermoplastic in either its rubblized or original state. Cement grout can offer chemical alteration/fixing of the waste (depending on the species) and physical encapsulation, while the thermoset polymers and thermoplastics accomplish physical encapsulation alone. The determining comparison factor is the resulting leachability index. The structure must be hydrologically isolated from the surrounding environment, which can be achieved via geosynthetic membrane liner, capping, thermoset vinyl ester resin sealer, microtunneling retrofit bottom sealing process, and water diversion drainage. Monitoring of hydrologic isolation and/or waste leachate could be done using embedded sensors or encapsulated instrumentation packages installed in horizontal wells.

Efficacy—Effectiveness unknown without demonstration but ranked medium to high depending on stabilization/solidification process and hydrologic isolation techniques used. Waste can be chemically stabilized in addition to physically contained, the leachability index of some void eliminators is extremely high, and containment integrity is thought to endure at least 100–300 years depending on hydrologic isolation success. Limitations are the expense of purchasing, developing, or disposing appropriate solidification/stabilization materials, and the ability of hydrologic isolation and monitoring methods to prevent untimely degradation of containment integrity.

Waste—Volume increase of waste approximately 50% depending on the waste loading of the particular solidification/stabilization technique, but no additional waste is generated by the entombment process except for protective clothing or equipment that would be needed for operators. **Cost**—Could range from \$500K–\$5.5M/building (100 ft × 100 ft × 10 ft) depending on location, structural complexity, and issues described under Science/Technology Needs.

Additional comments: Though conceptual, there is no doubt that entombment is technically feasible. The critical issue is a legal and regulatory one, namely, determining what degree of diffusivity from the subsurface structure into the surrounding environment is acceptable to government agencies. Time wise, the degree of entombment permanency desired affects the level of redundancy required under the assumption that redundant permeability and diffusivity controls prolong entombment integrity. Macroencapsulation is the EPA-specified technology for the treatment of radioactively contaminated lead solids.

Science/Technology Needs: Research and development for hydrologic isolation of subsurface building structure depending on: (1) types and amounts of structural contamination present, (2) type of waste stored within the structure and the leachability index of the solidification/stabilization material used, and (3) what level of moisture flow into the surrounding soil is environmentally acceptable. Research and development for detecting waste leachate and monitoring hydrologic isolation of the entombed structure if embedded sensors are used. Application-specific demonstrations of capping, hydrologic isolation, containment monitoring, waste leachate detecting, some solidification/stabilization processes, and microtunneling retrofit bottom sealing (done by Zublin, a German company) are needed.

Implementation Needs: Developing/demonstrating priority is essential. None of the solidification/stabilization, capping, or hydrologic isolation technologies have been previously applied to entombment. Therefore, characterization of waste, site location, and structural contamination are crucial in evaluating and identifying an optimal solution. Depending on the characterization results and the issues described in the Science/Technology Needs section, could range from a simple to extremely complex scenario. A simple example would consist of a construction-grade concrete mixing and filling operation with French drains surrounding the site. A highly complex example would involve laboratory development of an optimum solidification/stabilization grout for a multiple-component waste species, prototype development of embedded waste leachate and hydrologic isolation monitoring sensors, lining the internal fill volume with an impermeable geosynthetic membrane, microtunneling retrofit (external) bottom sealing, vertical external surface sealing with vinyl ester resin, capping the

tomb, and installing a WELLPACK horizontal drain system with instrumentation packages. A complete performance/assessment analysis is required by DOE, necessitating modification of existing Source II code for an entombment scenario. This modification would be extensive for the highly complex example. Aboveground building dismantlement, removal, decontamination, and rubblization, cement/grout disposal, and worker protection from hazardous/toxic/radiological wastes need to be addressed. Estimated time to maturity is 3-7 years.

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References:

1. Diversified Technologies.
2. Bill Key, 615-576-0278; personal communication.
3. Bill Barton, 615-576-0519; personal communication.
4. Roger Spence, 615-574-6782; personal communication.
5. Catherine Mattus, 615-574-6793; personal communication.
6. Hal Adair, 615-574-5900; personal communication.
7. Earl McDaniel, 615-574-0439; personal communication.
8. Southern Constructors, Inc.
9. Herschel Godbee, 615-576-2198; personal communication.
10. Ground Engineering Services.
11. Office of Technology Development Technical Task Plan, "Hazardous and Mixed Waste Treatment Technology Development," TTP No. SR101102, 1992.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment—These technologies apply either to temporary or to permanent isolation of the remainder of facilities or underground utilities to be permanently or temporarily abandoned in place. The technologies may apply to known contaminated soils area depending on the type of contaminants. Contaminants to be addressed are low-level uranium, mercury, lithium, PCBs, and oils of various types. An example of this would be lining an abandoned sump pit area or underground diffusion structures associated with 9201-4.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Entombment

Technology: Hydraulic isolation. Hydraulic isolation must be implemented around the wall perimeter and beneath the bottom surface (bottom sealing) of the basement structure. Wall sealing can be accomplished wrapping the wall perimeter with interlocking panels of high density polyethylene (HDPE) geomembrane barriers (another form of the capping material referenced in DISM-112-OL). Panels are installed with a vibratory hammer and insertion plate. The panels are flexible to resist penetration due to soil deformation. This geosynthetic hydraulic barrier can be used alone or in conjunction with traditional slurry walls. The latter case would form a concrete-based sandwich with a core of geonet liner. Integrity of liner can be determined over time by surcharging the geonet with water and measuring leakage rates. Embedded sensors could also be used. Another option is to use the vinyl ester resin in-situ (VERI) process referenced in DISM-109-OL to form an external VERI-curtain seal. The polymerization material could be injected down drill holes or a narrow trench skimming the wall surface. A third possible alternative is the use of rubber material but this would take further investigation as chemical resistivity is highly selective and radioactivity cross-links rubber making it brittle. An acrylonitrilbutadiene co-polymer blend, commonly called NBR-PVC, could make a fairly low-cost, ozone resistant seal. Any of these technologies could conceivably be used together to add redundant hydraulic isolation control.

Bottom sealing essentially uses the same materials as wall sealing with different insertion techniques. Jet grouting can be installed using high pressure pumps to impart cutting energy to grout jet stream or by using directional (horizontal) drilling techniques to insert and

manipulate a "soil saw" consisting of a drill casing containing a large array of jet cutting nozzles. These methods could conceivably be used to inject a VERI-curtain. Using microtunneling to install a continuous layer of HDPE liner appear sound. Monitoring of hydraulic isolation can be accomplished via sensors as described in DISM-118-OL, sensors for monitoring entombment integrity.

Status: Demonstration.

Efficacy—The major advantage of the soil saw with jet grouting is the ability to form a continuous bottom seal (unlike vibrated plastic tube bottom seal described in REMA-87-OL). Major drawbacks relate to encountering impenetrable obstructions such as boulders or utility pipes and generating excessive cuttings that could create waste handling problems if contaminated. High velocity jet grouting was successfully used full scale to form a bottom seal beneath radioactive waste at White Oak Creek Embayment, ORNL. Curing of grout may be problematic and grout curtain easily eroded by flowing water. Microtunneling technique needs jacking/reception pits down to elevation of bottom seal and is limited in ability to steer around curves. Advantages of microtunnel/liner system are the ability to seal continuously, to use a liner designed for a particular waste leachate, and to be installed in ground conditions ranging from soil to soft rock. As described in DISM-109-OL, VERI is superior to grouts in preventing waste leachate due to low porosity and hydraulic conductivity. An HDPE geomembrane/clay composite liner is also superior to grout, achieving a hydraulic conductivity on the order of 10^{-13} . In terms of long-term entombment efficacy, grouting is judged to be of medium value while the VERI and HDPE liner techniques are judged to be high.

Waste—Any waste produced would be generated by contaminated drill cuttings and protective clothing or equipment needed by operators.

Cost—A two year test program for microtunneled HDPE liner is estimated to be \$2M-\$3M. High velocity jet grouting is estimated to cost \$800K for demonstration. Using VERI as a sealant material would probably slightly increase this estimate due to higher polymer expense.

Additional comments: High velocity jet grouting is in the demonstration phase. The soil saw is in the pre-demonstration phase. Using these techniques with the VERI process is in the conceptual to pre-demonstration phase. Microtunneled HDPE liner is an evolving technology in the conceptual phase. Using rubber sealant materials is in the problem definition to pre-conceptual phase.

Science/Technology Needs: Grout formulations need to be developed. VERI injection for hydraulic isolation needs to be demonstrated. Need to demonstrate combination of microtunneling and HDPE liner technologies. Soil saw needs to be demonstrated. Microtunneling requires research and development to improve guidance system so that microtunneling can be conducted from ground surface or shallow shafts and to achieve ability to maneuver sharp turns.

Implementation Needs: Testing and demonstration priorities are extreme for all described technologies. Estimated time to maturity for using VERI in combination with high velocity jet, soil saw, or sidewall trench/borehole is 1-2 years more than any of these techniques would be involving grout. Estimated time to maturity for these and the other techniques is highly speculative since they are in phases ranging from pre-demonstration to demonstration.

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(Some text quoted directly or paraphrased from REMA-85-OL, REMA-86-OL, and REMA-88-OL authored by Bill Barton, and Gundle vendor literature.)

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References:

1. Bill Barton, 615-576-0519; REMA-85-OL.
2. Bill Barton, 615-576-0519; REMA-86-OL.
3. Bill Barton, 615-576-0519; REMA-88-OL.
4. "Gundle: If It Needs Lining, It Needs Gundle," Gundle Lining Systems, Inc., published by author, Houston, Texas; March 1993.
5. Goodyear Tire, personal communication. In this conversation I was advised to determine specific waste species to ensure further discussion would be worthwhile.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities as the last step of dismantlement after other decontamination and decommissioning steps have been completed. An example of this would be the filling of basement structures of a facility with impermeable material (concrete) to affix or immobilize remaining contamination.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Entombment

Technology: Capping—Aboveground environmental barrier.

Status: Accepted technology. Infiltration control (capping) technology is quite mature (U.S. EPA 1986 and 1989) for covering hazardous waste sites. Capping technology has been demonstrated for the purpose of long-term protection of trench-type burial sites and the Oak Ridge Y-12 Plant has capped waste with asphalt matrixed over polyurethane sheets. However, the most popular capping technology for municipal waste landfills, mining tailings disposal areas, potable water storage, and waste pools seems to be layered geosynthetic membranes in the form of high-density polyethylene (HDPE) geomembrane liners, bentonite blankets, geotextiles, and geonets combined to produce layered cap and closure systems. Geosynthetic membranes are resistant to a wide range of chemicals including acids, alkalis, salts, alcohols, amines, oils, and other hydrocarbons. They also have relatively high tensile strength before yielding, biaxial elongation, tear resistance, puncture resistance, ultraviolet light resistance, dimensional stability, heat resistance, stress crack resistance, and resistance to microorganisms and rodent damage. Use of geomembranes as primary liners and clay liners as secondary liners for waste disposal facilities has been recommended (U.S. EPA 1985 and 1988) because clay liners alone merely retard the movement of contaminants, which would diffuse under the influence of chemical gradients. A clay/HDPE membrane composite liner would be ideal for entombment capping because the geomembrane is a barrier to pressure-driven mass transfer, while the underlying clay liner forms a barrier to concentration-driven mass transfer. HDPE membranes typically have an effective hydraulic conductivity of 2.7×10^{-13} cm/sec, while bentonite (clay) hydraulic conductivity is about 3.7×10^{-10} cm/sec.

The combination liner comprised of consecutive geomembrane, drainage, geomembrane, and clay layers is the liner system required for hazardous waste containment under Subtitle C of the 1984 Hazardous and Solid Waste Amendments to RCRA. Geotextiles, geonets, and granular soils are utilized in combination for leachate collection systems. Gundle-brand liners are installed with their innovative hot wedge welding system and patented extrusion welding system. HDPE membranes range in thickness from 20–140 mils and are made from resins with a specific gravity greater than 0.935 prior to the addition of carbon black and additives. Fine particles of carbon black make the membranes highly resistant to UV radiation. White surfaced geomembranes reduces liner temperature by reflecting solar energy. Reducing liner temperature means less expansion/contraction, less subgrade desiccation, and more durability in long-term aging. The major material cost for a basement structure requiring 10,000 ft² of capping liner would be from \$5K–\$12K depending on the mil thickness of the geomembrane. Typical costs per thickness range from \$.45–\$.50/ft² for 30-mil up to \$1.20/ft² for 140-mil thicknesses.

Efficacy—Effectiveness is high. Geosynthetic/bentonite capping systems are superior to singular clay barriers in terms of chemical resistance and hydraulic conductivity, achieving conductivities on the order of 10^{-13} . Because of the newness of HDPE material technology, long-term durability data is lacking. However, EPA experts expect a lifetime of well over 400-plus years provided that (1) liner is buried, (2) liner is shown to be chemically resistant to buried contents, and (3) correct installation to ensure that liner is free of tension stress as much as possible.

Waste—None

Cost—From \$13K–\$30.5K, depending on the level of hazard involved in working conditions and whether a stainless steel batten is used in the foundation cap.

Additional comments: Because polyethylene was discovered only fifty years ago, a definitive answer to the question of durability is lacking. Twenty-year-old HDPE liners are still intact. Very little is known beyond this about the ultimate lifetimes of properly stabilized HDPE liners, although experts theorize from hundreds to thousands of years.

Science/Technology Needs: Accelerated aging tests must be studied and the lifetimes in these tests maximized in order to provide the greatest confidence in the liner's ultimate longevity. Deterioration of a geomembrane liner is interpreted as an irreversible process in which useful polymer properties degenerate when exposed to the environment. Both biological/chemical species and energy sources contribute to the deterioration. They include heat, UV light, high energy radiation, environmental stress, biological organisms, chemicals, and oxygen. The deterioration takes place because of the rupture of primary and secondary chemical bonds in the polymer matrix. Because HDPE liners do not contain plasticizers and other additives which act as foodstuffs for biological organisms, they are not susceptible to decay through biological activity. Practically speaking, degradation of HDPE liners takes place via five principle means: (1) UV light, (2) heat, (3) environmental stress cracking, (4) oxygen,

and (5) other reactive chemicals. Environmental stress cracking is in a category by itself and covers polymer cracking resulting from contact with surface-active agents in conjunction with low-level physical stress. UV light and many chemical reactants only initiate degradation; heat and oxygen are actually involved in the propagation of the degradative reactions. Thermal-oxidative stability was once thought to be the life-limiting category of polymer stability for HDPE geomembrane liners, but further testing has shown that stress-cracking is the ultimate barrier to longevity. With tension-free installation, stress-cracking is reduced and the liner is thought to last at least 400 years.

Implementation Needs: The price to install a 10,000 ft² foundation cap in Level D (nonhazardous) working conditions using 60-mil HDPE is a total lump sum of \$13,115. The cost breakdown is materials—\$4,015 and Labor—\$9,100. This scope of work includes: (1) there being no pipe penetrations, (2) all material being delivered by vendor to the job site, and (3) all relevant state and/or federal taxes, and (4) only one mobilization. Adding a stainless steel batten to the foundation cap would raise the price to \$23,773. Installing a foundation cap with batten in hazardous working conditions (requiring Tyvek suits, double-tape gloves, face masks, etc.) would cost \$30,520. Geosynthetic-membrane capping systems are speculated to last about 300–400-plus years with appropriate material chosen for chemical resistance and correct, tension-free installation.

Author: Linda J. Talarico, 615-574-9736

References:

1. Remedial Action Input Document, REMA-36-OL; Bill Barton, 615-576-0519.
2. Gundle Lining Systems, Inc., *Quality Assurance Manual for the Installation of Flexible Membrane Lining Systems*, published by author, Houston, Texas; January 18, 1993.
3. Gundle Lining Systems, Inc., *Gundle: If It Needs Lining, It Needs Gundle*, published by author, Houston, Texas; March 1993.
4. Cadwallader, Mark; "Durable Liners for Hazardous Waste Containment," presented at the World Conference on Hazardous Waste, Budapest, Hungary, October 25–31, 1987.
5. Ozsu, Elif and Acar, Yalcin B.; "Liquid Conduction Tests for Geomembranes," a paper submitted to *Geotextiles and Geomembranes*, an Official Journal of the International Geotextile Society, Elsevier Science Publishers Ltd., Essex IG11 8JU, England, April 29, 1991.
6. Gundle Lining Systems, Inc., FAXed cost estimate, May 21, 1993.
7. Gundle Lining Systems, Inc.; personal communication, May 24, 1993.

ENCASEMENT—SUBSURFACE WASTE STORAGE WITH VOID REDUCTION (ENTOMBMENT)

DISM-86-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities or underground utilities to be permanently or temporarily abandoned in place. The technologies may apply to known contaminated soils area depending upon the type of contaminants. Contaminants to be addressed are low-level uranium, mercury, lithium, PCBs, and oils of various types. An example of this would be filling an abandoned storm sewer or sanitary sewer line under or near a facility to be decontaminated and decommissioned.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Entombment

Technology: Encasement—Subsurface waste storage with void reduction. This technology involves waste storage in existing, modified, subsurface structures with void reduction as opposed to void elimination, which would occur in temporary or permanent entombment.

Status: Evolving Technology—conceptual. Pipes and utility inlets may be crushed or sealed off. Existing contaminated equipment may be encapsulated or crushed. Existing void space may be filled with loose sand, soil, or clay, drummed waste, other contaminated equipment, waste rubble, or waste rubble mixed with solidification grout, sand, soil, or clay. Compaction of structure contents would be necessary prior to grout pouring and capping to decrease future shifting or subsidence. Capping system likely to need foundation that is internally buttressed. The intent is to restrict physical movement of waste in a relative, as opposed to absolute, way. As for chemical fixation of waste species, the inherent voids would likely degrade the stabilizing effect of a specialty grout fill by providing locations for condensation collection to occur. This technology not thought to be as long-term as temporary or permanent entombment, but its lifetime may be increased by using the same hydraulic isolation, ground water and surface water diversion, sensor monitoring, and capping technologies as those used in temporary or permanent entombment.

Efficacy—Low to moderately high effectiveness depending on hydraulic isolation implementation. The implementation and cost advantages of encasement are that less

ENCASEMENT—SUBSURFACE WASTE STORAGE WITH VOID REDUCTION (ENTOMBMENT)

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attention is paid to the internal conditions of waste storage and specialized grout development may be judged unnecessary. Sealing, capping, water diversion, and hydraulic isolation concerns remain and must be evaluated in terms of governmental regulatory policy decisions. The overall cost may be lower than temporary or permanent entombment but the results may not be as cost-effective in the long term.

Waste—None, except for protective clothing or equipment that would be needed for operators, although there may be a volume increase up to 30%–40% if sand, soil, clay, or grout fill is used.

Cost—\$200K–\$2M per building (100 ft x 100 ft x 10 ft) depending on location, site requirements, allowable void content, structural complexity, and issues described in the Science/Technology Needs section of the Permanent Entombment data sheet.

Additional comments: Hydraulic isolation requirements must be evaluated relative to expected or intended lifetime of encasement waste storage.

Science/Technology Needs: Needs and development priorities are the same as those for hydraulic isolation, capping, solidification/stabilization process, water diversion, and sensor monitoring technologies. The crushing and compaction processes assumed to need little or no development.

Implementation Needs: Crushing, compacting, rubblizing, grout mixing and pouring (if used), and waste transportation equipment with adequate worker protection measures. Since these are routine operations needing little to no development, estimated time to maturity is governed by the hydraulic isolation techniques which are implemented.

Author: Linda J. Talarico, 615-574-9736

Reviewer: C. E. Hamilton/615-574-9653

References:

1. Bill Key, 615-576-0278; personal communication.

RUBBLIZATION VIA CRUSHING AND/OR SHREDDING (ENTOMBMENT)

DISM-87-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: This technology applies to the remainder of facilities as an interim step of dismantlement where rubblization of low-level solid waste is required for volume reduction prior to the final stages (hydraulic isolation) of modular, temporary, and/or permanent entombment. Examples of rubblization would include crushing of concrete structures, shredding of metal and plastic canisters, etc.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Entombment

Technology: Rubblization via crushing and/or shredding

Status: Demonstration. Some commercial products are available to crush, rubblize, and shred low-level solid wastes that are in the form of concrete, metal, wood, plastic, cloth, etc. The shredding devices available today are sensitive to the types of materials being shredded. For example, some systems work well with wood and plastic but do not provide adequate shredding of cloth and other pliable materials. Consequently, additional development of multifunctional systems may be required to reduce on-site labor requirements. Some materials also require substantially more torque than others. Crushers, on the other hand, are generally used for concrete structures and are also available commercially. Current systems can be acquired that range in size to accept small (hand-held) chunks of material up to systems that can accommodate large slabs.

Efficacy—Medium. The major strength of this technology is its ability to drastically reduce the volume of waste generated at a given site. A secondary strength is the improvement in physical stabilization through a reduction in long-term settling of entombed and capped materials that this technique provides. In many cases, this technology will be crucial to ensure that an a given site is physically capable (size-wise) of being entombed without adding more space to the existing site. The disadvantages of this technology are material sensitivity, extensive labor costs required to move, handle, and rubblize the various large structures, and the health and safety concerns related to the extensive material handling requirements.

RUBBLIZATION VIA CRUSHING AND/OR SHREDDING (ENTOMBMENT)

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Waste—Little additional waste is produced by this technology.

Cost—The cost of a rubblization device depends heavily on the mechanism by which it operates—\$5K–\$50K for portable units capable of shredding small amounts of plastic wood, and metal specimens and \$50K–\$100K for large units capable of crushing and shredding large amounts of masonry and metal structures.

Science/Technology Needs: Further development of higher-torque, longer-lasting shredders is needed along with the development of larger, faster, less-labor-intensive crushers.

Implementation Needs: Implementation plans for extensive dozer work and material handling will be required for this technology. Estimated time of maturity: 2 years. Priority need: medium.

Author: W. S. Key, J. D. Muhs/615-576-0278

Reviewer: C. E. Hamilton/615-574-9653

References:

1. Williams Patented Crusher Co., St. Louis, Missouri.
2. Shredding Systems, Inc., Wilsonville, Oregon.
3. Al Pruitt, Oak Ridge Y-12 Plant, Engineering.
4. Mike Witte, Oak Ridge Y-12 Plant, Engineering.

ENGINEERED STORAGE—FOR FUTURE DISPOSAL (ENTOMBMENT) DISM-88-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities as the last step of dismantlement after other decontamination and decommissioning steps have been completed. An example of this would be the filling of basement structures of a facility with impermeable material (concrete) to affix or immobilize remaining contamination.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Entombment

Technology: Engineered storage—for mercury-contaminated items, future disposal

Status: Demonstrated. Engineered Storage is currently used to dispose of various nuclear components, usually reactor vessels, and/or items activated by exposure to nuclear reactor shine. Current methods have been to design special cask or enclosures for each individual item on a case by case basis.

Similar technology is used in the nuclear weapons manufacturing facilities to ship components except the concept has been carried much further in that standardized and licensed shipping containers have been developed and specified. Therefore, when new items are shipped, previously designed shipping containers can be recalled and used, sometimes with minor modifications or as is, to ship components within the DOE Complex.

This concept is required for many facilities at ORNL and across the DOE Complex. The payback potential is large. Standardized storage could save \$200M–\$500M per major facility if standard containers were available. This is based on an estimated cost of \$300–\$500/ft³ for final storage of high-radiation-level components.

Efficacy—The technology is certain to work and, if properly integrated into the overall system for the Complex, could serve as the eventual final storage cask. Large existing facilities, such as the large diffusion buildings, could be used as long-term interim storage facilities for items not acceptable to existing waste disposal sites until final disposition is defined.

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Science/Technology Needs: No new science or technology is needed. Money could be saved if currently available materials could be recycled by building appropriate cask or containers from available contaminated materials within the Complex. Stainless steel, appropriate for long-term storage containers, could be smelted from available nickel, steel, and monel materials currently stored or laying in wait in the massive diffusion facilities.

Implementation Needs: Cask and shipping containers must be designed and approved as standard storage and/or shipping containers for very-high-level-radioactive items. This effort would take approximately \$1M to engineer and license the prototype casks. It would eventually require approximately \$5M-\$8M to set up an appropriate demonstration.

Author: L. C. Hensley/615-574-1988

Reviewer: C. E. Hamilton/615-574-9653

References: L. E. Galyon, Tool Design Engineering Department, Oak Ridge Y-12 Plant, P.O. Box Y, Building 9111, Oak Ridge, Tenn. 37831.

MODULAR ENTOMBMENT—WITH PROVISIONS FOR FUTURE REMOVAL (ENTOMBMENT)

DISM-89-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities or underground utilities to be permanently or temporarily abandoned in place. The technologies may apply to known contaminated soils area depending upon the type of contaminants. Contaminants to be addressed are low-level uranium, mercury, lithium, PCBs, and oils of various types. An example of this would be temporary storage of asbestos insulation contaminated with mercury and stored until a technology is developed to treat the contaminated material.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Entombment

Technology: Modular entombment—with provisions for future removal

Status: Demonstration. This technology's use is based on the assumption that modular entombed structures will be temporarily stored and later moved, as space becomes available at long-term hazardous waste storage sites. In this scenario, cement- or concrete-based grouts, thermal-setting plastics, or polyethylene melts will likely be used to stabilize shredded or pelletized waste in containment vessels fabricated from metal and/or polyurethanes. This technology has been demonstrated extensively at the K-25 Site for temporary entombment, but proper guidelines for the grout mixing process must first be established to ensure that corrosion and subsequent leaching does not occur. This has been a major area of concern in recent years at other DOE sites. This technology is also considered to be crucial to the success of the entire entombment process because of the space constraints at existing storage sites. These vessels also should include embedded sensors (discussed in another data sheet) to monitor structural and hydraulic isolation.

Efficacy—Considered moderate over the service lifetime of the entombment process. The biggest limitation of this technology is long-term stability.

Waste—With adequate design, reprocessing of secondary waste streams is possible, resulting in little or no generation of waste.

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Cost—Considered to be relatively low.

Science/Technology Needs: Problems with ensuring uniform mixing and proper stabilization/solidification of the composite mixture (grout plus waste) indicates a need for evaluating technologies such as embedded sensors for in situ testing and verification. Need to assess cast block size for optimization with respect to handling, storage, relocation, forming, etc.

Implementation Needs: Develop mixing methods, implementation controls, training needs, etc., to ensure proper use of the technology and to avoid problems with solidification that might entail retrofit costs and thus nullify the benefits of the technology (low cost, simplicity, accessibility of materials). Specifically, implementation planning should consider mixing to ensure avoidance of hot spots and developing pouring needs. Also, handling requirements of cast form must be assessed either for movement into the entombed area (precast) or for casting in-place and later removal.

Author: J. D. Muhs/615-574-9328, L. J. Talarico/615-574-9736, W. S. Key/615-576-0278

Reviewer: C. E. Hamilton/615-574-9653

References: Gundle Lining Systems, Inc., product brochure, published by author, Houston, Texas; 1993.

CONCRETE-BASED SOLIDIFICATION/STABILIZATION (ENTOMBMENT)

DISM-90-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities or underground utilities to be permanently or temporarily abandoned in place. The technologies may apply to known contaminated soils area depending upon the type of contaminants. Contaminants to be addressed are low-level uranium, mercury, lithium, PCBs, and oils of various types. An example of this would be filling an abandoned storm sewer or sanitary sewer line under or near a facility to be decontaminated and decommissioned.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Entombment

Technology: Concrete-based solidification/stabilization. Using specialized concrete grouts to physically and chemically restrict mass transfer of waste.

Status: Accepted technology. Concrete-based grouts are routinely used to physically encapsulate, or solidify, waste. The leachability index (LI) is the negative logarithm of effective diffusivity. The LI of an all-purpose concrete grout is about 6. For comparison, the LI of water is 5. This constitutes advective flow which ranges near 10^{-6} . Diffusive flow is defined to be on the order of 10^{-13} and lower. Containments with diffusivities on the order of 10^{-13} to 10^{-15} are considered, for all practical purposes, not to leak. The ability to contain waste constituents is not related to strength of concrete but rather to its porosity which naturally sustains advective flow of leachate. A specialty grout can be tailored to further decrease waste mobility by chemically interacting with, or stabilizing, the waste species raising the LI to 7-8 or possibly higher. Such grouts cannot deal with mixed waste unconditionally. The key is solubility of the waste species. Adequate waste characterization is needed to select a defensible technology. Some waste simply cannot be handled by concrete grouts. Nitrate, for example, is incapable of chemically interacting with cements and will leach from concrete. But for suitable waste applications, concrete-based grouts can be the most cost-effective solidification/stabilization technique available. Although secondary waste streams are always generated (at least from equipment clean-up) reprocessing of this secondary waste is possible with proper design so that no new waste is generated. Loose

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hazardous waste incurs a lower volume increase than radioactive waste. The former undergoes 70%-90% waste loading with a 10%-30% volume increase while the latter is capable of only 40%-60% waste loading with a 40%-60% volume increase. Cost depends on the waste species. Characterization and grout development could take as little as two weeks for a simple waste or as long as 1-3 years for an extremely difficult waste (with 8-9 mass fractions). This includes the verification and validation steps necessary to ensure solidification/stabilization encapsulation. The high compressive strength of concrete would protect against settling and shifting of contents and provide an adequate foundation for capping technologies.

Efficacy—This technology is highly effective for suitable wastes since chemical interaction is possible. Concrete has a compressive strength of 200-300 psi up to several thousand psi. Liabilities are the waste volume increase and the porosity which sustains advective flow even when chemical interaction occurs. Cannot handle mixed wastes unconditionally and not useful at all for some wastes. Adequate waste characterization is critical to success. Can be less expensive than thermoset polymers or thermal plastics.

Waste—The volume of waste would increase, up to 60%, depending on the type of waste, but additional waste would not be generated except protective clothing or equipment that would be needed for operators.

Cost—\$250K-\$3.8M depending on waste characterization and accessibility of basement location to cement mixing and pouring equipment. These figures are based on a basement volume of 100,000 ft³ (100 ft × 100 ft × 10 ft).

Additional comments: The least expensive waste for concrete-based grouts would be one composed of nonsoluble constituents capable of chemically interacting with concrete.

Science/Technology Needs: Waste characterization, grout development, and complete performance assessment including verification and validation of solidification/stabilization technology. Performance calculations must meet NRC and EPA regulations including dose assessments for intruder and escape scenarios.

Implementation Needs: Waste characterization and grout development priorities are extremely high. Source I or Source II code would have to be modified for entombment scenarios and grout performance characteristics entered in. Waste must be homogeneously mixed with grout to avoid "hot spots." Pouring may require extensive preparation work such as installing drains and using pumps over long distances. Mixture must be poured in two foot layers to ensure void elimination. Proceeding layers should be poured as soon as possible to enhance bonding between layers. Processing costs for grout about \$200/yd³. Disposal costs for cement are high. Estimated time to maturity is waste-species dependent, ranging from 1-6 months to 4 years.

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September 1994
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**CONCRETE-BASED SOLIDIFICATION/STABILIZATION
(ENTOMBMENT)**

DISM-90-OY

Reviewer: C. E. Hamilton/615-574-9653

References:

1. Southern Constructors, Inc., Knoxville, Tenn., personal communication.
2. Herschel Godbee, 615-576-2198; personal communication.
3. Earl McDaniel, 615-574-0439; personal communication.
4. Roger Spence, 615-574-6782; personal communication.
5. Mike Gilliam, 615-574-6820; personal communication.

SENSORS FOR MONITORING ENTOMBMENT INTEGRITY (ENTOMBMENT)

DISM-91-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Entombment. These technologies apply either to temporary or to permanent isolation of the remainder of facilities as the last step of dismantlement after other decontamination and decommissioning steps have been completed. An example of this would be the filling of basement structures of a facility with impermeable material (concrete) to affix or immobilize remaining contamination.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternatives: Entombment

Technology: Sensors for monitoring entombment integrity

Status: Predemonstration. This technology entails the use of remote sensors to determine the hydraulic isolation, structural integrity, and the overall stability of entombed structures. Several companies and national laboratories have developed or are in the process of developing remote sensors to determine such parameters as moisture infiltration, joint movement, crack formation, pressure, radiation, temperature, etc., all of which can be used to ensure that an entombed structure remains isolated from its surrounding environment. Most of these sensors have been evaluated only in a few operating scenarios and will require additional development to ensure longevity and reliability.

This technology is considered to be crucial to the success of the entire entombment process because of the longevity of a successfully entombed structure. By monitoring the entombed structure in situ with remote sensors, one can (1) minimize the need for periodic penetration-type sampling, (2) increase the service lifetime of an entombed structure, (3) network several entombment sites to a central unmanned control station, (4) minimize excavation, and (5) subsequently decrease the long-term cost of operating the entombment sites.

Methods for deploying the various types of sensors under an entombed site can be achieved using a horizontal drilling and embedding technique demonstrated at Lawrence Livermore National Laboratory. This technology employs an invertible pliable membrane that can be

SENSORS FOR MONITORING ENTOMBMENT INTEGRITY (ENTOMBMENT)

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deployed either under or within entombed sites. Lysimeters, pore pressure, temperature, and moisture sensors all have the potential to be deployed using this technology.

A single sensor costs \$10.00 to \$100K, depending on the functionality and complexity of the sensor. An entombed site is likely to house several dozen sensors at a total cost of \$100K-\$500K. The cost of the horizontal drilling and invertible membrane placement is about \$145/ft and can be made 400-600 ft in length. The cost of lysimeter installation is about \$20/ft.

Efficacy is high. Strengths include long-term internal monitoring, relatively low cost, and large return on investment.

Science/Technology Needs: Long-term survivability testing, accelerated lifetime testing, additional development of sensors that meet application-specific requirements.

Implementation Needs: Implementation of sensors during the entombment process will be required. Entry/exit ports could be a necessity for certain applications. Sensor specifications and requirements need to be developed along with deployment methods.

Author: J. D. Muhs/615-574-9328

Reviewer: C. E. Hamilton/615-574-9653

References:

1. FIMOD Corp., Blacksburg, Virginia.
2. Fiber and Sensor Technologies, Blacksburg, Virginia.
3. Sensors Buyers Guide, Helmers Publishing, Peterborough, New Hampshire.
4. Ground Engineering Services, Manchester, New Hampshire 03105.
5. Dick Van Hoeson, 615-574-7764; personal communication.

SHREDDING, SORTING, COMPACTION (PREDISPOSAL STAGING)

DISM-92-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Sorting for recycle

Technology: Predisposal staging

Status: Demonstration; Shred and Sort. Technology exists to shred and automatically sort materials. Drums, paint cans, and sheet metal, etc., are run through a shredder and onto a conveyor system. A magnet separates the metal from other wastes. The metal is then fed into a metal baler before or after to be contaminated. The other waste originally in the drum is reevaluated and disposed of. The system to shred and sort would cost approximately \$200K and would need to be sheltered from the elements.

Compaction: A metal baler with a 60 in. wide, 54 in. deep, and 120 in. long box that produces a 20 in. square bale with the length being variable. Cost is \$750K. A 20 in. square by 24 in. long bale of mild steel weighs approximately 900/1000 lb.

Total capital costs are \$1M plus foundation, building, and installation; development costs are \$0.75M; and operating costs are \$100/ft³.

The metal baler could be used to bale steel structural members, pipe, and machinery to reduce volume. The material that comes out of the pipes and machinery will need to be contained and disposed of.

Efficacy—High. Known technology will work and bulk could be reduced and possibly contaminated at this stage which would further reduce the low-level contaminated material required to be compacted and stored.

**SHREDDING, SORTING, COMPACTION
(PREDISPOSAL STAGING)**

DISM-92-OY

Waste—Mercury contaminated machinery, pumps, valves, tanks, and pipes with a trace of uranium that has possibly been washed down and compacted to reduce volume.

Science/Technology Needs: None

Implementation Needs: A complete system will be required to function as desired in size-/volume-reducing contaminated material from Y-12. The system should include containment and filtration, material feed and discharge, and remote manipulation interfaces provisions. A demonstration of the entire system should be completed to define and make necessary refinements to ensure adequate operation and maintainability.

Author: L. C. Hensley, Jr./615-574-1988

Reviewer: T. Barnes/615-675-3337

References: None.

ENGINEERED STORAGE FOR FUTURE DISPOSAL (PREDISPOSAL STAGING)

DISM-93-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, uranium processing facilities, and electrical switch gear facilities.

Problem Area/Constituents: Engineered storage—This technology applies to temporary storage of machinery, pumps, valves, tanks, pipes, etc., that are contaminated with mercury, lithium compounds, PCBs, and trace quantities of low-level uranium.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Waste Management

Alternative: Entombment

Technology: Predisposal staging

Status: Demonstrated. Engineered Storage is currently used for storage of various items activated by exposure to nuclear reactor shine. Current methods have been to design special container or enclosures for each individual item on a case by case basis. (B-25 Box, etc.)

Similar advanced technology is used in the nuclear weapons manufacturing facilities to ship components except the concept has been carried much further in that standardized and licensed shipping containers have been developed and specified. Therefore, when new items are shipped, previously designed shipping containers can be recalled and used, sometimes with minor modifications or as-is, to ship components within the DOE Complex.

This concept could be applied to many facilities at Y-12 and across the DOE complex. Standardized temporary storage containers could be reused as they become empty, making standard aiseways, stacking heights in the storage facility and standardize the handling fixtures.

Efficacy—High. This technology is certain to work and, if properly integrated into the overall system for the Complex. Large existing facilities, such as Building 9201-4, could be used as a long-term interim storage facility for items not acceptable to existing waste disposal sites until final disposition is defined, which would eliminate any new, temporary outside storage facilities.

ENGINEERED STORAGE FOR FUTURE DISPOSAL (PREDISPOSAL STAGING)

DISM-93-OY

Waste—The waste to be stored until disposal would be mercury on/in metal (steel, nickel) pipe, machinery, pumps, valves, tanks, etc.

Science/Technology Needs: No new science or technology is needed. Money could be saved if currently available containers could be used. Stainless steel, appropriate for long-term storage containers, could be smelted from available nickel, steel, and monel materials currently stored or laying in wait in the massive diffusion facilities.

Implementation Needs: Containers must be designed and approved as standard storage containers if existing containers can't be used. This effort would take approximately \$5M to engineer new containers and handling fixtures and set up appropriate demonstrations. Capital costs are \$100K for each new container style. Development cost is \$0.5M. Operating cost is \$200/yd³.

Author: L. C. Hensley/615-574-1988

Reviewer: T. Barnes/615-675-3337

References: L. E. Galyon, Tool Design Engineering Department, Oak Ridge Y-12 Plant, P.O. Box 2009, Building 9111, Oak Ridge, Tenn. 37831.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents:

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Predisposal staging

Technology: Using a hammermill that is capable of reducing a 3 ft² x 5 ft long steel-reinforced concrete block to small pieces (crushes concrete and shears reinforcing steel) fed over a shaker/screen to remove the smaller pieces of concrete. A magnet would remove the metal that would have all the concrete removed. The larger pieces of concrete could be used as is or refed to the hammermill for further reduction.

Status: Demonstration. This technology is not new but the exact application is not in use. Similar commercial applications can be visited.

Efficacy—High. The crushed concrete can be used as fill and possibly sold. The steel-reinforced bar can be used as fill or sold as scrap.

Waste—Can be sold or used as fill.

Science/Technology Needs: Technology exists and science development needs are none.

Implementation Needs: The exact component arrangement needs to be designed with similar commercial applications visited for evaluation.

Development and preparation costs of site are \$1M. Cost for capital equipment is \$1.5M, and operating cost is \$50/ft³.

Author: T. Barnes/615-675-3337

References:

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Predisposal staging

Technology: Glassification. Sealing: Involves a grinder, shredder, cutter, or accumulator linked to a machine which can bundle asbestos materials into a shape or size suitable for encapsulation of the asbestos with glass, thus alleviating the problem of suspended asbestos particles during shipping or disposal.

Glassification is accomplished by encasing a predetermined size of material in glass. The glass would be melted and asbestos fibers mixed in the glass; then the glass would be allowed to solidify. The size of the refuse can be linked to a machine which can reduce larger pieces of asbestos refuse, so that they can be run through the glassification process. Once the asbestos pieces have gone through the glassification stage, they can be handled easily for disposal. After glassification, the asbestos fibers would be encased and could virtually eliminate airborne particles of asbestos during shipping and storage.

Status: This technology is currently available. However, it has not been tested at Y-12. Cost payback: The elimination of bagging or wrapping, multiple handling, and man interface could save \$50M-\$100M during displacement operations. The system is potentially useful for encasing other hazardous materials such as PCBs, volatile organic compounds, etc. The operational cost for this technology has not been determined.

Efficacy—Technology has a very good chance of working but is in a basic conceptual stage and has not been demonstrated at Y-12. The glassified cubes would need some type of indentures for handling and stacking.

Waste—It is assumed that the cube would be 10% glass, 90% asbestos fibers, and would leave a limited amount of noncontaminated waste.

Science/Technology Needs: The need exists for feasibility and design engineering to interface a confined environment machine equipped with a vacuum recovery system to process large pieces of asbestos into workable configurations. A study will need to be done to determine whether this would create any new, unrecognized waste control or disposal problems.

Development of this technology and a cutter, shredder or grinder for demonstration would cost \$3.4M. Demonstration costs include building portable containment enclosures, personnel protection, clothing, and container storage but not transportation and burial charges.

Implementation Needs: The need exists to view videos available from other nuclear facilities and possibly to visit sites to evaluate recovery systems without on-site demonstrations. The need exists to determine what robotics have been developed using in-house seminars from vendors on the latest and future technologies. This technology is a high priority, because of the impact it will have on disposal savings. The time estimated for implementing this technology is 3-6 years. The cost of development is estimated to be \$3.4M.

Authors: R. L. Whaley/615-574-2271

References:

1. Vitrifix of North America, Alexandria, Virginia; 703-684-1090.

BAR CODE/LASER TOOLING LOCATION (ENABLING TECHNOLOGIES)

DISM-96-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Field assistance

Technology: Bar code/laser tooling location

Status: Demonstration. Technology exists to precisely locate tooling using a laser/bar code system. The Caterpillar Company has used this technology in warehouse/inventory systems to position stacker cranes to store and retrieve products in manufacturing facilities. The bar code can store site-specific operations and "next move" data. The stacker crane would contain the laser source and receiver. Bar codes are located on columns or other building features. This technology definitely may be applied in removing the operator from contaminated areas and is likely to work with very little "prove-in."

Efficacy—Low. Cost savings would depend on the degree of automation selected in the eventual philosophy of operation of the D&D effort. Full application of automatic positioning of tooling probably will not be justifiable. The optimum approach may be to conduct initial set-up with manual positioning for a dismantlement zone. The tooling then would reposition itself for the repetitive steps.

Waste—No waste will be generated by this technology.

Science/Technology Needs: No new science or technology needs have been identified.

**BAR CODE/LASER TOOLING LOCATION
(ENABLING TECHNOLOGIES)**

DISM-96-OY

Implementation Needs: A demonstration is needed. The demonstration must demonstrate the required instrumentation interfacing with the control computers and the interfacing with the robotics delivery platform and man-machine control area. Development costs are \$1.75M, capital costs are \$750K; and total costs are \$N/A.

Author: L. C. Hensley, Jr./615-674-1988

Reviewer: T. Barnes/615-675-3337

References: None.

ZONING FOR CONTAINMENT—THREE ZONES (ENABLING TECHNOLOGIES)

DISM-97-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Field assistance

Technology: Zoning for containment—three zones

Status: Accepted. At the Mound Laboratory Facility, a technique involving three zones—cold, buffer, and hot—is being used to isolate contamination. Temporary containment using stud partitions and .003-.005-mil plastic sheets to form a buffer area around equipment to be opened has been shown to prevent increasing contamination in the surrounding building when removing glove boxes. This technology will be necessary during dismantlement. It probably will allow a portion of the materials (slightly contaminated) removed to be treated as low-level waste.

Efficacy—High. Containment to prevent the spread of exposed contamination to less-contaminated areas has been demonstrated by ongoing D&D to be an effective cost reduction tool. Commercial suppliers are available that build standard sections of enclosures typically used to construct clean rooms and hoods. These same suppliers could be asked to supply panels that could be used and reused to enclose dismantlement activities within facilities. A portable air supply system would be used in conjunction with any temporary enclosure.

Waste—Low-level waste can be disposed at \$20/ft³. Material exceeding the limits for low-level waste cost approximately \$100/ft³ to dispose. Please note that recycling costs would be influenced in similar ways, but factors here are unknown. The spread of radiological contamination may prevent any practical recycling.

ZONING FOR CONTAINMENT—THREE ZONES (ENABLING TECHNOLOGIES)

DISM-97-OY

Science/Technology Needs: Lighter-weight materials such as honeycomb construction may make panels easier to handle and cheaper. Inflatable panels may be applicable.

Implementation Needs: A demonstration of how a temporary barrier would be constructed is needed. Bracing to allow proper negative pressures to be developed in the dismantlement zone need to be conceptually engineered. Optimization for standardization of panels needs to be engineered to allow reuse of panels in the next dismantlement zone. Designing for fire protection may be required. Flammable materials may be prohibited. Development costs are \$2.7M, capital costs are \$1.5M, total costs are not known.

Author: L. C. Hensley, Jr./615-574-1988

Reviewer: T. Barnes/615-675-3337

References: None.

LASER TRIANGULAR MAPPING OF FACILITIES (ENABLING TECHNOLOGIES)

DISM-98-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Field assistance

Technology: Laser triangular mapping of facilities. Triangulation mapping with laser scanning of equipment in contaminated areas will establish an as-built data base for the specific equipment immediately before decontamination and decommissioning (D&D). This technology can confirm or deny the true as-built status and allows decisions to be made real-time on the status of disassembly for the specific equipment in question. Once D&D has been approved, this technology has established an exact relative set of dimensions for the robotic or remote manipulations necessary to achieve the task at hand.

Status: Predemonstration. Laser scanning and distance mapping have been applied in many different disciplines. Actual integration into a computer three-dimensional (3-D) data base for remote manipulation is probably in the predevelopment stages at commercial enterprises.

Efficacy—Low. This technology allows the coordinates for remote or robotic manipulation of the D&D to occur without any hands-on measurements and, as such, eliminates the opportunity for worker exposure to hazards. The measurements are also extremely accurate and, in the appropriate integrated data base, can be used to verify the design intent before starting the D&D effort on any specific piece of equipment. This obviously gains several advantages for hands-on personnel doing D&D and running the potential to hazardous exposure as well as the speed of digital distance measurement and scanning. The instruments should scan and measure an entire designated area in approximately 30 min and relate these data to the design and graphics data base.

LASER TRIANGULAR MAPPING OF FACILITIES (ENABLING TECHNOLOGIES)

DISM-98-OY

In addition, the D&D effort can become extremely unwieldy if an unanticipated component or event takes occurs during the disassembly effort. The advantage of laser mapping and triangulation is that they anticipate these events before the existing structures are breached, avoiding the complications and potential occurrences that such an incident would beget.

Waste—No waste created.

Science Technology Needs: Specific, detailed software that integrates 3-D mapping into an existing data base for use in robotic or remote manipulation applications will be required. Manipulation of the data base and adjustment/calibration of the sensors in a real-time field mode of operation will be necessary to achieve success in this program.

Implementation Needs: A development effort between Energy Systems and commercial systems developers will be required. A resource of programmers, workstation computers, lasers, instrumentation and control coordinators, commercial firms, and best efforts contracts will be required to demonstrate this technology.

After a 1- to 2-year development effort with individuals skilled in robotics, mechanical design, electronics design, software design, and optics and optical mapping, sufficient expertise should be available to initiate a design and procurement specification for procurement of multiple units to accomplish the optimum methods of D&D using either remote or robotic methods. Development costs are \$3M, capital equipment costs are \$1.5M, and operating costs are \$150/hour.

Author: B. W. Van Hoy/615-574-9880

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Field assistance

Technology: Video mapping. The technology includes video (or photographic) imaging for configuration mapping, evaluation, and control.

Status: Demonstration. Video images can be an effective means of establishing configuration layouts for planning and executing work. Digitizing video (photographic) images for establishing baseline layouts and for computer-automated comparison of different positions with a baseline to characterize and establish equipment differences would facilitate planning and work direction. Comparison of multiple-digitized images to highlight differences and conversion of images to line drawings is a well-established, demonstrated set of technologies.

Efficacy—High. This technology allows a permanent set of images to be archived for later history of the site. Images are also easily inserted into existing desktop publishing software for comprehensive documentation in all-electronic format.

Digitized imaging is a proven technology and should be an important program tool, useful from project inception through completion. It also should be adaptable to facilitate dismantlement progress and to document completion. Cost for use would be small (<\$200K over the course of a dismantlement project).

Waste—This technology would not generate waste.

Science Technology Needs: Technology development needs include assembly of an imaging/computer system, software development, procedure development, and personnel training.

Implementation Needs: Following are resource requirements and development needs:

- Imaging, computer, and related hardware (approximately \$60K-\$80K);
- System integration and development (approximately \$200K-\$300K);
- Development personnel—image technologist, software specialist, project leader;
- System functional testing; and
- 8-12 months for development.

Following are deployment requirements:

- Procedure development and documentation (\$30K-\$50K);
- User training (\$10K-\$20K); and
- System replication cost, if more than one system (\$60K-\$80K).

Cost and schedule time were estimated by the contributor. Efficiency of the technology is based on a similar technology already demonstrated at the Oak Ridge National Laboratory. Development costs are \$1.5M, capital cost are \$1M, and operating costs are \$150/h.

Author: B. W. Van Hoy/615-574-9880

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

COMPUTER-BASED TRAINING SYSTEMS (ENABLING TECHNOLOGIES)

DISM-100-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Field assistance

Technology: Computer-based training systems. Field workers and equipment operators will have to be trained in the use of specialized methods or techniques to accomplish many remediation activities in potentially hazardous environments or in connection with safe handling of hazardous materials. Training programs for such activities are highly regulated and must be carefully documented in order to satisfy legal requirements. Developing and documenting training courses is a human-intensive activity requiring much time to organize, write, edit, modify, and publish. Visual presentations usually can convey information more effectively and in larger amounts than written or spoken word. Effective use of all three (video, printed text, spoken word) is most desirable. Computing technology can now support this at a reasonable cost and provides the important added benefit of enabling an entire multimedia presentation, test, and test results to be captured conveniently for review by managers and auditors. With a shift to greater use of videotape now possible, the time required to develop a course can be greatly compressed. Software is available to permit use of a wide variety of testing strategies, with all student responses recorded. These training systems can also be used to provide reference access to information so that critical procedures can be reviewed as many times as necessary by workers to assure that a high quality job will be done.

Status: Demonstration. A system for a Macintosh environment is available that permits developing courses in a short period of time. Comparable systems can be put together that run in various PC environments (DOS, Windows, Unix). Very sophisticated, yet cost effective training systems can be developed using the NextStep operating system and application developer's environment.

ENCLOSED UTILITY SYSTEMS (ENABLING TECHNOLOGIES)

DISM-101-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: Needed enabling technologies—This technology will address those areas where excavation needs to be minimized in known contaminated soil areas or to route a large number of underground utilities in a very small available area.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Field Assistance

Technology: Utility enclosure systems can be constructed in various sizes and shapes and of various materials. The systems can be constructed of corrugated metal pipe, steel pipe, precast reinforced concrete, or poured-in-place reinforced concrete. Precast reinforced concrete and poured-in-place reinforced concrete systems are the most commonly used. For security needs and to minimize maintenance costs of utility systems, the Y-12 Plant has in place a number of underground utility enclosure systems.

The utilization of underground utility enclosures systems will enhance the decontamination and decommissioning of Building 9201-4 building foundations and to minimize the generation of contaminated soils to treat or to store. The installation of underground utility enclosures will also reduce the long-term cost of maintaining those utility systems installed within the underground enclosures. Cost reduction will come about as a result of not having to excavate additional contaminated soils and the high cost of complying with OSHA regulations for trenching excavation and the accessibility to the utilities system for maintenance. The accessibility can be by removal of precast top panels or via personnel entry points. The poured-in-place reinforced concrete systems can be lighted and mechanically ventilated to ensure maintenance personnel safety in maintaining the utility system installed in the utility enclosures.

Status: Accepted; this technology is currently available and proven. The efficiency of this technology is high. Numerous underground utility enclosures have been constructed in different sizes, configurations, and soil conditions. Costs vary greatly depending on the soil types, rock presence, the depth of the installation of the utility enclosures, and the types and numbers of utility lines to be installed with the utility enclosures. A precast concrete utility

ENCLOSED UTILITY SYSTEMS (ENABLING TECHNOLOGIES)

DISM-101-OY

tunnel—8 ft wide, 10 ft high, and installed 14 ft in the ground with the installation of the project utility needs on the north side of Building 9204-1 at the Y-12 Plant—will run approximately \$11,000 per lineal foot. There are no development costs, and operating costs are \$11K/lineal ft.

Science/Technology Needs: None required.

Implementation Needs: An economically feasible design to minimize the contaminated soils to be excavated and to enhance the installation of the proposed utilities for the underground utility enclosure.

Author: Clarke E. Hamilton/615-574-9653. Reviewed by: T. Barnes 615/675-3337

References: Personal communication with Frank R. Trent of the engineering estimating group of Martin Marietta Energy Systems. 615-576-7959

POINT-AND-DIRECT TOOLING POSITIONING (ENABLING TECHNOLOGIES)

DISM-102-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Point-and-direct tooling positioning. A semiautomated approach to directing the cutting, disassembly, and removal of equipment or materials. This approach would use an operator with a light wand to identify work paths for optically guided tools.

Status: Evolving technology (conceptual). The concept is in the preproof-of-principle state but relies on off-the-shelf components to implement. Thus, minimal development will be needed. This technology should be a good compromise where full automation or robotics are impractical or not achievable.

Efficacy—High. Effective means to reduce worker exposure without teleoperated or fully automated equipment, low cost, and easily adapted to multiple uses.

Waste—None.

Cost—Minimal (estimated to be less than \$50K/unit).

Science/Technology Needs: Develop prototype and demonstrate efficacy. Requires integration of hardware and minimal software development. Development is estimated to take about 2 years and cost \$500K.

Implementation Needs: A prototype system should be field tested to evaluate and identify deployment needs. Testing could be done in conjunction with field demonstration of one of the dismantlement or decontamination technologies. Testing is estimated to cost about \$500K; implementation of a vendor-supplied unit is estimated to take about 3 years and cost

POINT-AND-DIRECT TOOLING POSITIONING (ENABLING TECHNOLOGIES)

DISM-102-OY

approximately \$50K/unit (10 units). Development and testing costs are \$1.5M; capital costs are \$500K; and operating costs are \$100/h.

Author: L. C. Hensley, W. S. Key/615-576-0278

Reviewer: T. Barnes/615-675-3337

References:

1. D. Farson, "Presentation of Point-and-Direct Robotic Welding," Penn State Applied Research Laboratory, April 15, 1992.
2. Farson, D. F., Penn State Applied Research Laboratory, personal communication, August, 1992.

COMPUTER-BASED D&D INFORMATION RETRIEVAL SYSTEM (ENABLING TECHNOLOGIES)

DISM-103-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Computer-based D&D information retrieval system. This technology involves fiber-optic, high-speed networks with corresponding servers.

Status: Demonstration. Fiber Distributed Data Interface (FDDI) networks are the primary nominees for this purpose.

A central data base and an information retrieval system design with a "one area" location for all information has been planned for the D&D Program. This data base will contain more graphics and visual information than has ever been planned before within Energy Systems. Data transmission rates and information data base size will require proper planning in design of the servers that access the data base and the networking transmission media to make the information accessible quickly.

It is intended that the data base will be accessible to all program participants that require any D&D information. Everything from schedules and budgets to design-intent drawings, actual as-existing photographs, laser-mapping, three-dimensional (3-D) data, final disposition of equipment, and detailed procedures customized for every piece of equipment on the D&D list will be in the integrated data base.

Planning and implementation of this capability is a part of the systems approach necessary for the entire data base function to approach a reasonable performance level. By addressing these requirements now, implementation of a Total Quality Management approach will be better integrated into the entire program.

COMPUTER-BASED D&D INFORMATION RETRIEVAL SYSTEM (ENABLING TECHNOLOGIES)

DISM-103-OY

Efficacy—Medium. The performance of the entire data base system relies as heavily on the performance of the networking hardware and software (and its capacity) as it does on the design of the data base and the query structure chosen.

An FDDI network exists within Energy Systems and is being evaluated through the Mathematics and Physics Group and the Computing and Telecommunications Division. Initially, application of this technology only requires customization to meet the exact distribution requirements of the D&D Program.

The ability to access this information, to automatically produce a customized procedure or specification by merely inserting text and pointers in the data base and having the information produced as hard copy or as mail and distributed with the inherent tracking systems to manage comments, etc., will require a massive amount of storage and server computational input/output capability.

Waste—No waste produced with this technology.

Science Technology Needs: Specific programs, and technology development and improvement are needed.

Implementation Needs: Cost of proof-of-principle, amount of resources, equipment, hardware, software, facility, and educational needs exist. Reference requirements are needed to deploy the technology successfully. Network costs are \$1.6M; with 100 terminals @ \$1K, each the cost is \$100K. Capital costs are \$1.3M, and operating costs are \$150/h.

Author: B. W. Van Hoy/615-574-9880

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

GIF IMAGES TO ENHANCE AS-BUILT DOCUMENTATION (ENABLING TECHNOLOGIES)

DISM-104-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Graphics Interchange Format (GIF) images to enhance as-built documentation. Specific technology exists in the image analysis and desktop publishing disciplines. The technology needs to be integrated into the design and as-built data base requirements for its benefits to be realized. This task can be integrated with video mapping for best use of the technology.

Status: Predemonstration. The concept is to take electronic images from digital cameras and camcorders as well as scanned images of common photographs and to enter them into the computer. These images will be converted to GIF format for storage and viewing and will use graphics programs for contrast enhancement to obtain scale measurements and to allow design personnel to evolve designs around complicated assemblies without having to routinely travel back to the contaminated site for observation. This will result in a large quality and time benefit.

Efficacy—High. Commercial products literally are being introduced every day. In addition, Instrumentation and Controls at the Oak Ridge National Laboratory currently is doing many image storage and compression techniques for the Bureau of Engraving and Printing and the Federal Bureau of Investigation which yield a 10:1 factor of file size with no discernable degradation in image quality. This type of industry-standard graphics manipulation to perform the job, state-of-the-art file compression to keep the data base size manageable, and consideration of the response time of the computer network should allow the system to serve the entire program with an all-electronic graphics library of the design work and visual verification of the design.

GIF IMAGES TO ENHANCE AS-BUILT DOCUMENTATION (ENABLING TECHNOLOGIES)

DISM-104-OY

Waste—No waste created.

Science Technology Needs: Some technology development needs exist. Most of these stem from a systems integration set of requirements. Selection of the most advantageous suite of hardware and software that allow ease of use, high accuracy and definition, and the ability to select and view these images and display them in publications are the kind of needs that should be addressed in a prototype system before initiation of a program-wide set of GIF image specifications.

Implementation Needs: Presently, these are vague. This technology is one of the fastest evolving in the computer industry. A development effort between Energy Systems and commercial systems developers will be required. A resource of programmers, workstation computers, lasers, instrumentation and control coordinators, commercial firms, and best efforts contracts will be required to demonstrate this technology.

After a 1- to 2-year development effort with individuals skilled in robotics, mechanical design, electronics design, and software design, sufficient expertise should be available to initiate a design and procurement specification for procurement of multiple units to accomplish the optimum methods of D&D using either remote or robotic methods. Development costs are \$2.15M, capital costs are \$1M, total costs are \$3.15M, and operating costs are \$150/h.

Author: B.W. Van Hoy/615-574-9880

Reviewer: T. Barnes/615-675-3337

References:

1. Martin Marietta Energy Systems, Inc., staff members.

PROJECT INFORMATION ACCESS SERVICES (ENABLING TECHNOLOGIES)

DISM-105-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Project information access services. Project investigators, managers, and technicians will all need access to administrative information such as written procedures, regulatory guidance, project schedules, technical standards, tracking status, and accounting information. Access to these kinds of information should be possible from desktop computers connected to plant-wide computer networks using software with display screen designs and use of menus so that most information on the system can be obtained without a user having to consult a manual.

Status: Demonstration. An integrated project information access and management system is sufficiently different from current types of electronic information access support within DOE facilities as to warrant requiring a demonstration before deciding to proceed with implementation.

Efficacy—High. Such widely available services are expected to have a large impact in greatly reducing the time and costs required to obtain or transfer information. Use of associated project management analysis tools should greatly improve reliability of all related activities. Electronic information transfer would replace paper movement through the plant mail system reducing transfer times from several days to several minutes. Complex adjustments to project schedules could be made on a daily basis rather than weekly, monthly, or quarterly once the required data bases and analysis tools are in operation.

Waste—No waste created by this technology.

PROJECT INFORMATION ACCESS SERVICES (ENABLING TECHNOLOGIES)

DISM-105-OY

Science/Technology Needs: Technology to implement such a system is commercially available and is found typically in financial-service companies and some large corporations. This type of technology needs to be demonstrated in the context of the types of activities found currently within the major DOE facilities with regard to identifying how best and how extensively to use it. Technology development needs exist primarily in the areas of having adequate on-line information data bases, on-line help systems, and a good visual user interface.

Implementation Needs: Computer networks, especially Ethernet (cable, fiber), need to be extended throughout the Laboratory and other Energy Systems facilities to provide a basic foundation for information sharing among computers on local area networks. User (display) interfaces will likely have to be developed to permit effective and wide-spread use of the access services. Project information access services support needs are different from data access services. The former must be useful regardless of technical discipline, measurement type or data analysis technology used; the latter can require very specialized computer applications to support a particular activity. Use of a common computer platform (esp. for high-performance workstations connected to the local area network) for both types of services should not be precluded, though. Development costs are \$1.5M, capital costs are \$1.3M, and operating costs are \$150/h.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References:

1. Database Access Integrated Services: Design and Application, EPRI RP 2949-5, Version 0.6, May 8, 1991.

NETWORK ARCHITECTURE WITH INTEGRATED WORKSTATIONS (ENABLING TECHNOLOGIES)

DISM-106-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Network architecture with integrated workstations. Network access to other computer systems of all types from a personal desktop computer permits rapid, convenient transfer of data and project information. The availability of powerful engineering workstations at reasonable cost now permits integration of quite different kinds of activities by a single user. Multitasking capabilities permit a user to switch back and forth between very different applications running in different windows and to move large blocks of information between these different applications quickly and easily. These systems permit sharing files, output devices (e.g., laser printers), and expensive hardware, such as specialized information storage systems, across a network.

Status: Demonstration. Commercial engineering workstations provide the capabilities to support this technology. These capabilities are migrating to the newer PCs, so are expected to be more available in the near future. Knowledge of the means to integrate a variety of different activities on a common platform is still not widespread, so what is now possible needs to be demonstrated. Otherwise, desktop system capabilities will be enhanced in a piecemeal fashion in which the pieces do not work well together, if at all.

Efficacy—Medium. This technology will work very well. Integration of workstation applications with network resources and with each other is like acquiring a powerful tool for people trained to make use of it. The amount of training required will vary considerably, depending on how well the user interface is designed. It is currently possible to develop or purchase user interfaces that minimize initial training requirements and almost eliminate the need to refer to a user's manual in order to make effective use of a new application.

NETWORK ARCHITECTURE WITH INTEGRATED WORKSTATIONS (ENABLING TECHNOLOGIES)

DISM-106-OY

Waste—No waste created by this technology.

Science/Technology Needs: The greatest obstacle to use of this technology is the current legacy of older operating systems (DOS, MacOS) not designed to support integration of desktop applications with each other and with network services.

Implementation Needs: This technology is best introduced in the context of a commitment to use open system standards for all new computer acquisitions, i.e., the POSIX suite of standards, use of TCP/IP for communications, and selection (and publication) of standards for all graphical user interfaces. The cost of two person years for development is \$500K–\$1.5M. Network costs are \$1M; with 100 terminals @ \$100K, the total cost is \$1.1M. Operating costs are N/A.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: IEEE 1003.1 Standard for Information Technology—Portable Operating System Interfaces (POSIX) - Part 1: System API Extensions (C Language).

(Note: This standard is the first of a suite of related standards covering all aspects of modern computer operating systems, application development, and application execution environment).

**CLIENT/SERVER ACCESS TO STANDARDS
AND REGULATORY GUIDELINES
(ENABLING TECHNOLOGIES)**

DISM-107-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Client/server access to standards and regulatory guidelines. Use of high-speed networks, high-performance workstations, and CD-ROM technology now permits fast, convenient access to very large text data bases such as standards and regulations that govern environmental remediation and waste management activities. The client/server architecture is very well suited to the implementation requirements for such a combination.

Status: Demonstration. Component technologies are well-established, commercially available, and affordable. They have not yet been integrated for use in a client/server environment. A stand-alone desktop system and a mainframe system are the current platforms on which standards are available in electronic form. A software product is needed that provides access across networks using only TCP/IP communications protocols.

Efficacy—Medium. Client/server technology appears to work well for similar uses for which it has been implemented, such as the U.S. House of Representatives Information System.

Waste—No waste created.

Cost—The technology base can be acquired at a reasonable cost: \$5K for a desktop system attached to a local area network and \$50K–\$100K for a server to manage access to the CD-ROM.

Science/Technology Needs: Technology development needs are greatest in the area of developing or acquiring a good common user interface to support integration of the

**CLIENT/SERVER ACCESS TO STANDARDS
AND REGULATORY GUIDELINES
(ENABLING TECHNOLOGIES)**

DISM-107-OY

component technologies, especially to provide access to the CD-ROM server with an application based on TCP/IP protocols for processing data base queries, returning query results, and managing data base access permissions.

Implementation Needs: No commercial software applications currently exist to provide client/server access to standards, codes, and regulatory guidelines on CD-ROM data bases, across networks, using only TCP/IP protocols. Such an open systems product is needed very much to support greater acceptance and use of standards. The costs of doing business in a highly regulated environment are currently much higher than they need to be due to the very inefficient ways now used to provide access to the regulatory documents. Quality of operations also suffers when information needed to do high quality work is not readily accessible. Development costs are 2 person years @ \$0.55M, capital costs are \$200K, and operating costs are \$100/h.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: Personal communication with Martin Marietta Energy Systems, Inc., staff.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Data access services. All aspects of environmental restoration activities will require access to and use of many kinds of data. Some data will be gathered into large centralized collections, but much will be scattered about in data bases on many different computers. These computers need to be linked to networks to provide physical access to the data. Application software will be needed to support network communications, data base management, directory and dictionary services for locating needed data or information, and standard ways to request, transfer, and use it effectively. For satisfactory access over networks, requirements must be developed for an integrated system architecture that addresses what services are needed, what mechanisms must be used to support them, and what functions must be covered by the services. These requirements must then be followed when specifying what commercial products must be acquired and what application software must be developed.

Status: Demonstration. Most of the pieces of the technology already exist. All the necessary technical capabilities exist. The particular network and communications configurations needed to support restoration activities may not exist and would have to be set up and successfully demonstrated.

Efficacy—Low. Data access services will be essential to availability and use of large amounts of data or timely access to data stored in remote data bases. They will probably be essential for many projects in minimizing life cycle costs and meeting schedules.

Waste—No waste created by this technology.

Science/Technology Needs: Software will be needed to support effective, convenient user access through a common set of services, regardless of the communication protocols and network architecture used. Some software will be available commercially; some will have to be developed locally.

Implementation Needs: Requirements and specifications for such services must be identified and documented to serve as a common reference so that data can be accessed using a single set of services regardless of the type of computer at each node on the network. An adequate technology base exists for implementation, but must be integrated to accomplish the particular objectives of the Environmental Restoration effort. Integration requires a conceptual framework expressed in terms of access architecture requirements. Development costs are \$.6M, total capital costs are \$450K, and operating costs are \$100/h.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References:

1. Database Access Integrated Services: Design and Application, EPRI RP 2949-5, Version 0.6, Electric Power Research Institute, Palo Alto, California, May 8, 1991.

**AUTOMATED SCANNING AND CONVERSION
OF ENGINEERING DRAWINGS
(ENABLING TECHNOLOGIES)**

DISM-109-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Automated scanning and conversion of engineering drawings. Many engineering drawings of existing buildings, equipment installed in buildings, aboveground containment structures, pits, burial trenches, and other containment systems will need to be consulted for a wide range of restoration activities. Existing drawings are distributed among many parts of the organization at each site. Conversion to electronic form would permit more effective management, access, and distribution of drawings. In terms of providing access to information, the ability simply to view a scanned image may often be adequate, in which case conversion to a form for easy editing or modification may not be necessary. With this information available in electronic form, incorporation into data bases will also be feasible.

Status: Demonstration. This technology has existed in some form for more than a decade. What must be demonstrated is whether the current state of the technology is appropriate for meeting the needs of the various environmental restoration projects to be done. How this technology might best be integrated with geographical information systems also must be demonstrated, as these need to be combined to provide the best type of support for all the configuration management activities which will have to be established.

Efficacy—High. Storage of engineering drawings in electronic form will simplify and speed up access to and distribution of this information. When used in an appropriate computing environment, electronic access to these drawings should also improve the reliability of operations dependent on the information contained in the drawings.

**AUTOMATED SCANNING AND CONVERSION
OF ENGINEERING DRAWINGS
(ENABLING TECHNOLOGIES)**

DISM-109-OY

Waste—No waste created by this technology.

Science/Technology Needs: Areas needing improvement include increasing the speed and accuracy of converting scanned images to other types of graphical representations. A vector representation is of particular use, for example, because it permits scaling the size of a drawing to look at fine detail when that is needed.

Implementation Needs: Much of the scanning and conversion process must be done manually. Drawings on large sheets of paper must be processed manually because of difficulties in working with the paper medium. The machinery to process stacks of large sheets of paper takes up a large amount of space and is expensive. Interpretation of scanned images also requires considerable levels of human intervention.

Development costs for three person years are \$.9M; the costs of two workstations and two scanners, with software and licenses is \$60K; the cost of two file servers with very large data storage capacities is \$300K; the total cost is \$360K; and operating cost is \$200/h.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: Personal communication with Martin Marietta Energy Systems, Inc., staff.

3-D CAD DATA BASE OF BUILDINGS AND STRUCTURES (ENABLING TECHNOLOGIES)

DISM-110-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: 3-D CAD data base of buildings and structures. Data bases with three-dimensional representations of buildings and other engineered structures are needed to help with tracking and monitoring associated with a range of environmental restoration activities such as sample collection and analysis, dismantlement, decontamination, and development of procedures needed to carry out various operations. These data bases are needed for use as a basis for tagging systems in which all information relating to sampling or measurement at a particular location (i.e., spot on a floor or wall) can be linked electronically to the data base for the affected structure. Information in such a data base can be used by visualization software to make simulated visual inspections of structures. Combined with tagging information, such simulated inspections could assist to remind project managers visually (reliably) of cleanup tasks still to be performed. Graphical renderings of structures could also be used to provide visual input to maneuverable robots needed for work in hazardous areas. Robotic procedures could thus be developed in a simulated environment, tested extensively (e.g., collision avoidance), and validated before committing expensive equipment to the actual set of tasks to be performed.

Status: Accepted. The basic technology is in wide use. A variety of commercial products is available for use on systems ranging from desktop computers to large mainframes.

Efficacy—High. This technology can have a broad impact on cleanup activities because so many other technologies can be very usefully tied to it and make extensive use of it. It should be classified as an essential technology because of the potential for reducing costs by virtue of cutting across so many aspects of any large-scale cleanup effort.

3-D CAD DATA BASE OF BUILDINGS AND STRUCTURES (ENABLING TECHNOLOGIES)

DISM-110-OY

Waste—No waste created by this technology.

Science/Technology Needs: Technology needs are expected to be greatest in the areas of what is needed to integrate this technology with those others that can benefit very well from it.

Implementation Needs: Integration of this technology with "end users" of the data will require early planning efforts to maximize the value of this technology to cleanup efforts. Data bases for 3-D structures require a large initial effort to capture and enter the data. Care will be needed to select those commercial products that will best support the anticipated end uses of the data (e.g., visualization for "walk-throughs" and "training" maneuverable robots, tagging system to aid with tracking operations). Three year development costs are \$2M, capital equipment costs are \$1.5M, total costs are \$3.5M, and operating costs are \$150/h.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: Personal communication with Martin Marietta Energy Systems, Inc., staff.

CLIENT/SERVER ARCHITECTURE FOR DATA BASE ACCESS (ENABLING TECHNOLOGIES)

DISM-111-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Client/server architecture for data base access. Use of a client/server architecture for data base access is a very effective, flexible approach to use when a variety of different kinds of computers are connected together by a local area network. Successful use of this architecture requires that certain types of standards be followed, such as network communications protocols (e.g., TCP/IP, Ethernet), hardware used for transmitting data (e.g., thin-wire for Ethernet, FDDI, broadband), data file formats (e.g., PostScript, Rich Text Format, ASCII, TIFF), and a data query language (e.g., SQL).

Status: Demonstration. The underlying technology needed exists. Installing cables needed to transmit data can be a very big expense, but already exists in many DOE sites. The effectiveness and appropriateness of a particular architecture design to meet the requirements of the restoration activities needs to be demonstrated.

Efficacy—Medium. This technology should be a very effective way to provide access to data bases implemented in a variety of different computing environments using a variety of different kinds of management system software. A big advantage of the client/server architecture is the ability to accommodate existing data bases as well as new ones.

Waste—No waste created by this technology.

Science/Technology Needs: Use of this technology will benefit from most improvements made in network technology. It will also benefit from improvements to query capabilities and development of natural language processing tools.

CLIENT/SERVER ARCHITECTURE FOR DATA BASE ACCESS (ENABLING TECHNOLOGIES)

DISM-111-OY

Implementation Needs: Implementation success will depend heavily on how the data bases to be accessed are defined and described to potential users on networked host computers (i.e., the data about the data bases). Data dictionaries and directories will have to be defined, developed, and documented in a way to provide efficient, fast, reliable access to the data bases "published" for network users to use. Interfaces to existing data bases in many instances will have to be developed. Many interfaces to commercial data base products in wide use already exist. Development costs for two man years is \$1.75M, capital equipment costs are \$1.3M, and operating costs are \$150/h.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: Personal communication with Martin Marietta Energy Systems, Inc., staff.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Hypertext information systems. New, more effective techniques or approaches are needed to process and appropriately use the growing volume of regulatory compliance requirements and technical standards which must be linked to the data and information needed for project planning and management, especially for environmental restoration related activities. The complexity of the interconnections has reached the stage at which traditional ways of using tables, diagrams, and linear presentation of text material are cumbersome and time consuming to prepare, to use, and to maintain. Hypertext provides a different way to organize and obtain quick access to pieces of information related by a complex web of logical associations.

Status: Demonstration. Computing technology exists to support a number of very useful hypertext applications. Much room for new applications, new ways to organize and provide access to information, and enhance currently available applications exists.

Efficacy—High. Use of hypertext technology to provide access to information can be very effective and very powerful.

Waste—No waste created by this technology.

Science/Technology Needs: Authoring and design tools are needed.

Implementation Needs: Hypertext information systems must be designed with great care if the information in them is changing rapidly and must be modified frequently to be useful. For purposes of designing and implementing hypertext systems, the development process

would be very similar to what must be done to develop expert systems. Maintenance can be time consuming. Such systems are most useful for providing access to material that is stable. In these cases efforts to make the best use of complex information organization structures and cross-links can pay off handsomely. Development costs are \$0.6M, capital costs are \$400K, and operating costs are \$200/h.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

Reference: Personal communication with Martin Marietta Energy Systems, Inc., staff.

**ELECTRONIC CATALOG DESCRIPTIONS AND
SOURCE LOCATIONS OF SITE HISTORICAL DATA
(ENABLING TECHNOLOGIES)**

DISM-113-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Electronic catalog descriptions and source locations of site historical data. A large amount of historical data exists for each DOE site that may be of significant help to restoration efforts. Some sort of electronic access to this data needs to be provided. Scanning and converting the original documents to electronic formats for storage may not be feasible. Lists of document titles also may not be adequate. An inventory data base of what is available, where it is located, who maintains it, and what the classification status is needs to be made as a first step. This information for a particular site needs to be accessible to those involved with cleanup activities at that site.

Status: Accepted. Standard data base products can be used to create and maintain the inventory data base. If wide access to particular documents is needed, they can be scanned and processed for electronic storage and subsequent retrieval across computer networks.

Efficacy—High. The importance of this technology will be highly variable and will depend on the problems that exist at a particular site. Usefulness of documents will also vary according to how well the authors recorded the kind of information needed to support later restoration activities.

Waste—No waste created by this technology.

Science/Technology Needs: Methods will be needed to evaluate and sort historical records according to their likely usefulness.

**ELECTRONIC CATALOG DESCRIPTIONS AND
SOURCE LOCATIONS OF SITE HISTORICAL DATA
(ENABLING TECHNOLOGIES)**

DISM-113-OY

Implementation Needs: Initial implementation efforts must focus on locating the collections of records and documents of historical value. Two top-end personal computers with software cost \$15K, the data collection and entry system (3 person years) cost \$375K, total cost is \$390K, and operating costs are \$150/h.

Author: John K. Munro/615-574-0635

Reviewer: T. Barnes/615-675-3337

References: Personal communication with Martin Marietta Energy Systems, Inc., staff.

**SIMULATED WALK-THROUGH FACILITY FOR ROBOTICS
TASK SEQUENCE ANALYSIS
(ENABLING TECHNOLOGIES)**

DISM-114-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Simulated walk-through facility for robotics task sequence analysis. A three-dimensional solids modelling capability is needed to assist with many aspects of robotics task sequence analysis, planning, and execution. A simulated walk-through facility is needed to assist with identifying situations in which collisions might occur between robot appendages and nearby stationary objects. Such analyses are needed whether a human operator is present or not, especially if the robot is to be used in an environment hazardous to humans, situations in which reliable operation is essential.

Status: Demonstration. The IGRIP applications software running on a Silicon Graphics workstation is capable of identifying situations in which collisions will occur. It can also use human factors and ergonomics data to indicate which tasks requiring human assistance are or are not possible or safe for a human operator to perform.

Efficacy—Medium. Limits of humans (strength, range of motion, agility) and machinery must be identified and understood in planning for work in hazardous situations in which reliable completion of a task is imperative. Solids modelling and visualization technology should be very valuable tools for planning operations that must be conducted in a hostile or harsh environment.

Waste—No waste created by this technology.

Science/Technology Needs: Standard data bases exist covering many types of industrial and process operations in which a human operator is required to assist with positioning

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(lifting, sliding, rotating) objects, some of which action may require having to reach or execute a complex sequence of motions. Minimum limits on volume of space in which many common operations must be performed are also available to assist in laying out dimensions for a work area. For some of the specialized operations associated with restoration at nuclear facilities, existing data bases related to the work space of the human operator may need to be extended. Parts of these data bases that pertain to the robotic equipment may have to be developed from the beginning in their entirety, especially if the robotics equipment used is unique to the task to be performed.

Implementation Needs: All basic computer components (hardware and software) needed should be available commercially. A certain amount of system integration may be necessary. The greatest part of the work to be done to apply this technology will be the human effort needed to acquire the basic data, organize, assemble, and store it. Development costs are \$.55M, capital costs are \$350K, operating costs are \$100/h, and implementation takes 3 years.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: Personal communication with Martin Marietta Energy Systems, Inc., staff.

COMPUTER-AIDED TASK ANALYSIS AND PROCEDURE PREPARATION (ENABLING TECHNOLOGIES)

DISM-115-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Computer-aided task analysis and procedure preparation. Complex tasks which must be planned and executed in a highly regulated environment can become very difficult to organize and schedule. Possible alternatives can become very difficult to identify. Optimization of activities may not even be possible using traditional manual analysis methods. Computer-based tools will be essential to providing timely and reliable analyses, to identifying logical inconsistencies that may exist in the applicable regulations, and to be able to consider alternative solutions. Computer-aided task analyses should be considered in cases in which safety of personnel is critical and in which assumptions made need to be identified and well-understood to avoid unintended consequences.

Status: Demonstration. This technology is used extensively in planning by various federal agencies, most notably the Department of Defense in military operations planning.

Efficacy—Medium. Demonstrations are needed to determine those areas and situations in which this technology would be most useful. It is very important to use this technology judiciously so as not to waste time and personnel resources.

Use of this technology should be considered when the people involved in task planning and execution find themselves having to keep track of too many details or having to make quick decisions when not adequately familiar with all the applicable regulatory requirements.

Waste—No waste created by this technology.

**COMPUTER-AIDED TASK ANALYSIS AND PROCEDURE
PREPARATION (ENABLING TECHNOLOGIES)**

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Science/Technology Needs: Improvement is probably needed most in capabilities for processing natural language.

Implementation Needs: The greatest implementation efforts will lie in the area of assembling and maintaining the knowledge base needed to support this technology. Many decision aids include some form of an expert system. Knowledge bases used by these expert systems require time to build, verify, and validate. Development costs for two person years are \$125K-\$250K, two workstations cost \$30K, software and licenses cost \$20K, total costs are \$50K, and operating costs are \$50K.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: Personal communication with Martin Marietta Energy Systems, Inc., staff.

GENERALIZED OBJECT-ORIENTED SIMULATION SOFTWARE (ENABLING TECHNOLOGIES)

DISM-116-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Generalized object-oriented simulation software. Interest in the use of object-oriented design and programming continues to grow because of a number of advantages offered by this approach. These include (1) ease of reusing modules of code that already exist, (2) more reliable operation of applications, (3) more rapid development times, and (4) access to powerful aids for building and modifying user interfaces. A library of modules currently exists for use in simulations of commercial nuclear power plant operations and studies of major power plant subsystems.

Status: Demonstration. The simulation environment is being used currently in ongoing studies associated with several different nuclear reactor design concepts. Modules would have to be written to model other types of systems. If graphical interfaces for displays are needed, these would also have to be provided.

Efficacy—Medium. The advantages of extending the existing library of modules to cover other application areas would be in the ease of reuse (provided by the inheritance property), shorter development times that are possible, and enhanced reliability (from use of information hiding principle) provided by the object-oriented design approach.

Waste—No waste created by this technology.

Science/Technology Needs: An adequate hardware and software product base (compilers, operating systems, development tools) exists for developing the models and algorithms needed in areas for which none yet exist. Graphical (iconic) representations must be prepared which can be linked together in a diagram using graphic design tools to provide a visual description

GENERALIZED OBJECT-ORIENTED SIMULATION SOFTWARE (ENABLING TECHNOLOGIES)

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of a system and the functions it performs. These graphical representations may be animated by the way they are linked to the models (i.e., driven by the results of simulation calculations) by use of changing color or size, digital readout, dials, or motion.

Implementation Needs: Satisfactory implementation depends on finding programmers who understand object-oriented design principles and how to apply them. The object-oriented design approach is currently very popular among programmers, but not generally well understood. Much of the implementation effort will be consumed by the user interface and design of graphical displays.

Development costs for 4 person-years for software design @ \$125K are \$500K, two workstations with software @ \$75K are \$150K, total costs are \$650K, and operating cost is \$150/h.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: None.

AUTOMATED ENGINEERING SYSTEM LIFE CYCLE PLANNING (ENABLING TECHNOLOGIES)

DISM-117-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Automated engineering system life cycle planning. Many aspects of system life cycle planning are common to a range of engineering disciplines, such as dividing a development or construction process into a sequence of well-defined phases. Each phase is terminated with some sort of review or test series to verify that the activities for that phase were completed correctly. Projects requiring the participation of many people from a number of different organizations can be difficult to manage reliably without assistance provided by computerized data bases and scheduling tools.

Status: Accepted. A variety of commercial products have been developed to assist with managing large software development processes.

Efficacy—Medium. Most of these products can be adapted for effective use in other engineering disciplines. Automated support helps to assure (enforce) consistency in design and aids in tracking status of project tasks.

Since many kinds of data bases will be used, capabilities for data evaluation, rapid information entry or transfer, and well-designed displays will be important, software to help with these support activities needs to be considered. Humans should not have to spend hours looking through hundreds of pages of the same text over and over to do a job when the search can be automated and accomplished in minutes or less and done much more reliably.

Waste—No waste created by this technology.

AUTOMATED ENGINEERING SYSTEM LIFE CYCLE PLANNING (ENABLING TECHNOLOGIES)

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Science/Technology Needs: Improvements needed will most likely be determined by requirements unique to the types of problems that exist at the various DOE sites, such as capabilities for doing certain types of risk assessments (hazardous chemicals and radioactive contamination), results from which must be taken into account in planning and execution of tasks.

Implementation Needs: Automated tools to assist with data base operations need to be identified and their impact evaluated. Just because a particular capability for a product is listed in the product description should be regarded with skepticism. How capabilities are implemented, how they affect performance, and how they must be used must all be evaluated. Good bargains on initial purchases can quickly and easily be lost by a user having to work around poor design features. Sometimes decisions need to be made to delay acquisition of a particular kind of aid. In the two years required for implementation, the operating costs are \$150/h, development costs are \$.4M, and the capital cost for two workstations with software is \$50K.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: Personal communication with Martin Marietta Energy Systems, Inc., staff.

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Automated system reliability and safety analysis. Much of the work in conducting system reliability and safety analyses involves the use of rules and logic to trace through paths in a tree structure of data collected about a system or its design. Rules used originate from many sources: project goals, system requirements, regulatory guidelines, professional society standards, and good engineering practice. With large, technically complex projects in a highly regulated environment, conflicts can arise. Such conflicts are more likely when safety and high reliability are primary concerns. The data bases and logical analysis tools needed in these cases are not used once or twice, but many times. They need to be offered as part of the package of deliverables in many cases to assist with proper ongoing maintenance after a product is in use.

Status: Accepted/Demonstration. Tools for some types of analyses are in common use. Many of these have been incorporated into engineering development environments for things like software, aircraft, communications satellites, and medical diagnostic equipment. Tools exist to assist with common mode failure analyses or for failure modes and effects studies, methods pioneered by the nuclear industry. In some cases, tools developed for other uses (e.g., smart use of the query capabilities of some data base products) can be adapted to assist with some types of logical analysis.

Efficacy—Medium. Computers are capable of analyzing for logical completeness and consistency far faster and more reliably than humans. Data bases for rules, system functions, control flow, information flow, etc., must be subjected to thorough verification and validation, just as for digital control system software.

AUTOMATED SYSTEM RELIABILITY AND SAFETY ANALYSIS (ENABLING TECHNOLOGIES)

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Science/Technology Needs: Activities described here require much mental effort. Not many tools exist to provide powerful ways to analyze problems at a conceptual level. This is a support technology area deserving more attention.

Implementation Needs: The results of applying the rules to the data will only be as good as the care taken to assemble and test them, then to apply them. When commercial products are purchased that were developed with the use of automated support for reliability and safety analyses, consideration needs to be given to requiring delivery of these development aids as necessary tools for ongoing maintenance and modifications. Development cost is \$500K, operating costs are \$150/h, and the capital cost of two workstations with software is \$50K.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References:

1. Refer to the NRC Handbook on the subject(s).

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Engineering assistance

Technology: Geographic information systems for DOE sites. At least two levels of geographic information will be needed: (1) site land area enclosed by property lines together with strips of land along and just outside property lines, and (2) spatial layouts and floor plans of engineered structures. Attention must be given to general surveys and locations of structures at the site land area level for tracking the distribution and migration of hazardous materials in the environment. Engineered structure data bases will have a large number of uses ranging from associating a variety of different tags (or pointers to data) with a spatial location to three dimensional modelling used to plan how heavy equipment may be used to dismantle complex structures inside buildings.

Status: Accepted. Most information, data, and computer system components for a basic geographic information system (GIS) for each DOE site should already exist. Adequate partial and complete implementations needed to support all aspects of environmental restoration probably exist for some sites and could be adapted for use at other sites. Integration of existing resources is expected to be the biggest task to get a system in place, especially assembling the data in electronic form.

Efficacy—High. Surface rendering capabilities, together with three-dimensional models of structures and equipment would make a GIS a very useful planning, procedure design, and check-out facility for use of heavy equipment, work that must be carried out in confined spaces, and evaluation of tasks to be sure they are within human physical capabilities to perform.

Visual displays showing spatial location and relationships of problems and restoration activities are much more effective means of conveying information than can be provided by tables of numbers. Because the human mind can deal much more easily with visual cues, displaying spatial patterns should also be a more reliable and much faster way to evaluate information needed for making decisions.

Waste—No waste created by this technology.

Science/Technology Needs: A GIS should be a valuable decision aid by itself, but could be enhanced to become far more valuable by the addition of a tagging feature that permits defining links between a spatial location and any type of information (e.g., a radiation survey reading) related to that location. Such an enhancement also needs to be implemented to permit the GIS to be integrated into various configuration management systems to assist in tracking remediation activities. In this respect, an enhanced GIS would greatly strengthen a project's quality assurance program. Other enhancements may have to be considered to provide additional needed functionality for more reliable project management.

Implementation Needs: Hard-copy drawings of engineered structures may have to be scanned and digitized for electronic access. Computer systems used for GIS related applications are usually more expensive because they require more memory and disk storage space to accommodate images. Two workstations with software cost \$100K, one person year data base input labor costs \$300K, total costs are \$225K, and operating costs are \$150/h.

Author: John K. Munro, Jr./615-574-0635

Reviewer: T. Barnes/615-675-3337

References: Personal communication with Martin Marietta Energy Systems, Inc., staff.

IMPROVED PROTECTIVE CLOTHING AND EQUIPMENT (ENABLING TECHNOLOGIES)

DISM-120-OY

EM Problem: Decontamination and Decommissioning

Y-12 Plant Problem: Building 9201-4, which contains process facilities, process support facilities, electrochemical machining facilities, electrical facilities, and electrical switch gear facilities.

Problem Area/Constituents: The disassembly of process equipment and utility support structures that are contaminated with trace amounts of mercury, uranium, asbestos, PCBs, and lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Field assistance

Technology: Improved protective clothing and equipment

Status: Evolving technology. Because of the large amounts of protective clothing and equipment required to protect workers during the dismantlement of Building 9201-4, a very large sum of money has been included in the base case estimate. This estimate includes both the direct cost of equipment and indirect cost of lost worker efficiency caused by the limitations of working in the currently available equipment. A total cost of over \$1 billion has been estimated. No known program currently exists to develop specific equipment of this nature for Building 9201-4 dismantlement tasks.

Science/Technology Needs: Investigation of specific requirements for the dismantlement of Building 9201-4 relative to criteria for this equipment must be conducted. Human engineering techniques must be used to model the donning and doffing routines, and new techniques must be developed to speed this process as well as to specify newer materials more capable of recycling and/or safe disposal. The cost of such a program may be in the \$3M-\$5M range.

Studies must be made to plan the dismantlement sequence to permit design of enclosures, both mobile equipment cabs and portable containment, that better suit the repetitive nature of the building to be dismantled. The cost of this program would be in the \$2-\$3M range.

Implementation Needs: Full engineering and development of the equipment is needed. Many commercial opportunities exist to work outside the government sphere to engineer and develop such equipment. Most of the work would not be highly technical but would require

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a dedicated team with ergonomic skills. The cost of such a task would be in the \$3M-\$6M range. Payback potential relative to the \$1 billion estimate within Building 9201-4 tasks could be up to 50%.

Author: L.C. Hensley/615-574-1988 (K-25).

Reviewer: G. A. Blankenship/615-574-9829 (Y-12)

References:

1. MMES staff members.

HIGH-PRESSURE ABRASIVE WATER JET SCARIFICATION (MASSIVE CONCRETE)

DISM-121-OY

EM Problem: Decontamination and Decommissioning

Y-12 Problem: Building 9201-4, which contains process facilities, process support facilities, electro-chemical machining facilities, electrical facilities and electrical switch gear facilities.

Problem Area/Constituents: Massive reinforced concrete structures may be contaminated with mercury, various oils, PCBs, low levels of uranium, and/or lithium compounds.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Dismantlement

Alternative: Removal

Technology: High-pressure abrasive water jet. Scarifing: A remotely manipulated, high-pressure water jet machine will be used. The machine will be track-mounted and can move in two directions over the rough surface. Scarifing: A remotely manipulated, high-pressure water jet machine that systematically scarifys the contaminated floor and ceiling will be used. It includes a vacuum recovery system that would collect contaminated slurry and recycle the water and possibly the abrasives, if used.

Abrasive water jet scarifing is ultrahigh-pressure water with and/or without abrasives that is forced through a small-diameter nozzle, creating a stream that cuts through up to a 3-ft-thick reinforced concrete with one pass. The contaminated surface removed by scarifing will be handled as contaminated waste, with the contaminated abrasives and water to be recycled. The technology has been demonstrated at Oak Ridge but not at the Y-12 Plant. Operational costs are estimated to be \$300/yd³.

A 100,000 ft² Mississippi River Bridge was scarified by high-pressure water jet in less than 4 months. The same job would have taken 10-15 men working 5 days/week approximately 2 years to accomplish using conventional jack hammers.

Status: Demonstrated. This technology is a DOE-sponsored development. Programmable robotic manipulators have been developed. The water can be recycled. Concepts exist for abrasives recycling, with 95% of the spoils recoverable. Battelle Pacific Northwest Laboratory has successfully demonstrated scarification and cutting of steel-reinforced concrete. This technology was successfully demonstrated at West Valley Nuclear Services, New York. Scarifing is used by the Tennessee Department of Transportation on bridges and is illustrated on video for the Mississippi River Bridge (see Flow, Inc., video).

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High maintenance items include nozzles, hoses, and pumps, when abrasives are used.

A high-efficiency recovery system is necessary for scarifying to keep contaminated runoff to a minimum. Cracks in concrete will be a problem, because contamination will still be present and will have to be addressed.

By removing the contaminated surfaces which will be roasted, stored in containers, shipped, and buried, the remainder of the decontaminated building can be crushed and used locally as fill. This will save \$17.00/ft³ for disposal. The mass of debris accumulated from demolishing concrete structures is estimated to be about 15% of the cubic dimension of the structure.

Cost payback: Based on scarifying a 3-ft-thick, 6-ft-square section of concrete and assuming that 3 in. are removed (top and bottom), decontamination would create 18 ft³ of contaminated debris with no void. The remaining decontaminated material would create 90 ft³ of usable material after crushing, which would be used locally. This would save \$1800 in storage cost alone, excluding reuse of the crushed material. This technology could be very useful if the floors are found to be contaminated only 2-3 inches from the surface.

Science/Technology Needs: A recovery system with recyclable water and abrasives needs to be demonstrated. This will require a portable facility, if available, or settling basins with the equipment necessary to separate and possibly decontaminate the water and abrasive for reuse.

Development of this equipment; manipulators for positioning on the floor, columns, and overhead; and settling basins for demonstration would cost \$1.5M. Demonstration costs include characterizing walls and floor, identifying grid patterns of reinforcing steel (if cutting concrete), building a portable containment enclosure, personnel protection, clothing, and container storage, but not transportation and burial charges.

Implementation Needs: The need exists to view videos and possibly to visit sites to evaluate recovery systems without on-site demonstrations. The need exists to research techniques which could be used to move this machine across the floor, up and around concrete columns, and overhead (the underside of the floor above). Methods of addressing cracks in concrete and containerization of contaminated material, water, and possibly abrasives will have to be developed. This technology has a low development priority. (Two years would be required to bring this technology to application. The cost to develop and demonstrate it is estimated to be \$2M.)

Per best engineering estimate, the projected capital cost of this technology is \$1M.

Authors: D. D. Haskell/615-675-3337 (X-10)

Reviewer: P. N. Hoskins/615-576-3369 (Y-12)

**HIGH-PRESSURE ABRASIVE WATER JET SCARIFICATION
(MASSIVE CONCRETE)**

DISM-121-OY

References:

1. Concrete Cutting Systems, Inc., Knoxville, Tennessee.