DATA COLLECTION, PROCESSING, VALIDATION, AND VERIFICATION

Deborah L. Martin,* Jennifer L. Hoff,† Roger A. Gard,† Richard J. Gregosky,‡ Hobert W. Jones,† Cheryl A. Kirkwood,§ Donald G. Morris,§ Tracey E. Shinsato,* and Cheryl L. Willott-Moore*

Abstract—**The collection, processing, validation, verification, formatting, filing, and storage of the required input data are some of the most important components in the National Institute for Occupational Safety and Health (NIOSH) Radiation Dose Reconstruction Program. Without question, the quality and scientific validity of the reconstructed dose estimates are totally dependent on these aspects of the program. Of equal importance is that the data be filed not only in a readily accessible format, but also in one that facilitates error-free retrievability. One often unrecognized key factor is that each and every item of data must be collected with careful consideration of the use to which it is to be applied. Two important databases have been established in support of the dose reconstruction operations. They are the NIOSH Office of Compensation Analysis and Support Claims Tracking System and the Site Research Database. The former contains information directly relating to individual workers. When such information is not available, surrogate sources (i.e., area monitoring data) are used to establish the "radiation environment" in which the worker was employed. This information is uploaded into the Site Research Database. Procedures for these systems entail identifying, collecting, and processing information from more than 300 Department of Energy and Atomic Weapons Employer related facilities. To date, more than one million worker-related employment and dosimetry records and more than 33,000 research documents have been uploaded into the associated computer systems.**
Health Phys. 95(1):36–46; 2008

Key words: dose reconstruction; exposure, occupational; computers; quality assurance

INTRODUCTION

THE NATIONAL Institute for Occupational Safety and Health (NIOSH) program for reconstructing the doses to people who have worked, or are working, at U.S. Department of Energy (DOE) and Atomic Weapons Employer (AWE) facilities and developed cancer involves the collection, processing, validation, and verification of data relating to tens of thousands of workers who have undergone this experience for which claims for compensation have been filed. Collecting these data is made more difficult because these people were exposed during work at one or more of hundreds of facilities, their exposures may have been internal and/or external, and the data sources may include those based on air monitors, personal dosimeters, urine bioassays, whole-body count analyses, and x-ray examinations. Furthermore, the information may be in one or more of a variety of formats (i.e., databases, documents, books, pictures, microfilm, microfiche cards, or spreadsheets). Since many records are 50 to 60 y old, they may be in very poor physical condition.

Other factors cause additional complications. One is the large number of DOE and AWE facilities, the majority of which are no longer in operation. The primary facilities are listed in the Appendix; in some cases, a single site had multiple facilities. Because some facilities have been closed, the location of their dosimetry records may not be known. Although such records may have been transferred to a Federal repository (Fig. 1), the nature of the data may not have been adequately described to facilitate their retrieval. These challenges are further compounded by facility limitations on available space, security restrictions, and delays for required classification review. In addition, there is the difficulty of developing and applying guidelines to decide which data are acceptable and which are not.

Once collected, the data must be categorized according to facility, work area, time period, and individual worker, including the job position in which the worker was employed. Finally, the data must be stored in such a way that they can be readily accessible.

* Dade Moeller & Associates, 1835 Terminal Drive, Suite 200, Richland, WA 99354; † Oak Ridge Associated Universities, 4850 Smith Road, Suite 200, Cincinnati, OH 45212; ‡ MJW Corporation, 4850 Smith Road, Suite 200, Cincinnati, OH 45212; § Dade Moeller & Associates, 4850 Smith Road, Suite 200, Cincinnati, OH 45212.

For correspondence contact: D. Martin, Dade Moeller & Associates, 1835 Terminal Drive, Suite 200, Richland, WA 99354, or email at dmartin@moellerinc.com.

(*Manuscript accepted* 26 *October* 2007)
0017-9078/08/0

Fig. 1. Locations of National Archives and Federal records centers.

To accomplish these goals, the following sequence of activities was developed and implemented: (1) data collection, (2) data processing, and (3) data validation and verification. Each of these is discussed in the sections that follow.

DATA COLLECTION

Two methods are used for collecting data depending on the availability, type, and intended use of the information. The first method relates to the situation in which dose-related information was maintained for each worker on an individual basis. Under these conditions, the required information is obtained through a request submitted to the designated point of contact at the appropriate facilities. When reviews of the provided data indicate the need for additional information, it is requested from the facility point of contact.** The most common need in the case of internal exposures is for individual bioassay results, including data for direct (in-vivo) bioassays (e.g., lung counts, whole body counts) and for indirect (in-vitro) bioassays (e.g., urinalysis, fecal analysis, and breath analysis). These bioassay records are extremely helpful, even if the quantity of the radionuclide in the body or in the bioassay sample at the time of measurement was below the limit of detection. Such situations are then reassessed based on the estimates of what is called “missed dose” (Merwin et al. 2008a). The most common supplemental request in the case of external exposures is for data by monitoring interval rather than the generally provided annual summaries.

When sufficient records to perform dose reconstructions for individual workers are not available, a second method involving the use of surrogate sources must be applied. One approach is to use the records of a co-worker; another is to seek to establish the “radiation environment” in which the worker was employed. The latter approach involves conducting a detailed review and collection[††] of the data generated through, for example, area surveys, fixed position external monitors, air sampling systems and evaluations, and radiological incidents. The accompanying dose rate estimates are then summarized in what is called a site profile (Kenoyer et al. 2008). To help ensure that each site profile is based on accurate scientific information, care is exercised to document that the leaders of these efforts have appropriate knowledge and experience in the derivation and interpretation of the required input information and are able to be objective and bias free in their analyses.

As is shown in the Appendix and Fig. 1, the data needed for dose reconstruction may be located at one or more DOE or AWE facilities, National Archives, and Federal records centers. The data may also be available through online DOE databases [i.e., Energy Citations Database (2007), Information Bridge (2007), and OpenNet (2006)].

DATA PROCESSING

Establishing databases

Once the worker-related employment and dosimetry data have been collected, inventoried, and organized by type, they are then scanned, cataloged, validated, verified, and made available in a format that is compatible and readily accessible for dose reconstruction.[‡‡] To accomplish this task, the records are scanned in portable document format (PDF) files and uploaded into the NIOSH Office of Compensation Analysis and Support Claims Tracking System (NOCTS), a database for information pertaining to individual workers. Users can query the system and retrieve a list of claims that match their search criteria (e.g., NIOSH identification number, DOE or AWE facility). Individual claimant information (e.g., claim status, claim documents, telephone interview report, and contact log) may be viewed from multiple tabs within a file. To date, approximately 1,085,000 documents have been uploaded to NOCTS (Table 1).

Data of a more generic nature, such as those in site profiles, are hosted in what is called the Site Research

** Oak Ridge Associated Universities Team. Additional requests for DOE information [internal procedure]. Cincinnati, OH: ORAUT-PROC-0022; 2005.

[††] Oak Ridge Associated Universities Team. Data reconnaissance and data capture [internal procedure]. Cincinnati, OH: ORAUT-PROC-0025; 2005.

[‡‡] Oak Ridge Associated Universities Team. Claims processing: receiving, scanning, quality reviewing, uploading, and filing of DOE exposure data [internal procedure]. Cincinnati, OH: ORAUT-PROC-0020; 2006.

Table 1. Total number of documents uploaded to NOCTS each year.

Year	Documents
2000	1
2001	2,935
2002	49,257
2003	182,039
2004	283,456
2005	247,849
2006	209,743
2007	110,471[a]
TOTAL	1,085,751[a]

[a] Through July.

Table 2. Total number of documents uploaded to the SRDB each year.

Year	Documents
2003	6,916
2004	7,406
2005	5,079
2006	8,241
2007	5,618[a]
TOTAL	33,260[a]

[a] Through July.

Database (SRDB).[§§] Finally, the data are also entered into spreadsheets that facilitate the dose reconstructors in using relevant data as inputs into the process of estimating both external and internal doses on an individual worker basis (Merwin et al. 2008b; Brackett et al. 2008; Maher et al. 2008). After the dose reconstruction is completed and approved by NIOSH, a complete copy of the worker's record is submitted electronically to the U.S. Department of Labor (DOL), the agency responsible for rendering a decision as to whether a case is compensable. To date, approximately 33,000 documents have been uploaded to the SRDB (Table 2).

Security and protection of records

All records must be properly maintained and protected in accordance with Federal regulations.*** These include the Privacy Act (U.S. Congress 1974); Title 36 CFR Part 1222, which covers the "Creation and Maintenance of Federal Records;" and CFR Part 1228, which applies to the "Disposition of Federal Records" and was promulgated by the U.S. National Archives and Records Administration (U.S. NARA 2006a and 2006b). Once it is determined that records are no longer needed on a routine basis, they are stored using appropriate security controls based on the sensitivity of the data. For database and information protection, all computer files are operated under redundant systems.

Managing working files

All files (e.g., email, spreadsheets, databases, controlled documents, research documents, worker records, and management reports) that are being used by project personnel are maintained on a shared computer server until they can be transferred to NIOSH for storage.[†††] The NOCTS and SRDB databases, as well as other files, can be accessed 24/7 by registered users through a virtual private network, and secure file transfer protocol, from their office, home, or while on travel.

DATA VALIDATION AND VERIFICATION

While it was not emphasized in the preceding sections, one of the primary factors that governs the collection and processing of data is the use to which they will be applied. Closely intertwined is the need for the quality of the data to be validated and verified. The discussion that follows illustrates the interrelations of these factors.

Reconstruction of internal doses

Since the 1930's, the use of bioassay procedures has been the primary method for assessing internal radionuclide deposition. As might be expected, the application of such procedures can be hampered by potential errors in the collection of the samples, the sensitivity and accuracy of the available analytical techniques, the sensitivity of the instruments required for performing the associated radioactivity assessments, and the available information on the manner in which the human body metabolizes different radionuclides. The importance of these factors was recognized in the late 1950's by the International Commission on Radiological Protection (ICRP 1959). Shortly thereafter, the Federal Radiation Council (FRC 1961) similarly cited the need for studies of the "metabolic factors" that affect "the uptake" of radionuclides. In fact, these and other inadequacies, as well as the need for new and better approaches for assessing the quantity of specific radionuclides in the body, continue to be a problem.

Over the years, significant progress has been made, such as the development of the gamma spectrometer. This tool significantly enhanced the rapid assessment of

[§§] Oak Ridge Associated Universities Team. Review process for documents in the site research database [internal procedure]. Cincinnati, OH: ORAUT-PROC-0088; 2005.

*** Oak Ridge Associated Universities Team. Protecting Privacy Act data [internal procedure]. Cincinnati, OH: ORAUT-PROC-0079; 2004.

[†††] Oak Ridge Associated Universities Team. Records management [internal procedure]. Cincinnati, OH: ORAUT-PROC-0015; 2006.

gamma-emitting radionuclides without losing or changing the "sample." Another major advance was the issuance by the ICRP Publication 23 that specified the characteristics of Reference Man (ICRP 1975). This standard, which subsequently has been used on a worldwide basis, provided a unified basis for converting bioassay data into the associated dose rates to an individual organ or the whole body. Another such contributor was Standard N-13.35, prepared under the auspices of the American National Standards Institute (ANSI 1999). This document provided a standard set of phantoms for in-vivo applications. Both of these standards have contributed immensely to improvements in the validity and accuracy of the data being generated in this field. With the subsequent development of very high-resolution solid-state detectors, multi-channel analyzers, and supporting computer systems, the speed and accuracy with which these assessments could be performed took another giant step forward. Through the publication of Report No. 87, the National Council on Radiation Protection and Measurements (NCRP 1987) provided guidance for developing the procedures necessary to ensure the quality of the resulting dose estimates.

To ensure the quality of the data being generated, the DOE national laboratories implemented all of the above recommendations. In a similar manner, urine samples containing known and unknown concentrations of specific radionuclides were circulated to all DOE facilities to cross-check the results of analyses for individual radionuclides. Another practice that has been underway for half a century is to exchange samples on a regular basis among the various analytical laboratories and to have each laboratory analyze its bioassay samples in accordance with ANSI N-13.30 (1996). Such samples are exchanged not only among the DOE laboratories in the United States but also with those in foreign countries.

For purposes of reconstructing doses under the NIOSH Radiation Dose Reconstruction Program, when there is doubt in the dose estimates, the more conservative (high) estimate is used. This is in accord with the requirement that all decisions made with respect to questions related to dose reconstructions be made in a manner to be "claimant favorable" (Merwin et al. 2008a).

Reconstruction of external doses

Included among the sets of data for earlier years are the records of external exposure assessments performed using pocket dosimeters and film badges. All of these data have accompanying uncertainties. Later, such measurements were made primarily through the use of thermoluminescent dosimeters (TLDs). Although this reduced many uncertainties, they were not eliminated (Merwin et al. 2008b). Another source of external exposures was the use of x rays in diagnostic medical examinations required in the course of employment by DOE and AWE facilities. The history of the methods used in such examinations are used as an example of procedures for validating and verifying the doses resulting from such examinations, the most common of which were diagnostic x-ray examinations of the chest. Unfortunately, however, few measurements were made of the accompanying doses, primarily due to the lack of integrating dose meters that could quantify the dose from medical x-ray equipment. These units continue today to serve as the standard for measuring doses from such equipment.

A major factor in quantifying doses received during chest examinations (the most common procedure being applied during the early 1940's) was whether they were performed using photofluorographic (PFG) or radiographic units (Shockley et al. 2008). This is because the estimated dose to the lungs from PFG units was one hundred times that from radiographic units (Moeller et al. 1953). Recognizing that this represented an unnecessary source of exposure, the use of PFG units, which began in the 1940's in conjunction with nationwide surveys for tuberculosis, had essentially been discontinued by 1970 (Shockley et al. 2008).

The above comments are not meant to imply that other efforts were not being made throughout this time to reduce the dose rates from medical x-ray equipment. For example, the U.S. Public Health Service (USPHS) initiated in 1952 a program of inspections of diagnostic x-ray units in all its hospitals. This led to the development of a manual (Ingraham et al. 1953) for conducting such inspections that was subsequently used by public health agencies throughout the United States. While the accompanying observations did not have a direct bearing on the NIOSH Radiation Dose Reconstruction Program, they confirmed that progress was being made in reducing the doses from such examinations. They also confirmed that the field was not static. As a result, there were major temporal differences in the doses being received by atomic energy workers in the United States. Later studies conducted by the Center for Devices and Radiological Health, Federal Food and Drug Administration, provided details on the progress being made in reducing medical x-ray doses. Fig. 2 provides an illustrative example of such progress.

Similar dose reduction progress was being made in terms of the size of the primary beam compared to that of the x-ray film. Ultimately, the capability to project light beams to simulate the x-ray beam enabled the x-ray unit operator to confirm the size of the x-ray beam and where it was directed. Supported by knowledge of when these

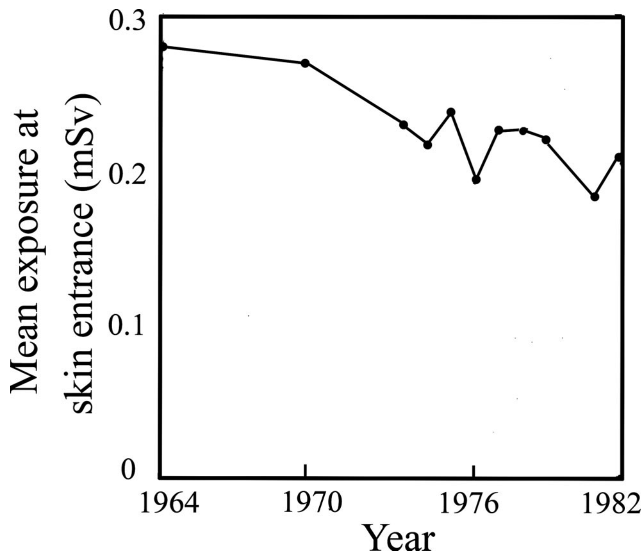

Fig. 2. Trend in reduction in the mean exposure at skin entrance; chest x-ray examinations.

advances were made, the dose reconstructors were able to estimate the doses from diagnostic x-ray procedures on a temporal basis, with confidence that the results were based on sound scientific information. Even so, to compensate for uncertainties, all estimates of doses from chest x rays assessed under the NIOSH Radiation Dose Reconstruction Program were increased by 30% to ensure that the dose was not underestimated (Shockley et al. 2008).

Implementation of basic science into the radiation dose reconstruction program

To ensure that all data and information collected, processed, and stored as described in the previous sections are both accurate and complete, a number of quality assurance (QA) and quality control (QC) checks are performed. In fact, every aspect of the dose reconstruction process—from the collection and recording of the data to the preparation of the accompanying reports—is conducted in accordance with the requirements of the program's quality management system.[‡‡‡] This system was established to ensure that employees are qualified, through experience, education, and training, to perform their work accurately and efficiently, and to ensure that efforts are continually being made to improve the system. In essence, the quality management system is designed to ensure that the dose estimates are free of both technical and nontechnical errors.

All data used for a dose reconstruction report, site profile, or Special Exposure Cohort (SEC) petition evaluation report are cross-checked for consistency. Conversely, these procedures can help identify data gaps or omissions that may prompt efforts to acquire additional data. Examples of the checks and balances that are employed to accomplish these goals are described below:

- Dose reconstruction reports, developed using data in NOCTS, are subjected to a three-stage QC review: nontechnical, technical, and a final comprehensive review.[§§§] After submittal to NIOSH, dose reconstruction reports are further reviewed and approved by NIOSH technical personnel. All equations and associated analytical processes are reviewed by an independent qualified expert in terms of accuracy and appropriateness (Maher et al. 2008);
- Site profiles, developed using data in the SRDB and NOCTS, are reviewed by several people not involved in their development, prior to issuance (Kenoyer et al. 2008); and
- SEC petition evaluation reports, developed using data in the SRDB, NOCTS, site profiles, and other sources, are also reviewed by individuals not involved in their initial development prior to being sent to NIOSH. The reports undergo an additional review by NIOSH before being forwarded to the Advisory Board on Radiation and Worker Health (Ziemer 2008).

COMMENTARY AND CONCLUSION

The theme of this paper may, at times, appear to be the difficulties in identifying the sources of the data to be collected. The real message, however, is care that must be exercised in collecting, processing, validating, and verifying data. This ensures the data are based on good science and representative of the doses that each individual worker received. This encompasses the need to document that the data are complete so as to avoid the necessity of resorting to the use of surrogate sources of information for estimating dose. This mandates that personnel are thoroughly experienced in understanding the methods through which the data were generated, the associated complexities, and the primary factors that contribute to their uncertainties and potential misinterpretations. Without such care, subsequent errors and the need to repeat the dose reconstruction calculations could lead to a significant waste of time and the associated creation of a lack of confidence in the program.

[‡‡‡] Oak Ridge Associated Universities Team. Quality assurance program plan [internal plan]. Cincinnati, OH: ORAUT-PLAN-0001; 2007.

[§§§] Oak Ridge Associated Universities Team. Initial quality control, technical editing, and final quality control of dose reconstruction reports [internal procedure]. Cincinnati, OH: ORAUT-PROC-0098; 2007.

The success of this program is also dependent on the recognition that the ultimate goal is to provide data that are not only accurate but also exactly what is needed and available in a format that can readily be retrieved. This makes it essential that all personnel develop an attitude of continuing to seek improvement, and the ability to recognize the importance of being alert to identify problems and taking action to solve them as rapidly as possible. In many ways, ensuring that the data are complete and not without significant voids is similar to assembling a crossword puzzle. Unless sufficient data are provided to enable a complete dose reconstruction to be prepared, no one can have confidence in the outcome. Finally, it might be noted that the activities described in this paper could never have been accomplished prior to the advent of computers and the accompanying programs that have been developed for analyzing, processing, and storing data. For example, as of July 2007, the NOCTS and SRDB databases contain 650 and 90 gigabytes of PDF images, respectively.

Acknowledgments—The work described in this paper was supported by the National Institute for Occupational Safety and Health under contract no. 200-2002-0593.

Disclaimer: The findings and conclusions in this paper have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

REFERENCES

American National Standards Institute. An American National Standard on performance criteria for radiobioassay. McLean, VA: Health Physics Society; ANSI/HPS N-13.30; 1996.

American National Standards Institute. An American National Standard on specifications for the bottle manikin absorption phantom. McLean, VA: Health Physics Society; ANSI/HPS N-13.35; 1999.

Brackett EM, Allen DE, Siebert SR, La Bone TR. Internal dose reconstruction under Part B of the Energy Employees Compensation Program Act. Health Phys 95:69–80; 2008.

Energy Citations Database [database online]. Oak Ridge, TN: Office of Scientific and Technical Information, U.S. Department of Energy; Updated 19 October 2007. Available at: http://www.osti.gov/energycitations/. Accessed 5 September 2007.

Federal Radiation Council. Background material for the development of radiation protection standards. Washington, DC: U.S. Department of Health, Education, and Welfare; Public Health Service; FRC Report No. 2; 1961.

Information Bridge [database online]. Oak Ridge, TN: Office of Scientific and Technical Information, U.S. Department of Energy; Updated 19 October 2007. Available at: http://www.osti.gov/bridge/. Accessed 5 September 2007.

Ingraham SC II, Terrill JG Jr, Moeller DW. Guide for inspection of medical and dental diagnostic x-ray installations in the Public Health Service. Washington, DC: U.S. Department of Health, Education, and Welfare; 1953.

International Commission on Radiological Protection. Report of Committee II: Permissible dose for internal radiation. New York: Pergamon Press; ICRP Publication 2; 1959.

International Commission on Radiological Protection. Report of task group on reference man. Oxford: Pergamon Press; ICRP Publication 23; 1975.

Kenoyer JL, Scalsky ED, Taulbee TD. Development of site profiles for dose reconstruction used in worker compensation claims. Health Phys 95:47–54; 2008.

Maher EF, McCartney KA, Mize BD, Sun L-SC, Siebert SR. Development of rapid methods for assessing doses from internally deposited radionuclides. Health Phys 95:89–94; 2008.

Merwin SE, Stewart DN, Smith MH, Potter KD, Hinnefeld SL. Implications of claimant-favorable approaches used in dose and probability of causation calculations under EEOICPA. Health Phys 95:148–159; 2008a.

Merwin SE, Smith MH, Winslow RC, McCartney KA, Fix JJ, Taulbee TD, Macievic GL. External dose reconstruction under Part B of the Energy Employees Compensation Act. Health Phys 95:95–106; 2008b.

Moeller DW, Terrill JG Jr, Ingraham SC II. Radiation exposure in the United States. Public Health Reports 68:57–65; 1953.

National Council on Radiation Protection and Measurements. Use of bioassay procedures for assessment of internal radionuclide deposition. Bethesda, MD: NCRP; NCRP Report 87; 1987.

OpenNet [database online]. Oak Ridge, TN: Office of Scientific and Technical Information, U.S. Department of Energy; Updated 21 December 2006. Available at: http://www.osti.gov/opennet/. Accessed 5 September 2007.

Shockley VE, Kathren RL, Thomas EM. Reconstruction of doses from occupationally related medical x-ray examinations. Health Phys 95:107–118; 2008.

U.S. Congress. The Privacy Act of 1974. Public Law 93-579; 5 U.S.C. 552a (as amended); 1974.

U.S. National Archives and Records Administration. Creation and maintenance of records; adequate and proper documentation. Washington, DC: U.S. Government Printing Office; 36 CFR Part 1222; 2006a.

U.S. National Archives and Records Administration. Disposition of Federal records. Washington, DC: U.S. Government Printing Office; 36 CFR Part 1228; 2006b.

Ziemer PL. Responsibilities and activities of the Advisory Board on Radiation and Worker Health. Health Phys 95:20–25; 2008.

■ ■

APPENDIX

Department of Energy (DOE) and Atomic Weapons Employer (AWE) facilities (Table A1).

Table A1. Department of Energy (DOE) and Atomic Weapons Employer (AWE) facilities.

Facility	City	State	Site type
AC Spark Plug	Flint	MI	AWE
Aeroprojects, Inc.	West Chester	PA	AWE
Ajax Magnathermic Corp.	Youngstown	OH	AWE
Alba Craft	Oxford	OH	AWE/DOE
Albany Research Center	Albany	OR	AWE/DOE
Albuquerque Operations Office	Albuquerque	NM	DOE
Aliquippa Forge	Aliquippa	PA	AWE/DOE
Allegheny-Ludlum Steel	Watervliet	NY	AWE
Allied Chemical and Dye Corp.	North Claymont	DE	AWE
Allied Chemical Corp. Plant	Metropolis	IL	AWE
Allis-Chalmers Co.	West Allis, Milwaukee	WI	AWE
Aluminum Co. of America (Alcoa) 1 (Pennsylvania)	New Kensington	PA	AWE
Aluminum Co. of America (Alcoa) 2 (New Jersey)	Garwood	NJ	AWE
Amchitka Island Nuclear Explosion Site	Amchitka Island	AK	DOE
AMCOT	Fort Worth	TX	AWE
American Bearing Corp.	Indianapolis	IN	AWE
American Chain and Cable Co.	Bridgeport	CT	AWE
American Machine and Foundry	Brooklyn	NY	AWE
American Machine and Metals, Inc.	E. Moline	IL	AWE
American Peddinghaus Corp.	Moonachle	NJ	AWE
American Potash & Chemical	West Hanover	MA	AWE
Ames Laboratory	Ames	IA	DOE
Anaconda Co.	Waterbury	CT	AWE
Area IV of the Santa Susana Field Laboratory	Santa Susana	CA	DOE
Argonne National Laboratory—East	Argonne	IL	DOE
Argonne National Laboratory—West	Scoville	ID	DOE
Armco-Rustless Iron and Steel	Baltimore	MD	AWE
Armour Fertilizer Works	Bartow	FL	AWE
Armour Research Foundation	Chicago	IL	AWE
Arthur D. Little Co.	San Francisco	CA	AWE
Ashland Oil	Tonawanda	NY	AWE
Associated Aircraft Tool and Manufacturing Co.	Fairfield	OH	AWE/DOE
B & T Metals	Columbus	OH	AWE/DOE
Baker and Company	Newark	NJ	AWE
Baker and Williams Warehouses	New York	NY	AWE/DOE
Baker Brothers	Toledo	OH	AWE/DOE
Baker-Perkins Co.	Saginaw	MI	AWE
Battelle Laboratories—King Avenue	Columbus	OH	AWE/DOE
Battelle Laboratories—West Jefferson	Columbus	OH	AWE/DOE
Bell Telephone Laboratories	Murray Hill	NJ	AWE
Bendix Aviation (Pioneer Division)	Davenport	IA	AWE
Beryllium Production Plant (Brush Luckey Plant)	Luckey	OH	DOE
Besley-Wells	South Beloit	WI	AWE
Bethlehem Steel	Lackawanna	NY	AWE
Birdsboro Steel & Foundry	Birdsboro	PA	AWE
Bliss & Laughlin Steel	Buffalo	NY	AWE
Blockson Chemical Co. (Building 55 and related activities)	Joliet	IL	AWE
Bloomfield Tool Co.	Bloomfield	NJ	AWE
BONUS Reactor Plant	Punta Higuera	PR	DOE
Bowen Engineering, Inc.	North Branch	NJ	AWE
Bridgeport Brass Co., Adrian	Adrian	MI	AWE/DOE
Bridgeport Brass Co., Havens Lab	Bridgeport	CT	AWE
Brookhaven National Laboratory	Upton	NY	DOE
Brush Beryllium Co. 1 (Detroit)	Detroit	MI	AWE
Brush Beryllium Co. 4 (Cleveland)	Cleveland	OH	AWE
BWXT [BWX Technologies, Inc. (Virginia)]	Lynchburg	VA	AWE
C–B Tool Products Co.	Chicago	IL	AWE
C. G. Sargent & Sons	Graniteville	MA	AWE
C. H. Schnorr	Springdale	PA	AWE/DOE

(*Continued*)

Table A1. Continued.

Facility	City	State	Site type
C. I. Hayes, Inc.	Cranston	RI	AWE
California Research Corp.	Richmond	CA	AWE
Callite Tungsten Co.	Union City	NJ	AWE
Canoga Avenue Facility (Vanowen Building)	Los Angeles	CA	DOE
Carboloy Co.	Detroit	MI	AWE
Carborundum Company	Niagara Falls	NY	AWE
Carnegie Institute of Technology	Pittsburgh	PA	AWE
Carpenter Steel Co.	Reading	PA	AWE
Chambersburg Engineering Co.	Chambersburg	PA	AWE
Chapman Valve	Indian Orchard	MA	AWE/DOE
Chemical Construction Co.	Linden	NJ	AWE
Chupadera Mesa	Chupadera Mesa	NM	DOE
Cincinnati Milling Machine Co.	Cincinnati	OH	AWE
Clarksville Facility	Clarksville	TN	DOE
Clinton Engineer Works (CEW)	Oak Ridge	TN	DOE
Colonie Site (National Lead)	Colonie (Albany)	NY	AWE/DOE
Combustion Engineering	Windsor	CT	AWE
Connecticut Aircraft Nuclear Engine Laboratory (CANEL)	Middletown	CT	DOE
Copperweld Steel	Warren	OH	AWE
Crane Co.	Chicago	IL	AWE
Crucible Steel Co.	Syracuse	NY	AWE
Dana Heavy Water Plant	Dana	IN	DOE
De Soto Avenue Facility	Los Angeles	CA	DOE
Dorr Corp.	Stamford	CT	AWE
Dow Chemical Co.	Walnut Creek	CA	AWE
Dow Chemical Co. (Madison Site)	Madison	IL	AWE
Downey Facility	Los Angeles	CA	DOE
Du Pont — Grasselli Research Laboratory	Cleveland	OH	AWE
Du Pont Deepwater Works	Deepwater	NJ	AWE/DOE
Edgerton Germeshausen & Grier, Inc.	Boston	MA	AWE
Electro Circuits, Inc.	Pasadena	CA	AWE
Electro Metallurgical	Niagara Falls	NY	DOE
Elk River Reactor	Elk River	MN	DOE
Environmental Measurements Laboratory	New York	NY	DOE
ERA Tool and Engineering Co.	Chicago	IL	AWE
Extruded Metals Co.	Grand Rapids	MI	AWE
Extrusion Plant (Reactive Metals, Inc.)	Ashtabula	OH	DOE
Feed Materials Production Center (FMPC)	Fernald	OH	DOE
Fenn Machinery Co.	Hartford	CT	AWE
Fenwal, Inc.	Ashland	MA	AWE
Fermi National Accelerator Laboratory	Batavia	IL	DOE
Foote Mineral Co.	East Whiteland Twp.	PA	AWE
Gardinier, Inc.	Tampa	FL	AWE
General Atomics	La Jolla	CA	AWE/DOE
General Electric Company (Ohio)	Cincinnati/Evendale	OH	AWE/DOE
General Electric Plant (Indiana)	Shelbyville	IN	AWE
General Electric Vallecitos	Pleasanton	CA	AWE/DOE
General Electric X-Ray Division	Milwaukee	WI	AWE
General Steel Industries	Granite City	IL	AWE/DOE
Grand Junction Operations Office	Grand Junction	CO	DOE
Great Lakes Carbon Corp.	Chicago	IL	AWE
Green Sludge Plant in Uravan	Uravan	CO	DOE
Gruen Watch	Norwood	OH	AWE
GSA 39th Street Warehouse	Chicago	IL	AWE
Hallam Sodium Graphite Reactor	Hallam	NE	DOE
Hanford	Richland	WA	DOE
Harshaw Chemical Co.	Cleveland	OH	AWE
Heald Machine Co.	Worcester	MA	AWE
Heppenstall Co.	Pittsburgh	PA	AWE
Herring—Hall Marvin Safe Co.	Hamilton	OH	AWE/DOE
High Energy Rate Forging (HERF) Facility	Oxnard	CA	DOE
Hooker Electrochemical	Niagara Falls	NY	AWE
Horizons, Inc.	Cleveland	OH	AWE
Hunter Douglas Aluminum Corp.	Riverside	CA	AWE
Huntington Pilot Plant	Huntington	WV	DOE
Idaho National Laboratory	Scoville	ID	DOE
International Minerals and Chemical Corp.	Mulberry	FL	AWE
International Nickel Co., Bayonne Laboratories	Bayonne	NJ	AWE

(*Continued*)

Table A1. Continued.

Facility	City	State	Site type
International Rare Metals Refinery, Inc.	Mt. Kisco	NY	AWE
International Register	Chicago	IL	AWE
Iowa Ordnance Plant	Burlington	IA	DOE
Ithaca Gun Co.	Ithaca	NY	AWE
J. T. Baker Chemical Co.	Phillipsburg	NJ	AWE
Jessop Steel Co.	Washington	PA	AWE
Joslyn Manufacturing and Supply Co.	Ft. Wayne	IN	AWE
Kaiser Aluminum Corp.	Dalton	IL	AWE
Kansas City Plant	Kansas City	MO	DOE
Kauai Test Facility	Kauai	HI	DOE
Kellex/Pierpont	Jersey City	NJ	AWE/DOE
Kerr—McGee	Guthrie	OK	AWE
Kirtland Operations Office	Albuquerque	NM	DOE
Koppers Co., Inc.	Verona	PA	AWE
La Pointe Machine and Tool Co.	Hudson	MA	AWE
Laboratory for Energy-Related Health Research	Davis	CA	DOE
Laboratory of Biomedical and Environmental Sciences	Los Angeles	CA	DOE
Laboratory of Radiobiology and Environmental Health	San Francisco	CA	DOE
La Crosse Boiling Water Reactor	La Crosse	WI	DOE
Lake Ontario Ordnance Works	Niagara Falls	NY	DOE
Landis Machine Tool Co.	Waynesboro	PA	AWE
Latty Avenue Properties	Hazelwood	MO	AWE/DOE
Lawrence Berkeley National Laboratory	Berkeley	CA	DOE
Lawrence Livermore National Laboratory	Livermore	CA	DOE
Linde Air Products	Buffalo	NY	AWE
Linde Ceramics Plant	Tonawanda	NY	AWE/DOE
Lindsay Light and Chemical Co.	W. Chicago	IL	AWE
Los Alamos Medical Center	Los Alamos	NM	DOE
Los Alamos National Laboratory	Los Alamos	NM	DOE
Lovelace Respiratory Research Institute	Albuquerque	NM	DOE
Magnus Brass Co.	Cincinnati	OH	AWE
Mallinckrodt Chemical Co., Destrehan St. Plant	St. Louis	MO	DOE
Massachusetts Institute of Technology	Cambridge	MA	AWE
Mathieson Chemical Co.	Pasadena	TX	AWE
Maywood Chemical Works	Maywood	NJ	AWE
McKinney Tool and Manufacturing Co.	Cleveland	OH	AWE
Medart Co.	St. Louis	MO	AWE
Medina Facility	San Antonio	TX	DOE
Metallurgical Laboratory	Chicago	IL	AWE/DOE
Metals and Controls Corp.	Attleboro	MA	AWE
Middlesex Municipal Landfill	Middlesex	NJ	AWE/DOE
Middlesex Sampling Plant	Middlesex	NJ	DOE
Midwest Manufacturing Co.	Galesburg	IL	AWE
Mill at Moab Utah	Moab	UT	DOE
Mitchell Steel Co.	Cincinnati	OH	AWE
Mitts & Merrel Co.	Saginaw	MI	AWE
Monsanto Chemical Co.	Dayton	OH	AWE
Mound Plant	Miamisburg	OH	DOE
Museum of Science and Industry	Chicago	IL	AWE
National Guard Armory	Chicago	IL	AWE/DOE
National Research Corp.	Cambridge	MA	AWE
Nevada Site Office	North Las Vegas	NV	DOE
Nevada Test Site	Mercury	NV	DOE
New Brunswick Laboratory	New Brunswick	NJ	DOE
New England Lime Co.	Canaan	CT	AWE
New York University	New York	NY	AWE
Norton Co.	Worcester	MA	AWE
Nuclear Materials and Equipment Corp. (NUMEC)—Parks Township	Parks Township	PA	AWE
Nuclear Materials and Equipment Corp. (NUMEC)—Apollo	Apollo	PA	AWE
Nuclear Metals, Inc.	Concord	MA	AWE
Oak Ridge Gaseous Diffusion Plant (K-25)	Oak Ridge	TN	DOE
Oak Ridge Hospital	Oak Ridge	TN	DOE
Oak Ridge Institute for Science Education (ORISE)	Oak Ridge	TN	DOE
Oak Ridge National Laboratory (X-10)	Oak Ridge	TN	DOE
Oak Ridge Thermal Diffusion Plant (S-50)	Oak Ridge	TN	DOE
Oliver Corp.	Battle Creek	MI	AWE
Ore Buying Station at Crooks Gap	Crooks Gap	WY	DOE
Ore Buying Station at Edgemont	Edgemont	SD	DOE

(*Continued*)

Table A1. Continued.

Facility	City	State	Site type
Ore Buying Station at Globe, AZ	Globe	AZ	DOE
Ore Buying Station at Grants, NM	Grants	NM	DOE
Ore Buying Station at Marysvale	Marysvale	UT	DOE
Ore Buying Station at Moab	Moab	UT	DOE
Ore Buying Station at Monticello	Monticello	UT	DOE
Ore Buying Station at Riverton	Riverton	WY	DOE
Ore Buying Station at Shiprock	Shiprock	NM	DOE
Ore Buying Station at White Canyon	White Canyon	UT	DOE
Pacific Northwest National Laboratory	Richland	WA	DOE
Pacific Proving Ground	Marshall Islands	MR	DOE
Paducah Gaseous Diffusion Plant	Paducah	KY	DOE
Painsville Site (Diamond Magnesium Co.)	Painsville	OH	AWE
Pantex Plant	Amarillo	TX	DOE
Peek Street Facility	Schenectady	NY	DOE
Penn Salt Co.	Philadelphia/Wyndmoor	PA	AWE
Pinellas Plant	Clearwater	FL	DOE
Piqua Organic Moderated Reactor	Piqua	OH	DOE
Podbeliniac Corp.	Chicago	IL	AWE
Portsmouth Gaseous Diffusion Plant	Piketon	OH	DOE
Precision Extrusion Co.	Bensenville	IL	AWE
Princeton Plasma Physics Laboratory	Princeton	NJ	DOE
Project Chariot Site	Cape Thompson	AK	DOE
Project Faultless Nuclear Explosion Site	Central Nevada Test Site	NV	DOE
Project Gasbuggy Nuclear Explosion Site	Farmington	NM	DOE
Project Gnome Nuclear Explosion Site	Carlsbad	NM	DOE
Project Rio Blanco Nuclear Explosion Site	Rifle	CO	DOE
Project Rulison Nuclear Explosion Site	Grand Valley	CO	DOE
Project Shoal Nuclear Explosion Site	Fallon	NV	DOE
Puerto Rico Nuclear Center	Mayaguez	PR	DOE
Purdue University	Lafayette	IN	AWE
Quality Hardware and Machine Co.	Chicago	IL	AWE
R. Krasburg and Sons Manufacturing Co.	Chicago	IL	AWE
R. W. Leblond Machine Tool Co.	Cincinnati	OH	AWE
Radium Chemical Co.	New York	NY	AWE
Rare Earths/W. R. Grace	Wayne	NJ	AWE/DOE
Reed Rolled Thread Co.	Worcester	MA	AWE
Revere Copper and Brass	Detroit	MI	AWE
Rocky Flats Plant	Golden	CO	DOE
Roger Iron Co.	Joplin	MO	AWE
Ross Aviation	Albuquerque	NM	DOE
Sacandaga Facility	Glenville	NY	DOE
Salmon Nuclear Explosion Site	Hattiesburg	MS	DOE
SAM Laboratories, Columbia University	New York City	NY	DOE
Sandia Laboratory, Salton Sea Base	Imperial County	CA	DOE
Sandia National Laboratories—Livermore	Livermore	CA	DOE
Sandia National Laboratories	Albuquerque	NM	DOE
Savannah River Site	Aiken	SC	DOE
Sciaky Brothers, Inc.	Chicago	IL	AWE
Seaway Industrial Park	Tonawanda	NY	AWE
Separations Process Research Unit (at Knolls Lab)	Schenectady	NY	DOE
Seymour Specialty Wire	Seymour	CT	AWE/DOE
Shattuck Chemical	Denver	CO	AWE
Shippingport Atomic Power Plant	Shippingport	PA	DOE
Shpack Landfill	Norton	MA	AWE
Simonds Saw and Steel Co.	Lockport	NY	AWE
South Albuquerque Works	Albuquerque	NM	DOE
Southern Research Institute	Birmingham	AL	AWE
Spencer Chemical Co., Jayhawks Works	Pittsburg	KS	AWE
Sperry Products, Inc.	Danbury	CT	AWE
St. Louis Airport Storage Site (SLAPS)	St. Louis	MO	AWE
Standard Oil Development Co. of NJ	Linden	NJ	AWE
Stanford Linear Accelerator Center	Palo Alto	CA	DOE
Star Cutter Corp.	Farmington	MI	AWE
Staten Island Warehouse	New York	NY	AWE
Stauffer Metals, Inc.	Richmond	CA	AWE
Superior Steel Co.	Carnegie	PA	AWE
Sutton, Steele and Steele Co.	Dallas	TX	AWE
Swenson Evaporator Co.	Harvey	IL	AWE

(*Continued*)

Table A1. Continued.

Facility	City	State	Site type
Sylvania Corning Nuclear Corp.—Bayside Laboratories	Bayside	NY	AWE
Sylvania Corning Nuclear Corp.—Hicksville Plant	Hicksville	NY	AWE
Tech-Art, Inc.	Milford	OH	AWE
Tennessee Valley Authority	Muscle Shoals	AL	AWE
Texas City Chemicals, Inc.	Texas City	TX	AWE
Thomas Jefferson National Accelerator Facility	Newport News	VA	DOE
Titanium Alloys Manufacturing	Niagara Falls	NY	AWE
Titus Metals	Waterloo	IA	AWE
Tocco Induction Heating Division	Cleveland	OH	AWE
Tonopah Test Site	North Las Vegas	NV	DOE
Torrington Co.	Torrington	CT	AWE
Trinity Nuclear Explosion Site	White Sands Missile Range	NM	DOE
Tube Reducing Co.	Wallington	NJ	AWE
Tyson Valley Powder Farm	St. Louis	MO	AWE
U.S. Steel Co., National Tube Division	McKeesport	PA	AWE
United Lead Co.	Middlesex	NJ	AWE
United Nuclear Corp.	Hematite	MO	AWE
University of California	Berkeley	CA	AWE/DOE
University of Denver Research Institute	Denver	CO	AWE
University of Florida	Gainesville	FL	AWE
University of Michigan	Ann Arbor	MI	AWE
University of Rochester Atomic Energy Project	Rochester	NY	DOE
University of Virginia	Charlottesville	VA	AWE
Uranium Mill in Durango	Durango	CO	DOE
Uranium Mill in Monticello	Monticello	UT	DOE
Utica St. Warehouse	Buffalo	NY	AWE
Ventron Corporation	Beverly	MA	AWE/DOE
Virginia-Carolina Chemical Corp.	Nichols	FL	AWE
Vitro Corp. of America (Tennessee)	Chattanooga	TN	AWE
Vitro Corp. of America (New Jersey)	West Orange	NJ	AWE
Vitro Manufacturing (Canonsburg)	Canonsburg	PA	AWE
Vulcan Tool Co.	Dayton	OH	AWE
W. E. Pratt Manufacturing Co.	Joliet	IL	AWE
W. R. Grace (Tennessee)	Erwin	TN	AWE
W. R. Grace and Company (Maryland)	Curtis Bay	MD	AWE
W. R. Grace Co., Agricultural Chemical Division (Florida)	Ridgewood	FL	AWE
Wah Chang	Albany	OR	AWE
Waste Isolation Pilot Plant	Carlsbad	NM	DOE
Weldon Spring Plant	Weldon Spring	MO	DOE
West Valley Demonstration Project	West Valley	NY	AWE/DOE
Westinghouse Atomic Power Development Plant	East Pittsburgh	PA	AWE
Westinghouse Electric Corp. (New Jersey)	Bloomfield	NJ	AWE
Westinghouse Nuclear Fuels Division	Cheswick	PA	AWE
Winchester Engineering and Analytical Center	Winchester	MA	DOE
Woburn Landfill	Woburn	MA	AWE
Wolff—Alport Chemical Corp.	Brooklyn	NY	AWE
Wolverine Tube Division	Detroit	MI	AWE
Wyckoff Drawn Steel Co.	Chicago	IL	AWE
Wykoff Steel Co.	Newark	NJ	AWE
Y-12 Plant	Oak Ridge	TN	DOE
Yucca Mountain Site Characterization Project	Yucca Mountain	NV	DOE