

## APPENDIX C

# U.S. HEU SPENT NUCLEAR FUEL INVENTORY

This appendix provides information on the location and quantity of spent nuclear fuel and other reactor irradiated nuclear materials containing highly enriched uranium (HEU) in storage at DOE facilities throughout the United States (U.S.) as of September 30, 1996. These quantities (summarized in Table C-1) are included as part of the overall U.S. HEU inventory (see Table 3-1). HEU in spent nuclear fuel is not weapons-usable unless it is reprocessed. While natural as well as low enriched uranium can be used as a reactor fuel, spent fuel produced from these materials is beyond the scope of this report.

## BACKGROUND

When a reactor is operated, uranium atoms in the fuel undergo a process known as fission, where atoms are split and create energy. Fission also creates radioactive waste products (fission products) inside the fuel elements. After a time, but before all the uranium atoms are consumed, the radioactive fission products build up, causing inefficient use of the fuel. At this point, fuel elements are considered “spent” and are removed from the reactor, and new fuel elements are installed. When removed from a reactor, spent fuel elements are intensely radioactive due to the fission product content. To allow time for some of the radioactivity to die down, spent fuel is stored, usually under water, for several months, a step known as decay cooling.

Once the decay cooling step is complete, the valuable unused uranium can be recovered from the spent fuel and used in new fuel elements. The recovery sequence begins when the fuel assemblies are loaded into heavily shielded transfer casks and shipped to a fuel reprocessing plant. The recovery of uranium from spent fuel involves a series of operations, most of which are conducted by remote control in equipment installed behind massive concrete shielding walls. To obtain purified uranium, the spent fuel is dissolved in acid and the uranium is extracted from the resulting solution and purified.

The purified uranium product, uranyl nitrate, is essentially free of all fission products and other impurities. The uranyl nitrate solution may be converted to hexafluoride and recycled through the enrichment process to restore its uranium-235 concentration to the pre-irradiation level, or it may be converted to uranium dioxide and blended with material of higher uranium-235 content and ultimately remanufactured into reactor fuel.

## SPENT FUEL REPROCESSING

Spent fuel containing HEU has been processed in the U.S. since 1953, primarily at DOE facilities in Idaho and South Carolina. In addition, small quantities of HEU spent fuel were processed at the Nuclear Fuel Services facility in West Valley, New York, in 1968. In 1992, the DOE ceased processing HEU spent fuel at Idaho. Savannah River has a defined mission to dispose of spent nuclear fuel and other reactor irradiated nuclear materials through processing.

## SPENT FUEL STORAGE

As a consequence of past policies, the DOE is storing large numbers of spent nuclear fuel and other reactor irradiated nuclear materials. DOE facilities that were designed, constructed, and operated to store spent nuclear fuel and other reactor irradiated nuclear materials for relatively short periods of time now store these materials pending disposition decisions.

In 1993, to ensure that the extended storage of these materials is safe, the DOE conducted an assessment of the environmental, safety, and health vulnerabilities associated with the storage of spent nuclear fuel and other reactor irradiated nuclear materials. Information on the results of the assessment are summarized in the DOE report, *Spent Fuel Working Group Report on Inventory and Storage of the Department's Spent Nuclear Fuel and Other Reactor Irradiated Nuclear Materials and Their Environmental, Safety and Health Vulnerabilities* (DOE 1993b).

As shown in **Table C-1**, approximately 82 percent of the HEU in spent nuclear fuel in the U.S. is stored at the Idaho National Engineering and Environmental Laboratory and the Savannah River Site. The remaining 18 percent is stored at eight other sites.

### IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

As shown in **Table C-2**, approximately 19.3 metric tons of uranium (MTU) in spent nuclear fuel is stored at the Idaho National Engineering and Environmental Laboratory (INEEL). Most of the spent fuel at INEEL is from naval propulsion and other government reactors and is stored primarily at the Idaho Chemical Processing Plant (ICPP). INEEL has also received spent fuel from university reactors and commercial reactors, as well as foreign research reactors that used U.S.-origin HEU. From 1953 to 1992, the ICPP processed spent nuclear fuel; in 1992, DOE ceased processing operations.

## SAVANNAH RIVER SITE

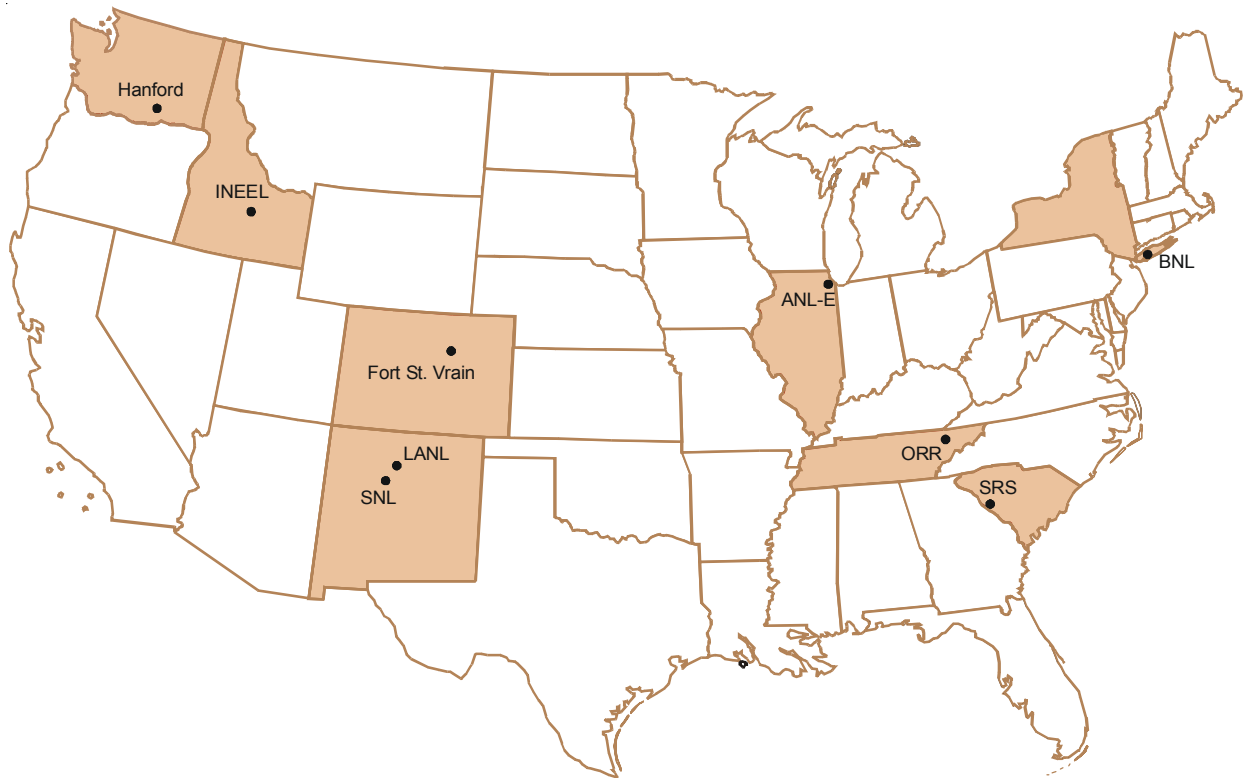
The Savannah River Site (SRS) has about 8.3 MTU in spent nuclear fuel, mostly from SRS production reactors. The remaining fuel is from foreign research, university, commercial, and other government-owned reactors (**Table C-3**). Currently, the SRS is accepting U.S.-origin HEU spent nuclear fuel from foreign research reactors to promote U.S. nuclear weapons nonproliferation policy objectives, by eventually eliminating HEU from civilian commerce worldwide. Foreign spent fuel is sent to the Savannah River Receiving Basin for Off-Site Fuel (RBOF) facility and the L Reactor disassembly basin.

## OTHER DOE SITES

In addition, seven other Department-owned sites and the Naval Nuclear Propulsion Program store spent nuclear fuel and other reactor irradiated nuclear material (**Table C-4**). Site inventories range from 15 kilograms of HEU to approximately 3.6 MTU.

HIGHLY ENRICHED URANIUM: STRIKING A BALANCE

Table C-1 Location and Quantity of HEU in Spent Nuclear Fuel



| Storage Site  | kg U            | kg U-235        |
|---|-----------------|-----------------|
| Idaho National Engineering & Environmental Laboratory (INEEL) | 19,281.4        | 12,952.6        |
| Savannah River Site (SRS)                                     | 8,257.9         | 5,441.8         |
| Other DOE Sites   |                 |                 |
| Argonne National Laboratory – East (ANL-E)                    | 16.2            | 10.4            |
| Brookhaven National Laboratory (BNL)                          | 275.9           | 222.1           |
| Hanford Site  | 230.7           | 63.3            |
| Oak Ridge Reservation (ORR)                                   | 695.6           | 613.6           |
| Sandia National Laboratory (SNL)                              | 523.4           | 406.8           |
| Miscellaneous Sites   | 4,475.5         | 3,436.1         |
| <b>Total HEU Spent Fuel in Storage</b>                        | <b>33,756.4</b> | <b>23,146.5</b> |

Notes:

- 1 Information is as of September 30, 1996.
- 2 Miscellaneous sites include the Los Alamos National Laboratory (LANL), Fort St. Vrain, and the naval reactor spent fuel in the possession of the U.S. Navy.

Table C-2 HEU Spent Fuel at INEEL

|   | kg U            | kg U-235        | % U-235    |
|---|-----------------|-----------------|------------|
| Advanced Test Reactor                           | 1,661.0         | 1,395.8         | 84%        |
| ARMF / CFMR                                     | 12.9            | 11.9            | 92%        |
| Berlin Experimental Reactor (BER-2)             | 9.2             | 4.0             | 44%        |
| Boiling Reactor Experiment V                    | 20.8            | 19.4            | 93%        |
| Engineering Test Reactor                        | 9.3             | 4.9             | 53%        |
| Enrico Fermi Atomic Power Plant                 | 3,874.3         | 992.8           | 26%        |
| Experimental Breeder Reactor - II               | 3,141.4         | 1,941.6         | 62%        |
| Experimental Propulsion Test Reactor            | 107.7           | 100.3           | 93%        |
| Fort St. Vrain Nuclear Generating Station       | 308.3           | 167.6           | 54%        |
| Gas-Cooled Reactor Experiment                   | 2.8             | 2.1             | 75%        |
| General Electric Test Reactor                   | 4.4             | 4.1             | 92%        |
| Heat Transfer Reactor Experiment                | 1.1             | 1.0             | 93%        |
| High Flux Beam Reactor                          | 63.4            | 50.7            | 80%        |
| Oak Ridge Research Reactor                      | 3.3             | 2.6             | 80%        |
| Naval Reactors                                  | 8,970.7         | 7,436.8         | 83%        |
| Pathfinder Atomic PWR Plant                     | 53.4            | 49.2            | 92%        |
| Peach Bottom Unit 1                             | 332.4           | 223.5           | 67%        |
| Power Burst Facility                            | 5.4             | 1.5             | 29%        |
| Shippingport Atomic Power Station (SAPS)        | 521.7           | 396.0           | 76%        |
| Special PWR Excursion Reactor Test              | 0.6             | 0.5             | 93%        |
| Stationary Medical PWR Plant 1A                 | 65.8            | 56.6            | 86%        |
| Systems for Nuclear Auxiliary Power             | 28.8            | 26.8            | 93%        |
| Transient Reactor Test                          | 14.9            | 13.9            | 93%        |
| TRIGA Reactors (Miscellaneous)                  | 12.8            | 8.8             | 69%        |
| University of Missouri – Rolla Reactor          | 38.0            | 33.3            | 87%        |
| University of Washington – Argonaut Reactor     | 3.9             | 3.6             | 93%        |
| Unknown   | 0.5             | 0.1             | 28%        |
| Vallecitos Boiling Water Reactor (BWR)          | 12.6            | 2.8             | 22%        |
| <b>Total HEU Spent Fuel in Storage at INEEL</b> | <b>19,281.4</b> | <b>12,952.2</b> | <b>67%</b> |

## Notes:

- 1 Information is as of September 30, 1996.
- 2 Information does not include naval reactor spent fuel stored at the Expended Core Facility.

HIGHLY ENRICHED URANIUM: STRIKING A BALANCE

Table C-3 HEU Spent Fuel at SRS

| Source of Spent Fuel                             | kg U           | kg U-235       | % U-235    |
|--|----------------|----------------|------------|
| Argonne Thermal Source Reactor                   | 3.2            | 3.0            | 93%        |
| ASTRA  | 3.6            | 2.5            | 68%        |
| Biological Research Reactor (JANUS)              | 2.8            | 2.6            | 93%        |
| Commercial (Miscellaneous)                       | 0.0            | 0.0            | 52%        |
| Denmark (DR-3)                                   | 2.9            | 2.2            | 76%        |
| Dresden – 1 Commercial Power Reactor             | 41.1           | 22.3           | 54%        |
| Elk River Reactor                                | 224.3          | 186.2          | 83%        |
| Experimental Boiling Water Reactor               | 30.7           | 28.3           | 92%        |
| Experimental Breeder Reactor – II                | 2.0            | 1.6            | 80%        |
| FMRB   | 8.2            | 7.2            | 88%        |
| FRG-1  | 4.4            | 3.6            | 82%        |
| Gas Cooled Reactor Experiment                    | 61.3           | 56.6           | 92%        |
| Georgia Tech Research Reactor                    | 4.5            | 4.0            | 90%        |
| Greek Research Reactor                           | 9.3            | 7.8            | 84%        |
| Heat Transfer Reactor Experiment                 | 4.0            | 3.4            | 85%        |
| Heavy Water Components Test Reactor              | 39.8           | 33.8           | 85%        |
| High Flux Isotope Reactor                        | 23.5           | 20.3           | 86%        |
| IAN – R1   | 3.1            | 2.8            | 91%        |
| Japanese Material Test Reactor (JMTR)            | 16.7           | 14.8           | 88%        |
| La Reina, RECH – 1                               | 3.9            | 2.4            | 61%        |
| MIT Research Reactor                             | 19.4           | 16.0           | 82%        |
| Mobile Low Power PWR Plant No. 1                 | 58.6           | 54.5           | 93%        |
| Oak Ridge Research Reactor                       | 21.1           | 17.1           | 81%        |
| Ohio State Research Reactor                      | 3.4            | 3.2            | 93%        |
| R Haut Flux (RHF) Reactor – France               | 25.5           | 20.8           | 81%        |
| R-2 Research Reactor                             | 16.6           | 12.0           | 72%        |
| Rhode Island Nuclear Science Center              | 8.5            | 7.7            | 91%        |
| Saphir – Switzerland                             | 11.5           | 7.8            | 68%        |
| Savannah River Site Production Reactors          | 7,295.5        | 4,624.4        | 63%        |
| Sodium Reactor Experiment                        | 156.0          | 143.4          | 92%        |
| University of Delft (HOR)                        | 4.0            | 3.1            | 77%        |
| University of Missouri Research Reactor Columbia | 103.6          | 90.7           | 88%        |
| University of Missouri Rolla Reactor             | 4.8            | 4.3            | 90%        |
| University of Virginia Reactor                   | 6.9            | 6.1            | 88%        |
| Unknown  | 0.2            | 0.2            | 97%        |
| Vallecitos Boiling Water Reactor                 | 4.0            | 1.0            | 25%        |
| Sterling Forrest fuel                            | 28.4           | 23.9           | 84%        |
| ANL Mixed Oxide                                  | 0.4            | 0.4            | 86%        |
| <b>Total</b>                                     | <b>8,257.7</b> | <b>5,442.0</b> | <b>66%</b> |

Note: Information is as of September 30, 1996.

Table C-4 Location of HEU Spent Fuel at Other DOE Sites

| Location and Source of Spent Fuel                        | Kg U           | Kg U-235       | % U-235    |
|--|----------------|----------------|------------|
| <b>Argonne National Laboratory – East</b>                |                |                |            |
| Chicago Pile 5   | 1.2            | 1.1            | 92%        |
| Experimental Breeder Reactor-II                          | 6.1            | 3.5            | 57%        |
| LMFBR Test Fuel  | 5.3            | 3.0            | 57%        |
| Miscellaneous Irradiated Fuel                            | 3.6            | 2.8            | 78%        |
| <b>Brookhaven National Laboratory</b>                    |                |                |            |
| Brookhaven Medical Research Reactor                      | 4.9            | 4.3            | 88%        |
| High Flux Beam Reactor                                   | 271.0          | 217.8          | 80%        |
| <b>Hanford Site</b>                                      |                |                |            |
| Experimental Breeder Reactor-II                          | 25.9           | 5.3            | 20%        |
| FFTF Fuel  | 1.0            | 0.4            | 40%        |
| LMFBR Test Fuel  | 203.8          | 57.6           | 28%        |
| <b>Oak Ridge Reservation</b>                             |                |                |            |
| Bulk Shielding Reactor                                   | 6.9            | 6.2            | 90%        |
| Health Physics Research Reactor                          | 104.1          | 96.9           | 93%        |
| High Flux Isotope Reactor                                | 575.4          | 501.9          | 87%        |
| Tower Shielding Reactor No. II                           | 9.2            | 8.6            | 93%        |
| <b>Sandia National Laboratory</b>                        |                |                |            |
| Annular Core Research Reactor                            | 125.0          | 35.7           | 29%        |
| Sandia Pulsed Reactor-II                                 | 139.0          | 129.4          | 93%        |
| Sandia Pulsed Reactor-III                                | 259.4          | 241.7          | 93%        |
| <b>Miscellaneous Sites (Storage Site in Parentheses)</b> |                |                |            |
| Fort St. Vrain (Fort St. Vrain)                          | 822.4          | 404.5          | 49%        |
| Naval Reactors (Possession of the U.S. Navy)             | 3,638.2        | 3,018.8        | 83%        |
| Omega West Reactor (Los Alamos National Laboratory)      | 14.9           | 12.8           | 86%        |
| <b>Total</b>   | <b>6,217.3</b> | <b>4,752.3</b> | <b>76%</b> |

Notes:

- Information is as of September 30, 1996.
- The Naval Reactors quantity does not include HEU spent fuel stored at the Knolls Atomic Power Laboratory and the Bettis Atomic Power Laboratory.





*The Idaho Chemical Processing Plant at INEEL recovered HEU from spent nuclear reactor fuel elements, mostly from government-owned reactors.*

*Shown is a view of workers inside the Idaho Chemical Processing Plant.*

