INEEL/CON-97-01161
CONF-980520--

UNIQUE CHALLENGES FOR STORAGE AND DISPOSAL OF DOE OWNED SNF AT INEEL

Toney A. Mathews
Lockheed Martin Idaho Technologies Company, Inc.
P. O. Box 1625, MS 5306
Idaho Falls, ID 83415
(208)526-8710; FAX (208)526-3484
tam2@INEL.gov

Work supported by the U. S. Department of Energy, Assistant Secretary for Environmental Management under DOE Idaho Operations Office Contract DE-AC07-94ID13223.

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible electronic image products. Images are produced from the best available original document.

Final Abstract
ICONE-6 Paper #6271

UNIQUE CHALLENGES FOR STORAGE AND DISPOSAL OF DOE OWNED SNF AT INEEL

Toney A. Mathews
Lockheed Martin Idaho Technologies Company, Inc.
P. O. Box 1625, MS 5306
Idaho Falls, ID 83415
(208)526-8710; FAX (208)526-3484
tam2@INEL.gov

ABSTRACT

Non-commercial Spent Nuclear Fuel (SNF) owned by the Department of Energy presents some unique challenges for interim storage as well as ultimate disposal in a repository. There is an important link between Yucca Mountain Repository work and the future needs of the DOE SNF program. Close coordination and early definition of acceptance criteria are essential.

Much of the Yucca Mountain Repository work has focused on commercial SNF which has very high structural integrity and a well documented set of characteristics and burn-up histories. In contrast, DOE non-commercial SNF at the Idaho National Environmental and Engineering Laboratory (INEEL) represents over two hundred fifty fuel types, much of which is degraded. DOE SNF degradation occurred during planned reactor excursions or as a result of mechanical damage during disassembly for post irradiation testing. Corrosion during storage in old water basin facilities has become a problem for many fuel types since reprocessing was discontinued at the INEEL in April 1992.

Fuel designs by DOE were centered around various test objectives in experimental reactors. The result was a proliferation of fuel types. Interest in enhanced heat transfer led to use of sodium as a bond between the fuel and cladding. The desire for smaller more compact reactors with higher power densities led to a variety of enrichments from less than 20% to greater than 90%. INEEL has most of the United States U-233 spent nuclear fuel, which came from breeder reactor concepts and consideration of a thorium fuel cycle. These various fuel types now must be placed in safe, stable interim dry storage. Emphasis is being placed on the use of commercially available dry storage designs and independent spent fuel storage installations licensed under NRC criteria. A lot of technological development is being done to characterize fuels that do not have the documented fabrication and operational histories of commercial LWR fuels. Program objectives are safe interim storage and least cost transition to geological repository storage.

6th International Conference on Nuclear Engineering
ICONE-6
May 10-15, 1998

UNIQUE CHALLENGES FOR STORAGE AND DISPOSAL OF DOE OWNED AT INEEL

Toney A. Mathews
Lockheed Martin Idaho Technologies Company, Inc.
P. O. Box 1625, MS 5306
Idaho Falls, ID 83415
(208)526-8710; FAX (208)526-3484
tam2@INEL.gov

INTRODUCTION

Department of Energy (DOE) owned non-commercial spent nuclear fuel (SNF) is stored in numerous facilities around the United States and in foreign research reactors. An environmental impact statement (DOE/EIS-0203-F, April 1995) and the subsequent record of decision (DOE/ROD, May 30, 1995) has the domestic spent nuclear fuel being consolidated by fuel type at three DOE installations: Hanford Reservation, Idaho National Engineering and Environmental Laboratory (INEEL), and Savannah River Site (SRS). Foreign research reactor SNF is being consolidated at INEEL and SRS to reduce nuclear proliferation concerns regarding highly enriched uranium (HEU). Ultimate disposal of DOE owned non-commercial SNF is planned to be in a geological repository.

The INEEL has more than two hundred fifty individual spent nuclear fuel types. Activities at INEEL to manage these fuel types are leading to solutions which have applicability to almost all of DOE owned SNF. The focus at INEEL is to reduce near-term vulnerabilities associated with the SNF and storage facilities. Along with reducing vulnerabilities, the SNF is being consolidated to reduce the cost of storage and fuel management. An essential part of the consolidation is to get all INEEL SNF positioned for transport out of the State of Idaho to a geological repository by 2035 (Settlement Agreement, U.S. District Court for the District of Idaho, October 17, 1995).

A carefully coordinated program between interim consolidation and storage activities at INEEL and the DOE Office of Civilian Radioactive Waste Management (OCRWM) preparation of a geological repository at Yucca Mountain, Nevada, is essential for the successful cost effective ultimate disposal of DOE-owned non-commercial SNF at INEEL.

CATEGORIES OF INEEL FUEL TYPES

There are a number of ways to group the various spent nuclear fuels stored at the INEEL. In developing a strategy to remove SNF from the inadequate storage basins in CPP-603 (1950's vintage pools at the Chemical Processing Plant), fuels were grouped according to common characteristics which would facilitate optimum use of tools, repackaging configurations, safety analyses and new storage locations. Likewise, it is useful to categorize INEEL spent nuclear fuel going to the repository according to characteristics which facilitate an optimum approach to stable, interim storage and ultimate repository disposal. An INEEL Spent Nuclear Fuel Task Team developed seven categories based on this objective (INEEL SNF Task Team Report, March 1997). The categories along with information about enrichment, volume and weight are shown in Figure 1, which was taken from the referenced report. The categories were developed based on chemical composition (e.g., metal, oxide, carbide), enrichment, fuel integrity (disrupted or intact), and special cases (e.g., U-233/thorium fuels or reactive metal composition).

PLACE FIGURE 1 HERE

Category 1 is intact oxide fuels of various enrichments. These fuels are physically and chemically stable. Repository considerations are generally those which would be applied to commercial SNF, except for added criticality concerns for the higher enrichments. Several fuel types are commercial SNF which were brought to INEEL for testing purposes. Various PWR fuels are stored wet and dry at the INEEL's Test Area North facility. Higher enrichments are found in fuels from test or prototype reactors. A test reactor example is the ternary oxide ceramic fuel from the Power Burst Facility (PBF). Prototype reactor fuel (high enriched) is from the Shippingport Pressurized Water Reactor. The PBF and Shippingport fuels are currently stored in good wet storage facilities at INEEL.

Category 2 consists of low enriched uranium oxide fuel which has been disrupted by tests, destructive examination or an operational accident. The largest quantity of fuel in this category is the Three Mile Island Unit 2 (TMI-2) core debris. This fuel is stored wet in vented containers at Test Area North. It presents some of the most challenging obstacles to repository disposal due to water in the material, fission product leachability, uncertain characteristics relative to criticality analysis, and the presence of cadmium (a RCRA waste) from disrupted control rods.

Category 3 consists of medium and highly enriched TRIGA fuel. TRIGA fuel has been widely used in research reactors around the world. TRIGA fuel at INEEL is being moved under the provision of a court order to remove all SNF from the CPP-603 pools by December 31, 2000. Stainless steel clad TRIGA fuel has been moved to modern wet storage in CPP-666, and aluminum clad TRIGA fuel will be moved to dry storage. Repository concerns are potential criticality of high enriched TRIGA fuel, diffusion of hydrogen from the uranium/zirconium hydride fuel meat, and possible breach of aluminum cladding (TRIGA is clad with stainless steel, zirconium or aluminum). Non-proliferation actions supported by DOE and the plan to consolidate DOE-owned SNF by fuel type will bring over 500 shipments to the INEEL during the next twenty years (DOE/EIS-0203-F, April 1995). Much of this fuel is TRIGA.

Category 4 consists of highly enriched uranium metal or uranium alloy fuels. These fuels were used in a variety of experimental reactors. An example of this SNF is the uranium/molybdenum alloy Fermi fuel. Repository concerns are the potential criticality of highly enriched uranium and pyrophoric reaction of the uranium metal. The INEEL has considerable experience with handling uranium metal safely. Although not a part of this category, a depleted uranium fuel filter (DUFF) from the Coupled Fast Reactivity Measurement Facility reactor at INEEL was removed from the reactor core as part of a defueling operation. The DUFF was first flooded with water in its storage container to passivate the fuel prior to shipment from Test Reactor Area (TRA) to the Chemical Processing Plant (CPP). The DUFF was shipped, then dried at CPP prior to being placed in dry storage in an above ground storage facility at CPP (Irradiated Fuel Storage Facility). Drying operations were carefully controlled to prevent any pyrophoric reaction.

Category 5 consists of uranium and thorium carbide highly enriched fuels. Most of these nuclear fuels were part of test and commercial reactor projects utilizing a thorium/uranium-233 fuel cycle often in gas-cooled reactors. Some fuel types in the category are uranium carbide or uranium oxide in graphite rods clad with metal (e.g., sodium reactor experiment fuel). (INEEL SNF Task Team Report, March 1997). The dominant quantity of SNF in this category is from the Fort St. Vrain (FSV) reactor operated by Public Service of Colorado. All FSV fuel is either in dry storage at INEEL (about 1/3) or at FSV, Colorado (about 2/3). DOE owns all of this fuel as a result of an agreement reached with Public Service of Colorado on February 9, 1996.

Another Category 5 fuel in large quantities at INEEL is from the Peach Bottom reactor. This fuel is currently stored dry in below ground wells at the CPP. Periodic inspection has identified some corrosion of the fuel assemblies in "first generation" wells due to moisture intrusion. Over the next few years, these fuel assemblies will be moved to "second generation" wells, which are better designed to exclude moisture. One Peach Bottom assembly which had been stored in a transportation cask was successfully stored in a second generation well on December 15, 1997. This is the first operational activity to move or store fuel in the CPP-749 wells in many years. A total of forty-five more assemblies will be moved from first to second generation wells.

Category 5 fuels present significant repository challenges because of physical, chemical, and nuclear characteristics which are far different from commercial Light Water Reactor (LWR) fuels. The graphite matrix which served as a moderator is potentially combustible. Metallic carbides could react with water producing flammable gases and the highly enriched constituents (U-235 and U-233) are a criticality concern.

Category 6 fuels consist of uranium oxide and thorium oxide fuel. This fuel is from the Shippingport Light Water Breeder Reactor (LWBR) program. The purpose was to produce fissile uranium 233 from thorium 232 in a light water reactor. It was part of thorium fuel cycle experiments designed to provide an alternate fissile reactor fuel because of limited available fissile uranium 235. Some irradiated and unirradiated LWBR fuel assemblies are stored dry in

CPP-749 second-generation wells. The fuel is in excellent physical condition, and is protected by Zircaloy-4 cladding. Repository considerations are potential criticality of the highly enriched uranium (U-235 and U-233).

Category 7 consists of various fuel types, some are relatively stable and some present significant challenges to repository disposal. Some of the most challenging fuel types are the sodium-bonded metallic fuels from Experimental Breeder Reactor-II and the Fermi reactor blanket. Sodium was bonded between the metallic fuel meat and the cladding to improve heat transfer characteristics. EBR-II fuel is stored at the Chemical Processing Plant and Argonne National Laboratory – West (ANL-W). Test results regarding fuel condition in wet storage and methods of removing the sodium will be covered later in this paper. High enrichment criticality concerns and RCRA characteristics (sodium reactivity) associated with the fuel make it unacceptable for direct repository disposal. Another fuel type in this category is a large quantity of aluminum-clad, highly enriched uranium fuel from the Advanced Test Reactor (ATR).

Most of the ATR fuel is in relatively good physical condition because of storage in a modern storage pool at the CPP, but continued wet storage of aluminum-clad fuel is a concern. ATR fuel stored in CPP-603 is severely corroded and will be dried and stored in the IFSF in the next few years. Repository concerns are criticality of the highly enriched uranium and deterioration of the fuel and cladding.

INTERIM STORAGE STRATEGY

The INEEL is pursuing a four point strategy in dealing with spent nuclear fuels from legacy operations, current receipts, and anticipated future receipts as allowed by the 1995 Settlement Agreement. The strategy is designed to achieve ultimate removal of all spent nuclear fuel from the INEEL by the year 2035 (Settlement Agreement, October 16, 1995).

The first point of the strategy is stabilization of SNF which has deteriorated due to corrosion and/or was disrupted by testing and destructive examination. Until reprocessing was discontinued for economic reasons in 1992, these fuels would have been stabilized by separation of recoverable uranium from the fission products and other constituents of the fuel. Continued wet storage of some fuels after 1992 presented significant safety concerns due to the potential for structural failure of the fuel storage system and reconfiguration in a critical geometry in the bottom of storage pools. An expedited program was begun in 1993 to deal with the highest risk fuels in CPP-603. This effort has moved forward successfully, with all milestones being met ahead of schedule. Stabilization has involved repackaging fuels in containers which assure structural integrity for a safe storage configuration. A similar approach is being applied to SNF in storage at Test Reactor Area, Power Burst Facility and Test Area North.

The second point of the strategy is consolidation of INEEL spent nuclear fuel to the Chemical Processing Plant in existing wet or dry storage and into modern dry storage facilities yet to be built. This consolidation will reduce the surveillance and maintenance cost of SNF storage and release older facilities for decontamination and demolition (D&D).

A key element of this part of the strategy is to license, build and operate new dry storage facilities to Nuclear Regulatory Commission (NRC) regulations. Initially, this is more costly and time-consuming , but the experience with NRC licensing for storage and transportation is expected to save time and money in the long run. Savings will be in the construction of additional modular storage units and in aligning with the requirements of an NRC licensed geological repository. Savings are also expected by taking maximum advantage of commercial nuclear Independent Spent Fuel Storage Installation (ISFSI) experience. In fact, DOE is in the process of transferring the Fort St. Vrain ISFSI NRC license from Public Service of Colorado to DOE-Idaho. A license application has been submitted for construction of an ISFSI at the Chemical Processing Plant for storage of TMI-2 core debris, and a license application is expected soon for an ISFSI at CPP to allow dry storage of additional DOE-owned SNF at the INEEL.

The third point of the strategy is to move all INEEL spent nuclear fuel into "road ready" dry storage by the year 2023. At this point all SNF will be in interim storage which provides maximum protection of the Snake River Plain Aquifer, and it also positions SNF to be removed from the State of Idaho by 2035. Both dates are part of the agreement between DOE, the U.S. Navy and the State of Idaho (Settlement Agreement, October 16, 1995).

The fourth point of the strategy is to utilize the National Spent Nuclear Fuel Program to cost effectively meet the developmental needs of the INEEL Spent Nuclear Fuel Program. This includes technological development for fuel packaging and characterization, developing alternatives to condition fuels so that they meet the repository acceptance criteria, and participation in transportation decisions which must account for the needs of all DOE laboratories and facilities. The INEEL is designated the Lead Laboratory for Spent Nuclear Fuel, and the DOE-Idaho Operations Office directs this national effort.

ACTIVITIES REGARDING UNIQUE FEATURES OF SNF

As the Lead Laboratory for SNF, the INEEL has undertaken several activities to prepare for geological repository disposal of DOE-owned spent nuclear fuel. Many other activities must be undertaken to resolve the multitude of technical problems related to meeting the repository acceptance criteria, the most basic of which is establishing a technically sound and feasible acceptance criteria early enough to permit cost effective planning for each fuel type.

One of the repository problems for DOE is the EBR-II and Fermi blanket fuel containing a metallic sodium bond between the fuel and cladding to enhance heat transfer. After lengthy irradiation in a reactor, the sodium is absorbed in the fuel and can only be separated by chemical processing (DOE Draft EIS, Electrometallurgical Treatment, DOE/EA-1148, January 29, 1996). Both of these nuclear fuels are stored at the INEEL, some at the Chemical Processing Plant and some at Argonne National Laboratory – West.

Various means of removing the sodium have been studied, but the most promising is electrometallurgical treatment. Conceptually, this process refines the uranium metal resulting in recovered, pure uranium metal for storage as highly enriched uranium (HEU). The sodium is stabilized as sodium chloride (table salt), and the fission products and transuranics are stabilized as High Level Waste (HLW) and prepared for disposal. Stainless steel hulls and other undissolved metals (i.e., zirconium and molybdenum) are melted and cast into ingots for disposal. The ingots are highly corrosion resistant. Keeping the refined uranium in HEU form is not desirable, so it would be blended down with depleted uranium and potentially used as feedstock for commercial reactors. The molten salt of the electrorefiner is cleaned of fission products and transuranics using a zeolite. The resulting crystalline powder is converted into a sealed ceramic cylinder using a hot isostatic press. A demonstration of this technology is planned at the ANL – W facility at the INEEL (DOE Draft EIS, Electrometallurgical Treatment, DOE/EA-1148, January 29, 1996). This demonstration project is also important in resolving a problem with leaking canisters. In early 1998, sixteen EBR-II canisters from CPP-603 were returned to ANL-W for study. Eleven of these were identified as leaking past the swagelok closure fitting during inspections in December 1994. Ultrasonic examination has confirmed the water intrusion. These sixteen canisters will remain at ANL-W for treatment.

Criticality concerns associated with HEU fuels call for innovative solutions. Analysis to justify as dense a packing as possible is one approach. The INEEL has some of the best criticality analysis capabilities in the DOE complex. This capability has recently been bolstered by a technological exchange with the Russian Federation. Lockheed Martin Idaho Technologies Company (LMITCO) engineers at the INEEL have utilized four series of criticality experiments performed at the Russian Research Center "Kurchatov Institute" to validate and update the computer codes used here. LMITCO capabilities in this area are available to other DOE facilities to advance the common interest in criticality analysis (Trip Report, JBB-56-97, November 4, 1997).

Another technique being investigated to handle HEU concerns is co-disposal. In this concept, spent nuclear fuel and ceramic logs of high level waste are put in a common container. This maximizes the use of available repository space while providing the necessary separation of SNF to eliminate criticality concerns.

Packaging and storage decisions being made now and over the next few years can significantly impact long-term costs. Several studies of packaging and storage options have been conducted to take maximum advantage of having a few standard sizes and designs for storage canisters. A scoping study was done by the INEEL Spent Nuclear Fuel Task Team. Nominal canister diameters of 10", 12", 17" and 24" to 27" with lengths of ten and fifteen feet were considered (INEEL Spent Nuclear Fuel Task Team Report, March 1997). Because of the numerous fuel types at INEEL, several types may be placed in a single canister. Standardized baskets will be used to divide the canister into discrete spaces for each fuel type. Pieces of spent nuclear fuel will be placed into smaller containers which can be placed inside a standard grid. Baskets will be in standard lengths to allow 1, 2, or 3 tiers per canister. Some fuels require much shorter baskets, potentially allowing more tiers.

By evaluating geometric possibilities and fissile mass loading constraints, a reasonable estimate of the number and type of canisters can be made. Additional study will be essential to assure that the resultant investment in canisters meets interim storage needs and repository acceptance requirements.

INEEL CAPABILITIES REGARDING SNF

The INEEL is uniquely suited to support the long-term programmatic needs for managing DOE-owned spent nuclear fuel. The Lead Laboratory designation carries a significant responsibility to use INEEL experience with multiple fuel types to benefit other DOE SNF facilities.

The INEEL is leading the DOE complex in NRC licensing experience under 10CFR50, Parts 71 and 72. This experience should result in long-term savings for the INEEL SNF program and other DOE facilities.

At the INEEL, Lockheed Martin Idaho Technologies Company has developed and executed very successful actions to deal with a wide variety of SNF problems. At the same time, operators have attained excellent performance in Conduct of Operations. Lessons learned and techniques of continuous improvement are available to share with other DOE SNF facilities.

The INEEL seeks cooperative efforts with other DOE labs to resolve the technological and integration needs of meeting repository acceptance criteria. A carefully coordinated effort for technology development can minimize duplicate efforts and capitalize on the unique strengths of each laboratory.

REFERENCES

1. INEEL Spent Nuclear Fuel Task Team, "Technical Strategy for the Management of INEEL Spent Nuclear Fuel," March 1997.
2. TRIP REPORT – First Joint U.S./Russian Federation Criticality Safety Benchmark Experiments, JBB-56-97, November 4, 1997.
3. SETTLEMENT AGREEMENT Resolving Public Service Company of Colorado versus Batt, No. CV-91-0035-S-EJL (D. Id.) and United States v. Batt, No. CV-91-0054-S-EJL (D. Id.).
4. U. S. DEPARTMENT OF ENERGY, "DOE-Owned Spent Nuclear Fuel Interim Storage Plan," DOE/SNF/pp-003, Revision 0, November 1995.
5. U. S. DEPARTMENT OF ENERGY, "DOE-Owned Spent Nuclear Fuel Program Plan," DOE/SNF/pp-001, Revision 0, November 1995.
6. U. S. DEPARTMENT OF ENERGY, "Draft Environmental Assessment, Electrometallurgical Treatment Research and Demonstration Project in the Fuel Conditioning Facility at Argonne National Laboratory – West," DOE/EA-1148, January 29, 1996.
7. U. S. DEPARTMENT OF ENERGY, Final Environmental Impact Statement Concerning Foreign Research Reactor Spent Nuclear Fuel, DOE/EIS – 0218F, February 1996.
8. U. S. DEPARTMENT OF ENERGY, "Guidelines for Meeting Repository Requirements for Disposal of U. S. Department of Energy Spent Nuclear Fuel (Draft)," DOE/SNF/REP-009, March 28, 1997.
9. U. S. DEPARTMENT OF ENERGY, "National Spent Nuclear Fuel Program Preliminary Report, RCRA Characteristics of DOE-Owned Spent Nuclear Fuel," DOE-SNF-REP-002, Revision 3, July 1995.
10. U. S. DEPARTMENT OF ENERGY, Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement," DOE/EIS-0203-F, April 1995.
11. U. S. DEPARTMENT OF ENERGY, "Record of Decision, Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs," May 30, 1995.
12. U. S. DEPARTMENT OF ENERGY, "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," Vol. I, November 1993.

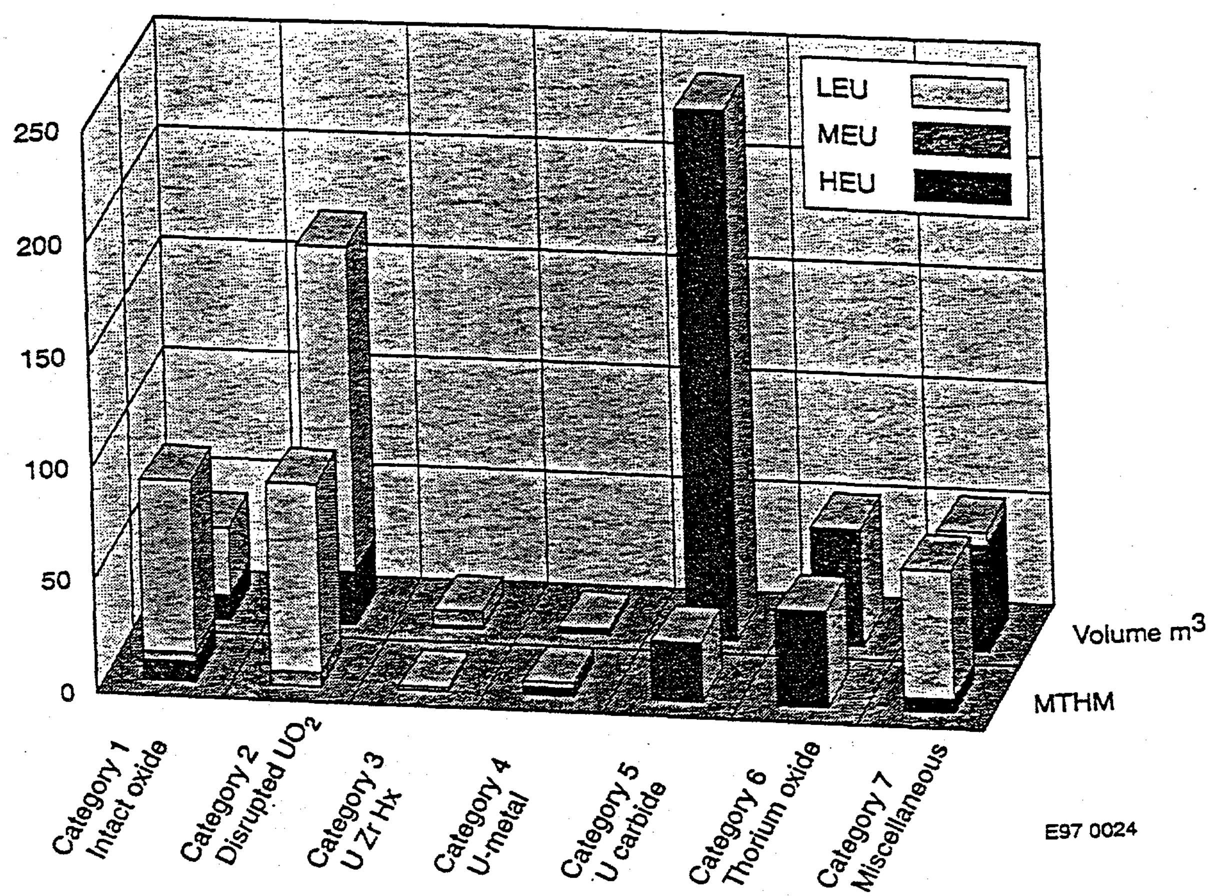

Figure 1 INEEL SNF inventory by category.