Foreign Research Reactor Uranium Supply Program: The Y-12 National Security Complex Process

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The Foreign Research Reactor (FRR) Uranium Supply Program at the Y-12 National Security Complex supports the nonproliferation objectives of the HEU Disposition Program, the Reduced Enrichment Research and Test Reactors (RERTR) Program, and the United States FRR Spent Nuclear Fuel (SNF) Acceptance Program. The Y-12 National Nuclear Security Administration (NNSA) Y-12 Site Office maintains the prime contracts with foreign governments for the supply of Low-Enriched Uranium (LEU) for their research reactors. The LEU is produced by down blending Highly Enriched Uranium (HEU) that has been declared surplus to the U.S. national defense needs. The down blending and sale of the LEU supports the Surplus HEU Disposition Program Record of Decision to make the HEU non-weapons usable and to recover the economic value of the uranium to the extent feasible. This program supports the important U.S. government and nuclear nonproliferation commitment to serve as a reliable and cost-effective uranium supplier for those foreign research reactors that are converting or have converted to LEU fuel under the guidance of the NNSA RERTR Program. In conjunction with the FRR SNF Acceptance Program which supports the global nonproliferation efforts to disposition U.S.-origin HEU, the Y-12 FRR Uranium Supply Program can provide the LEU for the replacement fuel fabrication. In addition to feedstock for fuel fabrication, Y-12 supplies LEU for target fabrication for medical isotope production. The Y-12 process uses supply forecasting tools, production improvements and efficient delivery preparations to successfully support the global research reactor community.

Y-12 Foreign Research Reactor Supply Program Overview

Y-12 supplies foreign research reactors with low enriched uranium (LEU) at 19.75 wt. % ^{235}U under the Foreign Research Reactor (FRR) Uranium Supply Program. The LEU is produced at Y-12 by down blending U.S.-origin highly enriched uranium (HEU). In a 1994 Presidential declaration 174 metric tons (MT) of HEU were declared surplus to national security needs by a 1995 presidential order. Although current LEU production is primarily in the form of uranium metal, Y-12 production processes have the capability to provide various forms and enrichments of LEU, depending on research reactor requirements.

In keeping with the commitment made by the U.S. to permanently remove the declared surplus HEU from the U.S. defense stockpile and to use it for peaceful uses to the extent possible, the HEU Disposition Program, under the Office of Fissile Material Disposition, manages and integrates the surplus HEU disposition activities. The down blending and sale of the LEU for FRR fuel supports the Record of Decision for the Surplus HEU Disposition Program to make the material non-weapons usable and to recover the economic value of the uranium to the extent feasible.

As of the end of January 2010, over 131 MT of surplus HEU have been down blended and approximately 3.1 MT have been down blended at Y-12 for research reactor fuel feedstock. In 2005, an additional 200 MT were declared excess to weapons needs. Between the two surplus declarations, approximately 10 MT have been designated for disposition to research and test reactor fuel and targets for medical isotope production through at least 2016.

The FRR uranium supply program supports the important U.S. government nuclear nonproliferation commitment to serve as a reliable and cost-effective supplier of feed material for those foreign research reactors that are converting or have converted to LEU fuel under the guidance of the NNSA Reduced Enrichment for Research and Test Reactors (RERTR). The Y-12 NNSA Site Office is authorized to administer the FRR uranium supply contracts with foreign governments in accordance with Section 54a of the Atomic Energy Act of 1954, as amended, and Section 3112 (d) and (e) of the United States Enrichment Corporation (USEC) Privatization Act of 1996. DOE is authorized to distribute special nuclear material to countries who have entered into an Agreement for Cooperation with the U.S. Government concerning peaceful uses of nuclear energy and that DOE may sell enriched uranium to “any State or local agency or nonprofit, charitable, or educational institution for use other than the generation of electricity for commercial use.” In addition, DOE may now sell LEU to commercial research reactors as long as the material is not necessary for national security needs; the sale will not have an adverse impact on the domestic

uranium industry; and the price is not less than the fair market value of the material.

LEU Supply Process

The research reactor representative submits an expression of interest to Y-12 specifying the LEU requirements, including quantity by calendar year, desired delivery schedule by quarter, enrichment (19.75% weight percent ^{235}U, typically) and material form. Y-12 evaluates the request and determines material availability. At the customer's request, Y-12 provides a cost proposal. If the quoted price is accepted, the customer sends a letter of intent and Y-12 provides a draft contract with standardized General Terms and Conditions to begin contract negotiations.

The successful completion of the uranium supply contract is contingent on the timely submission and receipt of an export license issued by the U.S. Nuclear Regulatory Commission. The export license process is often the limiting factor for finalizing the delivery schedule because it requires NNSA and/or State Department review and approval and foreign government assurances for the peaceful use of the requested enriched uranium. The NNSA Y-12 contracts require the customer to agree to utilize the Y-12 supplied, U.S.-origin uranium in the reactors listed in the contract as well as in the export license application where the ultimate end use of the material is specified.

The LEU demand for foreign research and isotope production reactors is approximately 1,500 to 2,000 kilograms per year and is expected to increase as reactors convert from HEU to LEU. As the global LEU demand increases, it is important for a research reactor to have a reliable fuel supply. NNSA Y-12 encourages multi-year supply contracts because of several mutual benefits. The customer receives a competitive base price with the option to negotiate a lower base price each year, assurance of fuel feedstock supply, and a high quality product. An export license application can be submitted for multiple deliveries to accommodate multi-year supply contracts, thereby reducing administrative costs and potential delays in deliveries.

Y-12 benefits include better production planning and campaigning efficiencies, which results in lower production costs for the customer. Also, Y-12 can assure production capacity is available to meet the demands for LEU. In addition, the multi-year contracts provide a long-term disposition path for surplus HEU.

Pricing Policy

Y-12 utilizes a DOE pricing policy developed specifically for DOE contracts executed for the sale of LEU to authorized users for use in foreign research and test reactors. This pricing policy was developed to assure competitive pricing for NNSA sales of uranium to foreign research reactors in order to attract worldwide research reactor community support for the nonproliferation objectives of the RERTR and FRR SNF Acceptance Program. The policy requires that the LEU be sold at fair market value as well as requiring full cost recovery. Because of the extreme fluctuations in the uranium market over the past several years, implementation of the NNSA pricing strategy was modified from month-end spot prices to an averaging over a period to provide the fair market value to the FRR customer. The current pricing policy is based on the Y-12 costs to produce the LEU metal plus the average market value for 19.75% enriched uranium. The average market value, which includes the sum of the published uranium component market prices for uranium feed and separative work units (SWU), typically, averaged over the two quarters prior to contract negotiation, is used to calculate the corresponding market price per kilogram to be charged for 19.75% LEU.

In recognition of the uranium market fluctuations and the objective to provide the fair market value to its FRR customers, NNSA includes in new contracts an option for the FRR customer to negotiate a new base price if the average market value decreases below the base price of the component values in the contract. The Y-12 processing costs have to be incorporated into the price since Y-12 is a government facility which requires its operations to be full cost recovery.

In support of the NNSA Office of Global Threat Reduction and the FRR Spent Nuclear Fuel Acceptance Program goal for the safe, secure removal of U.S.–origin HEU from foreign research reactors, NNSA often negotiates the removal of HEU by offering an equivalent LEU credit based on the net value of the material to be returned. The FRR can apply the LEU credit to an order under a LEU supply contract with NNSA Y-12.

Ultimately, Y-12 strives to provide the FRR customer with the most fair and beneficial price based on the current state of the uranium market. Y-12's customer base includes research reactors in Europe, Asia, North and South America, and Australia.

LEU Production Process

Y-12 employs a molten metal casting process to down blend the surplus HEU with either depleted or natural uranium to nominally 19.75 weight percent ^{235}U. The HEU is selected based on chemical analysis and

availability. The feed materials are melted in a vacuum induction furnace and cast into a right angular cylinder (or hollow log), which has a critically safe geometry.

Samples are drilled from the hollow log for analysis to ensure enrichment, uranium isotopic composition and impurities meet the material specifications. The hollow logs are broken in a hydraulic press, and then sheared to make broken metal pieces ranging in size from 80 to 300 grams. The broken metal is loaded into carbon steel or stainless steel cans with press-fit lids under an argon atmosphere. The cans are 4.25 inches by either 4.75 or 8.75 inches tall and are lined with either aluminum or carbon steel mesh to minimize movement of the material during transport.

When a customer's order is placed, then the cans are loaded into the selected shipping container certified for international transport of fissile material. A Mylar tamper indicating device is applied to the cans and/or shipping container. The containers are then staged for shipment. Y-12 coordinates with the customer's transportation services company to develop the shipping logistics and to execute the delivery.

Y-12 LEU Quality

There are over 250 research reactors worldwide, many of which operate using LEU fuel enriched from 5% to less than 20% in ^{235}U. The primary feed material form provided is uranium metal which is used to produce uranium silicide, uranium aluminum, or uranium titanium fuels. Some reactors also need U_3O_8 and UO_2 oxides. International initiatives guided by the RERTR Program are continuing to convert several of those remaining reactors using HEU into LEU fueled reactors.

The origin of the material in the production of LEU for the research reactor community is the major contributor to the quality of the LEU product. At Y-12, the LEU is produced by down blending weapons-grade HEU material with carefully selected diluent. Reprocessed material is usually less suitable due to the minor uranium isotope concentrations and the processing required to remove the impurities.

Efforts have been made in the past by research reactor suppliers to agree upon a worldwide unified technical specification for LEU. An American Standards and Test Materials (ASTM) standard specification (ASTM specification C-1462-00) was developed in order to facilitate supplies of LEU for fabrication of research reactor fuel elements. However, the effort to develop one specification that met the different organizational needs created a specification that is not acceptable to many research reactor

customers. For example, C-1462-00 has higher ^{234}U, ^{236}U, and transuranic element limits to allow the use of reprocessed uranium, which is not acceptable to some of the fuel fabricators and reactor users.

Consequently, Y-12 developed a standard specification for LEU based on its understanding of the material quality and the requirements of the various FRR customers. By producing LEU that meets a standard specification, Y-12 is able to maintain an inventory of LEU metal in support of current and future NNSA uranium supply contracts.

All the limits (except for dysprosium) in the Y-12 LEU Standard Metal Specifications for Research and Test Reactors are equal to or less than the ASTM-C-1462-00 specification limits. Table 1 shows a comparison of the specification limits for several of the parameters between the Y-12 LEU metal produced from down blended HEU and the ASTM-C-1462-00 standard specification limits.

Standardization has enabled Y-12 to respond quicker to FRR customer requests by maintaining an LEU inventory that meets a standard specification and it has simplified production requirements and quality control checks which have improved Y-12's efficiency to prepare LEU orders for delivery.

Y-12 continues to evaluate ways to standardize the uranium metal form that is provided to its FRR customers. The current form is broken metal with irregular shaped pieces. One objective is to cast material into small, regular shapes at a more uniform mass that would meet a customer's equipment and process requirements. Several mold designs have been tested on surrogate material and efforts continue to develop an acceptable product. A standard form will also greatly optimize production efficiency by reducing material handling and packaging requirements.

Y-12 can provide uranium oxide ($U_3 O_8$) and metal plates or coupons and other LEU assays. Since these are not the normal form supplied by Y-12 the production costs will be higher. Y-12 is actively involved in the development of new LEU fuels in support of the RERTR Program assisting reactors to convert from HEU to LEU fuel. Y-12 is developing and validating a production oriented, monolithic uranium molybdenum (U-Mo) foil fabrication process. Between 2006 and 2009, Y-12 produced multiple U-Mo foils and coupons for testing and evaluation.

Table 1. Comparison of Y-12 Specification to ASTM-C-1462-00

			Y-12 LEU Metal	ASTM
Element	**Symbol**	**Units**	**Y/GNSS-05-02 r2**	**C1462-00**
Uranium	U	wt %	99.88%	99.85%
U-232	U-232	µg/gU	0.002	0.002
U-234	U-234	wt %	0.26%	1.00%
U-235	U-235	wt %	19.75%	19.75%
U-236	U-236	µg/gU	4,600	40,000
Trans-U (Alpha)	TRU	Bq/gU	100	250
Activation Products	ActProd	Bq/gU	100	
Fission Products	Gamma	Bq/gU	600	600
Carbon	C	µg/gU	350	800
Cobalt	Co	µg/gU	5	10
Dysprosium	Dy	µg/gU	5	Sum < 3
Europium	Eu	µg/gU	2	Sum < 3
Gadolinium	Gd	µg/gU	1	Sum < 3
Lead	Pb	µg/gU	5	10
Lithium	Li	µg/gU	2	10
Manganese	Mn	µg/gU	24	50
Phosphorus	P	µg/gU	50	100
Samarium	Sm	µg/gU	2	Sum < 3
Silicon	Si	µg/gU	100	250
Total Impurities	TotImp	µg/gU	1,200	1,500
Equivalent Boron Content			3	4

Summary

The Atoms for Peace initiative launched by President Eisenhower in 1954 and the creation of the International Atomic Energy Agency were successful in establishing research reactors around the world. The Department of Energy NNSA and Y-12 is honored to support the research reactor community by supplying enriched uranium.

The Y-12 process has resulted in a reliable and cost-effective FRR uranium supply program. The Y-12 supply of high-quality LEU is essential to the present and future successful operation of the world's research reactors.