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Status of the TRIGA Shipments to the INEEL from Europe

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Abstract

This paper reports the activities underway by the United States Department of Energy (DOE) for returning Training, Research, Isotope, General Atomics (TRIGA) spent nuclear fuel (SNF) from foreign research reactors (FRR) in four (4) European countries to the Idaho National Engineering and Environmental Laboratory (INEEL). Those countries are Germany, Italy, Romania, and Slovenia. This is part of the "Nuclear Weapons Nonproliferation Policy" of returning research reactor SNF containing uranium enriched in the United States. This paper provides a describes the results of a pre-assessment trip in September, 1997, to these countries, including: history of the reactors and research being performed; inventory of TRIGA SNF; fuel types (stainless steel, aluminum, or Incoloy) and enrichments; and each country plans for returning their TRIGA SNF to the INEEL.

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Background

In February 1996, the U.S. Department of Energy (DOE), in consultation with the U.S. Department of State (DOS), issued the *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* (DOE/EIS-218F). On May 13, 1996, DOE announced its new foreign research reactor (FRR) spent nuclear fuel (SNF) program in a Record of Decision (ROD). The purpose of the acceptance policy is to support the broad United States' nuclear nonproliferation policy calling for the reduction and eventual elimination of the use of highly enriched (weapons-grade) uranium in civil commerce worldwide.

The Savannah River Site (SRS) is to receive all the aluminum based (material test reactor, MTR) SNF and the Idaho National Engineering and Environmental Laboratory (INEEL) is to receive the Training, Research, Isotope, General Atomics (TRIGA) SNF. There are 41 countries that could participate in the program of which 19 countries have TRIGA SNF. There are 20 metric tons of material available worldwide that could be returned to the United States, of which 1 metric ton is TRIGA SNF.

This FRR SNF acceptance policy expires May 12, 2006. An eligble country desiring to participate in this policy must have entered into formal agreement with the United States prior to May 12, 2006 and have either converted or shut down their reactor by May 12, 2006. The policy provides a three (3) year period, until May 12, 2009, to allow SNF removed from the research reactor by May 12, 2006 to cool down before being shipped. The United States will not extend the policy beyond May 12, 2006 or the acceptance period past May 12, 2009. All countries will need to be prepared to provide their own disposition of their SNF after the policy period is over.

The ROD also identified financing arrangments for returning the SNF to the United States. All of the countries with research reactors using fuel containing uranium enriched in the United States were divided into two categories, high-income and other-than-high-income countries. To encourage reactor operators in other-than-high-income countries to participate in the program, the United States will subsidize receipt of their SNF. The high-income countries will be responsible for transporting their SNF to the management site in the United States, i.e., SRS for MTR type fuel and INEEL for TRIGA type fuel. They will also be required to pay a fee to DOE for handling, storing and ultimate disposal of the SNF in the United States.

The first TRIGA SNF shipment to the INEEL is scheduled to come from two Pacific Rim Asian countries, South Korea and Indonesia. This shipment is scheduled to be made in 1998. It will arrive on the West Coast of the United States at the Concord Naval Weapons Station (a more detailed discussion about this shipment can be found in References 1-3). The second shipment to INEEL will be a European shipment and will arrive at an east coast port, the Naval Weapons Station Charleston. The casks, loaded with TRIGA SNF, will be transported from there by railroad to SRS, then across country to the INEEL in Idaho. The route for this shipment has not yet been identified.

In September 1997, a team of DOE members, and support service contractors visited four (4) European countries with a total of 7 TRIGA research reactors (a representative from Argonne National Laboratory East participated in one of the reactor visits and a representative from the Arms Control and Disarmament Agency participated in 2 reactor visits). The purpose of the visits was to: introduce the research reactor operators to the program; identify key contacts; assess the fuel and cask handling capabilities; and determine if they want to participate in the program and, if so, identify when they would be ready to ship; and begin discussions on the contract to return the SNF to the United States. The countries and TRIGA research reactors visited were:

- Italy
  - Italian National Agency for New Technology, Energy and the Environment (ENEA), Rome
  - University of Pavia, Applied Nuclear Energy Laboratory [Universita di Pavia, Laboratoria Energia Nuclearie Applicata (LENA)], Pavia

- Romania
  - Institute for Nuclear Research (ICN), Pitesti

- Slovenia
  - Institute Jozef Stefan (IJS), Ljubljana

- Germany
  - Medical University of Hannover [Medizinische Hochshule Hannover (MHH)], Hannover
  - Institut Fur Kernchemie (IFK), Mainz
  - German Cancer Research Center [Deutsches Krebsforschungszentrum (DKFZ)], Heidelberg

From these preliminary assessments it was determined that four (4) of the research reactors may want to participate in a 1999 shipment (i.e., ENEA, ICN, IJS, and MHH), one is considering a 2000 shipment (DKFZ), and the other two (2), IFK and LENA, are either undecided or will not have enough SNF until later in the policy period. This paper describes the findings from these preliminary assessments.

Italy

ENEA, Rome

The reactor began operations in 1959 and operated at 100 kW until 1968. At that time the 65 aluminum-clad rods were removed and the reactor was converted into a 1 MW reactor using stainless steel-clad fuel rods. The reactor is used to produce medical isotopes and for neutron activation analysis, neutron radiography, and neutron diffractionation. They are anticipating making major electrical and mechanical upgrades of the facility and believe the reactor could operate for an additional 20 years.

The ENEA TRIGA reactor program has a total of 273 low enriched uranium (LEU) TRIGA fuel rods. There are 106 stainless steel rods in the reactor, 20 stainless steel fresh fuel rods in storage, and the remaining 147 SNF rods (23 stainless steel stored in pits, 59 stainless steel stored in racks in the pool, and 65 aluminum rods are stored in pits) are stored in 5 racks around the side of the reactor pool or in the five (5) storage pits in the floor of the reactor building. There are three (3) spent fuel follower control rods and one (1) potentially damaged aluminum-clad rod.

The ENEA wants to participate in a 1999 shipment, assuming the IU-04 shipping cask is available. They would keep the remaining SNF at the reactor until the end of the acceptance period when more SNF is available. ENEA estimates generating one (1) SNF rod each year.

LENA, Pavia

The LENA research reactor is located at the University of Pavia. The 250 KW TRIGA reactor was built in 1965. The reactor has a 81 fuel rod core that is nearly spent. There are 28 stainless steel rods in the inner and 53 aluminum clad rods in the outer positions of the core. LENA estimates there is enough fuel in the core to operate the reactor one year. LENA would like to operate the reactor an additional 5 to 7 years, however, 10 to 15 new TRIGA rods would be needed to extend the life of the core.

The reactor has primarily been used for research in neutron activation analysis, boron neutron capture therapy (BNCT), and production of some medical isotopes. The neutron activation analysis is used for carbon dating objects. The BNCT is focused on treating liver cancer.

LENA has a total of 90 LEU TRIGA fuel rods. There are 28 stainless steel and 53 aluminum clad rods in the reactor. LENA has nine (9) damaged SNF rods that cannot be used in the reactor, seven (7) are stored in the dry storage vaults in the floor of the reactor building and two (2) are stored in racks in the reactor pool.

LENA has not made a final decision on its participation in a 1999 shipment.

Romania

ICN, Pitesti

The ICN reactors and facilities began operations in 1979. It has two TRIGA reactors, a 14 MW Steady-State and an Annular Core Pulsing Reactor (ACPR).

The 14 MW reactor was originally designed to run with 93% enriched fuel but is currently in the process of converting to LEU. Since startup in 1979, the reactor has been utilized for in-core irradiation of experimental (CANDU) fuel, radioisotope production, and other scientific and technical applications. The reactor has operated for over 50,000 hours. In the future the reactor will be used for structural material irradiation and for radioisotope production about 200 days/year at 10 MW mean power.

The ACPR can be operated at a steady state mode of 500 kW or less and up to 20,000 MW in pulse mode. The reactor is used for short irradiation in steady state mode and for neutron radiography. In pulse mode, it is used for nuclear safety studies of the fuel for power reactors in anticipated transient conditions. This reactor contains 153 fuel elements which are 19.7% enriched. The fuel is 1.5-in. diameter stainless steel clad. The ACPR is used about 300 h/yr in steady state mode and a maximum number of 50 pulses per year.

The reactors are part of a large complex that includes: a large high bay for the reactors, reactor pool, beam room, delay tank, heat exchangers, storage pool, hot cell complex, and operating gallery.

ICN has 54 Incoloy TRIGA fuel clusters, 35 containing highly enriched uranium (HEU), at 93% enrichment, and 19 LEU. Each cluster consists of 25 fuel pins. Of the 35 HEU clusters, 28 are currently in the reactor, but 4 will be removed before the end of October 1997. ICN has two LEU clusters that are suspected of being damaged. Another fuel cluster is slightly damaged at the bottom plug, but is still tight. There are currently seven (7) HEU clusters in the spent fuel rack. A total of 11 spent fuel clusters will be available by the end 1999.

ICN anticipates removing three (3) or four (4) HEU clusters per year until the core is completely converted to LEU. This conversion will be completed before May 2006. Under this program, no LEU will be returned until all HEU has been shipped. ICN plans to ship a total of at least 40 fuel clusters, including all 35 HEU clusters, to the U.S. under the FRR SNF program.

Slovenia

IJS, Ljubljana

The IJS 250 kW TRIGA reactor began operations in 1966. It was refurbished from 1991 to 1992, adding new instrumentation and new control panels. With this refurbishment, IJS estimates that the life of the reactor has been extended 10-20 years. It is a pool type reactor, with solid fuel elements in which zirconium-hydride moderator is homogeneously distributed with uranium enrichments of 20% or 70%. The maximum neutron flux in the central thimble is 1.10^{13} $n/cm^2/s$. A 40 position rotary specimen rack around the fuel elements, a pneumatic transfer rabbit system, as well as a central thimble are used for irradiation of samples. The thermal neutron flux at the rotary specimen rack is 1.4×10^{12} n/cm^2 s. Other experimental facilities include two radial and two tangential beam tubes, a graphite thermal column, and a thermalizing column. The reactor has been utilized for radioisotope production, neutron activation analysis, neutron scattering, neutron radiography, and other scientific and technical applications.

Spent fuel is currently stored in racks in the reactor pool and in two storage pools at the basement level of the reactor building. The reactor is currently operating on a new LEU fuel core. The reactor is part of a complex that includes: a large high bay for the reactor, two storage pools, a hot cell, and operating gallery. The aluminum-clad and stainless steel clad elements are stored in separate pools to mitigate corrosion.

IJS has 313 TRIGA fuel rods, including 26 HEU (FLIP, 70% enriched) and 287 LEU. Of these, 67 rods are aluminum-clad and 246 rods are stainless steel-clad. IJS received 85 of its LEU fuel rods from a shutdown German reactor in 1989. There are 218 SNF rods available for shipment. One stainless steel clad rod from Germany has been placed in a can. One instrumented FLIP rod was leaking and was removed from the reactor core. IJS has nine different types of TRIGA fuel.

IJS intends to participate in a 1999 shipment.

Germany

MHH, Hannover

The MHH TRIGA reactor is located in the basement of a building in the Medical University of Hannover, Germany. The Institute was opened in 1965 and the MHH 250 kW TRIGA reactor began operation in 1973. The reactor stopped operations in December 1996. Since the TRIGA reactor is in the basement of a medical facility, a specially designed transfer device will be used to transfer the SNF from the basement, up an elevator, and through the halls to a temporary storage facility being built outside the medical facility. The temporary facility will be used to shelter the transportation cask while the fuel is being transferred from the basement. After the spent TRIGA fuel has been removed, the reactor will be decommissioned and the facility will be refurbished and used for other medical purposes.

MHH has 76 spent LEU TRIGA fuel rods, including 71 aluminum and five (5) stainless steel rods. Sixty-four of the rods are stored in the reactor core and the remaining 12 rods are stored in racks along the wall of the reactor vessel. MHH intends to participate in a 1999 shipment.

IFK, Mainz

The University was founded in 1477 and the TRIGA reactor is part of the Institute of Nuclear Chemistry. The 100 kW TRIGA Mark II pulse reactor began operation in 1965 and has operated in a steady state and pulse mode. The reactor has been pulsed over 14,000 times. The reactor underwent refurbishment in 1995, to upgrade their heat exchangers, all electrical circuits, and clean-up cycle. This upgrade extended the life of the reactor and will allow it to be operated at 300 kW. However, the decision to increase the operating power has not been made at this time.

The reactor is presently operated at 100 kW 6 to 8 hours per day, five (5) days a week, unless it is being pulsed. The reactor is used for fundamental research in short lived isotopes, chemical behavior of the heaviest elements, neutron activation analysis, and training.

IFK has a total of 85 LEU TRIGA fuel rods. The core has 73 rods, including 58 aluminum, 13 stainless steel, two (2) instrumented [one (1) stainless steel and one (1) aluminum]. There are five (5) fresh stainless steel-clad fuel rods, one (1) slightly irradiated stainless steel-clad element, and two (2) additional elements with thermocouples [one (1) stainless steel and one (1) aluminum]. There are four (4) aluminum SNF rods which were removed from the reactor because of elongation although the elements are still within General Atomics specifications. They estimate there is enough fuel to operate the reactor for up to 25 years.

IFK will not participate in a 1999 shipment.

DKFZ, Heidelberg

The DKFZ TRIGA research reactor is located in the cancer research complex on the campus of the Heidelberg University in Heidelberg, Germany. The original TRIGA research reactor began operation in 1966 and operated until 1977. A new modified 250 kW TRIGA Mark III was built and is in operation today. The reactor is used for the production of radionuclides for medical research and for neutron activation analysis.

There are spent fuel storage racks in the reactor pool and dry/wet storage vaults in the floor in the reactor room. The reactor will be decommissioned after the spent TRIGA fuel has been removed from the facility.

DKFZ has 142 LEU TRIGA fuel rods, including 65 aluminum rods, 68 stainless steel rods, and 9 fuel follower control rods with stainless steel cladding. This total includes 16 fresh fuel elements, 114 elements in the core, 11 spent or warped fuel rods, and one (1) fuel follower control rod.

DKFZ may be interested in shipping their fuel in early 2000, depending upon completion of their ongoing research projects.

Conclusions

The INEEL has begun the planning for a 1999 shipment from four (4) European countries, involving four (4) research reactors. The research reactors are ENEA in Italy, ICN in Romania, IJS in Slovenia, and MHH in Germany. This shipment will provide several unique challenges. First, this will be the first shipment to the INEEL from the east coast of the United States. As such, there will be an intensive transportation process involving the states, tribes and local governments. Secondly, this will be the first shipment to INEEL involving both high-income and less-than-high-income countries in one shipment. There is an opportunity to save a significant amount of money for both DOE and the high-income countries by cooperating and coordinating the shipments together. Thirdly, this will be the first shipment to INEEL of mixed TRIGA SNF including LEU, HEU, aluminum-clad, stainless steel-clad, and Incoloy-clad rods. This shipment will also include more than one type of shipping cask. INEEL will need to prepare the safety documentation, procedures, and make the equipment and facility modifications necessary to handle the different fuel and cask types.

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