RESEARCH AND TEST REACTOR CONVERSION TO LOW ENRICHED URANIUM FUEL: TECHNICAL AND PROGRAMMATIC PROGRESS

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International Conference on Research Reactors: Safe Management and Effective Utilization

Rabat, November 14-18, 2011

National Nuclear Security Administration
Defense Nuclear Nonproliferation

U.S. DEPARTMENT OF ENERGY

GTRI – Global Threat Reduction Initiative

DOE STRATEGIC GOAL 2.2

Prevent the acquisition of nuclear and radiological materials for use in weapons of mass destruction and other acts of terrorism

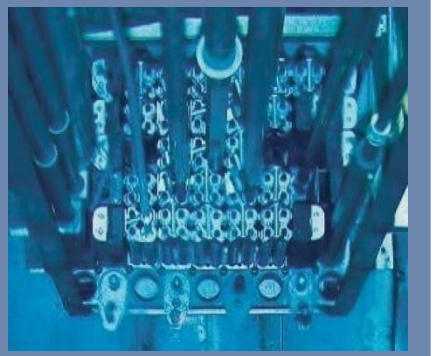
GTRI MISSION

Reduce and protect vulnerable nuclear and radiological material located at civilian sites worldwide.

GTRI is:

- A part of President Obama's comprehensive strategy to prevent nuclear terrorism; and
- The key organization responsible for implementing the U.S. HEU minimization policy.

Convert



Convert research reactors and isotope production facilities from the use of highly enriched uranium (HEU) to low enriched uranium (LEU)

These efforts result in permanent threat reduction by minimizing and, to the extent possible, eliminating the need for HEU in civilian applications – each reactor converted or shut down eliminates a source of bomb material.

Remove

Remove and dispose of excess nuclear and radiological materials; and

These efforts result in permanent threat reduction by eliminating bomb material at civilian sites – each kilogram or curie of this dangerous material that is removed reduces the risk of a terrorist bomb.

Protect

Protect high priority nuclear and radiological materials from theft and sabotage

These efforts result in threat reduction by improving security on the bomb material remaining at civilian sites – each vulnerable building that is protected reduces the risk until a permanent threat reduction solution can be implemented

GTRI-Conversion Program

- The program to convert research reactors from the use of highly enriched uranium (HEU) to low enriched uranium (LEU) started under the U.S. Department of Energy (DOE) with the RERTR (Reduced Enrichment for Research and Test Reactors) in 1978
- RERTR became an international program, establishing multiple collaborations leading to LEU fuel development and reactor conversion to LEU fuels
- In 2004 the DOE's National Nuclear Security Administration (NNSA) established the Global Threat Reduction Initiative (GTRI) that incorporated the reactor conversion program as one of the main pillars for HEU minimization
  - 39 Research reactors had converted to LEU by 2004
    - 11 of these reactors were in the U.S. and the remaining 28 were in foreign countries
  - GTRI has accelerated the program to minimize HEU utilization in civil applications
  - 76 research reactors have converted to date or have shutdown before conversion
    - 20 of these reactors were in the U.S. and the remaining 56 were in foreign countries

GTRI-Conversion Program (cont'd)

- Current GTRI Conversion program continues to focus both on US research reactors and in foreign reactors. In the U.S.:
  - All reactors in the US that could convert with existing fuel have been converted
    - Last ones converted in 2009 (University of Wisconsin and NRAD TRIGA-type reactors)
  - Large efforts are being made to develop and qualify the LEU fuel that enables the conversion of the U.S. high flux reactors (USHPRR)
- Foreign reactor conversion program under GTRI has made very significant progress in conversion of Russian-supplied reactors in third countries
- Current efforts continue with:
  - Other US-supplied foreign reactors
  - Remaining Russian-supplied reactors in third countries
  - LEU fuel qualification and conversion of high flux reactors in Europe
  - Chinese-supplied reactors (MNSRs)
  - Initiation of feasibility studies for the conversion of specific Russian domestic reactors

GTRI-Conversion Program Implementation

- Develop or identify an alternative LEU fuel assembly with a service lifetime at least similar to that of the HEU fuel assembly
  - LEU fuel provides a similar service lifetime as the HEU fuel
  - There is no significant penalty in reactor performance – ensure that the ability to perform its scientific mission is not significantly impacted
  - Safety criteria are satisfied
- Ensure that conversion can be achieved without requiring major changes in reactor structures or equipment
- Determine, as possible, that the overall costs associated with the conversion do not increase significantly the annual operating costs
- Remaining research reactors becoming increasingly challenging:
  - Higher density fuels; fuels of unique design
  - Possible reactor modifications may be necessary for some facilities

Conversion Analysis

- Perform FEASIBILITY STUDIES to determine suitable LEU fuel assembly designs for each reactor:
  - Design fuel assemblies using qualified LEU fuels and fuels under development
  - Compare reactor performance with HEU and LEU fuels
  - Calculate key safety parameters
- Perform the OPERATIONAL AND SAFETY ANALYSES to show:
  - Transition from HEU to LEU fuel can be done safely and without interrupting normal operations
  - LEU reactor satisfies all safety requirements.
- Resolve REGULATORY ISSUES
  - Formulate safety requirements
  - Answering questions posed by regulatory bodies and their experts regarding the reactor's safety documentation.

Significant Accomplishments under GTRI

- Conversion to LEU of first set of Russian-supplied reactors in third countries
  - Strong collaboration with Russian Institutes and Government organizations, including the supply of the LEU fuel as well as the return of the HEU spent fuel to Russia
  - Russian institutes developed two types of LEU fuel that enabled the conversion of multiple reactors:
    - VR-1, LWR-15 in the Czech Republic
    - IRT-1 and its Critical Assembly in Libya
    - IRT-200 in Bulgaria
    - BRR in Hungary
    - WWR-SM in Uzbekistan
    - DRR in Vietnam
  - Strong collaboration with Russian Institutes for the development of UMo higher density fuels is being completed and can support further reactor conversions
- Conversion of US-supplied research reactors, with fuels developed in collaboration with the conversion program, including:
  - HFR at NRG, Petten in the Netherlands
  - KUR at Kyoto University in Japan
  - RPI at ITN in Portugal
  - SAFARI-1 in Pelindaba, South Africa

Current GTRI-Conversion Efforts:
US Domestic Reactors

- **5 reactors & 1 critical assembly: MITR, MURR, NBSR, ATR, HFIR, ATRC**
- **The effort is divided into three parallel pillars:**
  - **Fuel Development** of Uranium-Molybdenum (UMo) Monolithic Fuel, led by INL
  - **Fuel Fabrication Capability**, led by PNNL
  - **Reactor Conversion** (analyses and implementation), led by ANL
- MITR, MURR, and NBSR will use the Base UMo Monolithic Fuel
- ATR, ATRC, and HFIR require Complex Fuel
  (with integral burnable absorber and grading)

USHPRR

Reactor	HEU Core Power	Primary Uses	*Regulator*
MITR	**5 MW** (6 MW planned)	**Mixed**	***NRC Regulated***
MURR	**10 MW**	**Isotope Production, Activation**	
NBSR	**20 MW**	**Beam Science**	
ATR (ATRC)	**100-250 MW** (ATRC 600 W)	**Fuel & Material Irradiation**	***DOE Regulated***
HFIR	**85 MW**	**Beam Science & Isotope Production**	

USHPRR Conversion Potential

- Require very high density fuels able to withstand
  - High to very high heat flux (fission rate)
  - High burnup (fission density)
  - High to very high coolant flows (potential for hydrodynamic challenges)
  - GTRI is developing a high density fuel (U-Mo monolithic fuel) and enabling the establishment of a fabrication capability, as the fuel fabrication process is different from the current HEU fuels
    - U-Mo Monolithic fuel (U density up to ~17 g/cc.)

- Feasibility studies completed for these reactors
  - Conversion found feasible provided the completion of the qualification of the U-Mo fuel, which is well under way;
  - Mitigation actions being pursued to minimize the performance penalty and maintain their current mission and applications

Current Efforts: US-supplied reactors

- European High Flux Reactors
  - Current activities with qualification of high density LEU fuel for European Union High Flux Reactors (EUHFR)
    - European LEONIDAS project – interaction with GTRI
      - LEONIDAS: SCK/CEN, ILL, CEA, Areva-CERCA
    - U-Mo dispersion fuel qualification
  - Belgium: BR-2 Reactor at SCK/CEN
  - France: RHF at ILL, Grenoble
  - Feasibility studies completed for these reactors
    - Conversion found feasible provided the completion of the qualification of the U-Mo dispersion fuel, which is under way

Current Efforts: US-supplied reactors (cont'd)

- Other US-Supplied Reactors
  - Discussions with operator and other stakeholder organizations under way to determine possibility for conversion, regulatory implications, fabrication of the fuel, etc. for reactors for which fuel development is not necessary:
    - UTR-Kinki, Kinki University, Japan
    - SLOWPOKE reactor in Jamaica
    - Agreement is still needed regarding the conversion of the two operational SLOWPOKE reactors in Canada
  - Potential for conversion assessed on a case by case basis for facilities that would require a uniquely designed fuel
    - KUCA, Japan: thermal spectrum critical assemblies, conversion feasibility studies under way

Current Efforts: Chinese-supplied reactors

- Miniature Neutron Source Reactors (MNSRs)
  - Two reactors in China, including prototype reactor at CIAE
  - Five reactors in third countries: Nigeria, Ghana, Pakistan, Iran, and Syria
- Cooperation through the IAEA Coordinated Research Project (CRP) in converting the MNSRs to low enriched uranium fuel is key to global HEU minimization efforts
  - Studies performed under CRP established feasibility of conversion
  - Generic safety analysis for the LEU fuel to enable the development of updated SARs for each reactor to facilitate conversion
- Bilateral cooperation with Ghana and Nigeria organizations to complete specific Safety Analysis and plan conversion
- China and the United States agreed to collaborate in building a Zero Power Test Facility to assemble and measure the LEU cores for conversion of the MNSRs
  - Contract signed between CIAE and GTRI/ANL in September 2010

Current Efforts: Russian-Supplied reactors in Third Countries

- Efforts continue on the conversion of reactors in Kazakhstan
  - WWR-K and its critical assembly at INP, Almaty
    - New fuel design; irradiation testing started in March 2011
    - Possibility of converting Critical Assembly in 2012 being studied
    - Reactor planned for conversion in 2014, after 60% BU reached in irradiated test assemblies
  - IGR and IVG-1 reactor at IAE, Kurchatov City
    - Feasibility studies started in 2011 and are currently being completed
    - Availability of LEU fuel being investigated
    - Potential reactor modification requirements to accommodate LEU fuel, especially for IGR, are being assessed
- Efforts for the conversion of the MARIA reactor in Poland
  - Irradiation testing of LEU fuel supplied by Areva-CERCA was completed earlier this year
    - PIE being completed
  - Conversion requires the upgrades of the primary coolant pumps
    - Replacement project under way
  - Conversion to LEU fuel planned for August 2012

Current Efforts: Russian Domestic Reactors

- Rosatom and NNSA reached an agreement to conduct feasibility studies for the conversion of 6 research reactors
  - OR, IR-8, ARGUS at National Research Center-Kurchatov Institute, Moscow
  - IRT-MEPHI reactor at the National Research University MEPHI, Moscow
  - MIR.M1 reactor at the Research Institute of Atomic Reactors, Dimitrovgrad
  - IRT-T reactor at Tomsk Polytechnic Institute, Tomsk
- Implementing Arrangement to initiate the feasibility studies for the six research reactors signed by Rosatom Director Kiriyenko and DOE Deputy Secretary Poneman on December 2010
  - Scopes of work had been previously agreed and institutes started the studies shortly thereafter

- A working group has been established to monitor progress on these studies
- Russia has not decided whether to convert domestic reactors
  - It is anticipated that a decision to convert research reactor in Russia will be partially based on the outcome of the feasibility studies

Summary

- **Reactor conversions in U.S. and foreign countries under GTRI accelerated program have resulted in successful projects**
  - Conversion performed on the basis of assessing feasibility, determining the appropriate LEU fuel, and working closely with facility operator
- **Current efforts cover a large variety of reactors and include multiple designs and material origin**
- **Many of the reactors being currently studied require advanced, higher density fuels**
  - Fuel development and qualification efforts are being conducted as part of the conversion efforts

Close technical and political cooperation between the research institutes and the government organizations is key to the progress in the reactor conversion projects and, ultimately, an absolute requirement for their success