IAEA COOPERATION WITH RERTR AND SPENT FUEL RETURN PROGRAMMES: A RETROSPECTIVE AND FUTURE LOOK

PABLO ADELFANG, IRA N. GOLDMAN, EDWARD E. BRADLEY AND DARIO O. JINCHUK

Research Reactors Group
Division of Nuclear Fuel Cycle and Waste Technology
International Atomic Energy Agency
Wagramer Strasse 5, P.O. Box 100
A-1400 Vienna, Austria
P.Adelfang@iaea.org I.goldman@iaea.org, E.Bradley@iaea.org, O.Jinchuk@iaea.org

ABSTRACT

The IAEA has been involved for almost 30 years in supporting international nuclear non-proliferation efforts associated with reducing the amount of highly enriched uranium (HEU) in international commerce. IAEA projects and activities have directly supported the Reduced Enrichment for Research and Test Reactors (RERTR) programme, as well as directly associated efforts to return research reactor (RR) fuel to the country of origin where it was originally enriched. IAEA efforts have included a variety of activities ranging from dissemination of information and transfer of pertinent technology to management of contracts related to RR conversions and shipments of spent and fresh HEU fuel. Future IAEA's activities on the subject will be designed to match requirements and pace of ongoing international undertakings.
The paper presents a retrospective on the work carried out by the IAEA in the past years and gives an overview of ongoing and future activities and projects in support of the global efforts to minimize the use of HEU in civilian applications.

1. Introduction

The IAEA has been involved for almost 30 years in supporting international nuclear non-proliferation efforts associated with reducing the amount of highly enriched uranium (HEU) in international commerce. IAEA projects and activities have directly supported the Reduced Enrichment for Research and Test Reactors (RERTR) programme, as well as directly associated efforts to return research reactor (RR) fuel to the country of origin where it was originally enriched. IAEA efforts have included a variety of activities ranging from dissemination of information and transfer of pertinent technology to management of contracts related to RR conversions and shipments of spent and fresh HEU fuel. Future IAEA's activities on the subject will be designed to match requirements and pace of ongoing international undertakings.
The paper presents a retrospective on the work carried out by the IAEA in the past years and gives an overview of ongoing and future activities and projects in support of the global efforts to minimize the use of HEU in civilian applications.

2. Historical Overview

2.1 Support to the RERTR Programme

2.1.1 Introduction

The RERTR was initiated by the U.S. in 1978, with the objective of developing the technologies necessary to convert research and test reactors from the use of fuels and targets containing HEU to the use of fuels and targets containing low enriched uranium (LEU). The RERTR programme objective is to minimize and eventually eliminate the use of HEU in civil programmes worldwide.
The IAEA has been involved with and has fully supported RERTR since its inception, initially through its Department of Research and Isotopes (now named the Department of Nuclear Sciences and Applications), Division of Research and Laboratories, Physics Section (R. Ellis, H. Reijonen, and U. Schutt). This included the development of international guidelines and standards to assist the overall reduced enrichment effort as well as providing, upon request, assistance to Member States for the conversion of specific RRs through the coordination and facilitation of interactions between Member State reactor organizations and laboratories in France, Germany, and the U.S. The IAEA also participated actively in the annual RERTR Conferences that began in 1979 and co-organized the 2004 RERTR Conference in Vienna.
Beginning in 1979, the IAEA convened meetings, which produced a series of IAEA Technical Documents (TECDOCS) directly relevant to the RERTR, as guides for the conversion of RRs.
After 1993, the IAEA Department of Nuclear Energy, Nuclear Fuel Cycle and Waste Management Division extended the scope of its spent fuel management programme to include programmes which focused specifically on spent fuels from research and test reactors. These activities cover the collection, analysis and dissemination of information on storage, management and related experience with spent fuels, formulation of norms and provision of technical assistance to developing Member States.
This corresponded with the rising awareness that many RRs were in or rapidly approaching a crisis situation and in every case, due to spent fuel storage and management problems and the constraints of national laws. It was clear that the capacity for spent fuel storage had been reached or was close to the limit at many RRs and there were concerns from a materials' science point of view about ageing materials in ageing storage facilities. Consequently, the IAEA's activities in this area were formulated to address these concerns and proved to be helpful to the RERTR programme and to related efforts in the mid-1990's to repatriate spent RR fuel to the country of origin.
A major expansion and strengthening of IAEA activities in support of RERTR started in 2004 after three important events were held in Vienna:
i) Announcement of the Global Threat Reduction Initiative (GTRI) by United States Secretary of Energy Spencer Abraham on May 2004 at the IAEA headquarters. The announcement was followed by several discussions between IAEA and U.S. officials to clarify cooperative activities;
ii) The GTRI Partners Conference on September 18-19, 2004, which adopted conference findings supportive of the goal of accelerating and expanding relevant programmes such as RERTR and the spent fuel take back programmes; and
iii) The 2004 RERTR meeting, held at the IAEA headquarters on November 2004.

Activities under IAEA's Subprogramme D.2 (RRs) were extensively reformulated at the end of 2004 in order to start implementation of the new programmatic tasks in support of GTRI early in 2005. In addition, a comprehensive set of new activities in support of GTRI were included in the formulation of Subprogramme D.2 for IAEA programme and budget for the bienniums 2006-2007 and 2008-2009. Highlights and main achievements under these new activities are presented in 2.1.2.

2.1.2 Activities from 2005 to 2008

2.1.2.1 Research Reactor Conversion

The IAEA has applied an array of approaches to facilitate specific conversion endeavours, as well as support the overarching RERTR programme in general. These different approaches permit the IAEA to cater its support to the specific challenges unique to each conversion effort.
Technical Cooperation (TC) projects have in the past, and continue to be a means for the IAEA to implement HEU to LEU conversion of RRs in different member states. However, the approach and scope for each project often differ significantly depending on the individual facility constraints. Main RR conversion activities carried out by the IAEA under Technical Cooperation projects from 2005 to 2008 are summarize in the following paragraphs.

- Conversion of the RECH-1 RR in La Reyna, Chile was completed in May 2006 when a full core of 32 LEU fuel elements was loaded into the reactor. Chilean authorities developed a qualified domestic LEU fuel manufacturing capability to facilitate their conversion programme. IAEA support for this effort commenced in 2001 through TC project CHI/4/021. The objective of CHI/4/021 was to qualify Chilean CCHEN as a fabricator of silicide LEU fuel. The scope of the IAEA project included equipment and services as well as human resource development in support of an irradiation and post irradiation qualification programme conducted at the Nuclear Research and consultancy Group (NRG) High Flux Reactor (HFR) facilities in Petten, the Netherlands.
- Conversion of the RR cores (10 MW IRT-1 and critical facility) in Tajoura, Libyan Arab Jamahiriya was performed under a direct government to government agreement and not as a specific IAEA conversion project. Nevertheless, the government of the Libyan Arab Jamahiriya has requested assistance from the IAEA for: i) assessment of the quality of the proposed LEU IRT-4M replacement fuel, and ii) implementation of poolside inspection capabilities at Tajoura. The IAEA also assisted in selecting and purchasing a new Instrumentation and Control system for the 10 MW RR. The IRT critical facility and the IRT-1 RR were fully converted in 2006.
- The MARIA reactor, operated by the Polish Institute of Atomic Energy (IAE), is a Russian-designed RR that operates with Russian-supplied HEU fuel. The present objective is to convert the current core to LEU fuel under the IAEA TC project POL/4/017. Recently, IAE has been studying the possibility of using fully qualified LEU silicide fuel to convert the MARIA reactor. However, the assembly design proposed for use in MARIA is unique and must be qualified for the MARIA operating conditions by irradiating lead test assemblies in the MARIA reactor. Under TC project POL/4/017 a tripartite contract was signed by IAE, INVAP (Argentina) and the IAEA after a call for tenders process. Procurement of the LEU fuel will be carried out in 2 discrete phases: Phase I scope includes research, engineering and design and the supply of two LEU Lead Test Assemblies (LTA). Satisfactory demonstration of correct irradiation behaviour in the Maria RR of these two LTAs is a mandatory condition to qualify the fabricator for the supply of fuel assemblies necessary for the conversion of the Maria core. Phase II involves purchasing the number of LEU fuel assemblies necessary for conversion of Maria RR. This step is conditional on the successful completion of the LTA qualification irradiation as mentioned above. Phase I is being implemented at present.
- Conversion of the Reactor Português de Investigação – RPI was carried out under TC project: POR/4/016 “Core Conversion of the Portuguese RR to LEU”. The IAEA issued a call for tenders for LEU fuel, convened an independent international expert consultancy meeting to evaluate the offers and selected the preferred tender. The LEU fuel was purchased under a tripartite contract signed by RPI, Compagnie pour l’Etude et la Réalisation de Combustibles Atomiques (CERCA), and the IAEA and supplied in early 2007. RPI full conversion to LEU was successfully completed in September 2007.
- Full conversion of the 14 MW TRIGA reactor in Pitesti, Romania was completed in May 2006 under IAEA TC Project ROM/4/024. A contract to supply the fresh LEU fuel was signed by IAEA, the Romanian government (RAAN/Research Institute Pitesti & Regulatory Authority CNCAN), and CERCA/TRIGA International in early November 2003. It is important to note that

during the implementation of this project, fuel supply operations were transitioning from General Atomics to the CERCA facilities in France. This challenge was adequately managed by CERCA with no adverse impact on the project cost, schedule or quality. The last irradiated HEU fuel elements were removed from the TRIGA prior to May 12, 2006 and after proper cooling, this U.S.-origin HEU will be shipped to the US under the FRRSF Acceptance Programme.

- The IAEA is also supporting other Member States, like Uzbekistan, Kazakhstan and Vietnam in pre and post conversion activities. In Vietnam, after conversion of the Dalat RR, growing Vietnamese interest in nuclear technologies is expected to result in significantly increased utilization of the Dalat RR. IAEA's principal role in this endeavour is to manage the parallel procurement of goods and services as well as the development of human resources skills to enable the increased utilization foreseen following the conversion. In total, IAEA will implement US/DOE contributed funds for upgrades, improvements and skill development.

2.1.2.2 Fostering the Use of LEU in Mo-99 Production

The IAEA's Coordinated Research Project (CRP) on "Developing techniques for small-scale indigenous production of Mo-99 from LEU or Neutron Activation" has been working since 2005 to assist participating countries to assess, evaluate, and implement nuclear technology for producing Mo-99 without HEU in order to meet local nuclear medicine requirements. The objective of the CRP is to provide interested countries with access to non-proprietary technologies and methods to produce Mo-99 using LEU foil or LEU mini-plate targets, or for the utilization of (n, gamma) neutron activation, e.g. through the use of gel generators. Seven institutions in six countries have been awarded research contracts (Chile, Egypt, Kazahkstan, Libya, Pakistan and Romania) and seven institutions in six countries have been awarded research agreements (Argentina, Republic of Korea, India, Indonesia, Poland and the U.S).
As reported in RERTR Conferences 2005-2007, this project has made significant progress in a number of IAEA Member States in advancing such non-HEU based technologies for producing Mo-99 in line with global efforts to minimize the use of HEU in civil nuclear applications.
The relevance of the IAEA CRP assumes much greater significance with the recent developments related to cessation of efforts to operate new isotope production reactors. A number of the participants of the CRP have relatively new or recently refurbished RRs and/or turnkey Mo-99 production capability which – through coalitions, cooperative arrangements, or contracts – could provide important new sources of Mo-99 for national and regional requirements. There are a few participants in the CRP who are already producing Tc-99m generators regularly (e.g. Chile, Pakistan, Poland) and would hence be able to consider establishing integrated facility including Mo-99 production from LEU targets and achieve self-sufficiency and avoid vulnerability in effecting supplies to medical users. Further, the Egyptian participation in the CRP has an additional advantage, since they are also seeking to set up comprehensive facilities for Mo-99 production with professional help of INVAP, Argentina. The fact that the ETRR reactor is relatively new and very well-suited for radioisotope production is an important feature in this new potential source of Mo-99. The CRP is directly supportive of RERTR objectives, as it will help encourage the further use of LEU and neutron activation technologies by building experience and consensus on their use, within the context of an internationally-coordinated project. In addition, it will facilitate enhanced utilization of RRs by increasing local production of radioisotopes, and consequently could serve to improve sustainability of such institutions.

2.1.2.2 IAEA Publication on "Good Practices for Qualification of High Density LEU Research Reactor Fuels".

One result of the present strong international collaboration in LEU fuel development and qualification has been the realization that participants from different countries do not always understand the terminology in the same way; for example, the term 'qualification' is currently interpreted differently in different countries. Consequently, an internationally accepted definition of fuel 'qualification' is needed. Also, it is expected that the high level of fuel development and qualification activity around the world will lead to a high level of demand for the qualified fuels for conversion of existing, and use in new, RRs. Such demand will mean that fuel-supply arrangements must be made with RR fuel manufacturers and that regulatory

bodies will be faced with the need to judge the suitability of the newly developed fuels in the RRs that they oversee. The International Atomic Energy Agency (IAEA), recognizing the need for a universal understanding of what is required to qualify a new fuel and what information a potential user of the fuel or a regulatory body should expect the fuel developer to provide, convened a consultancy in Vienna during March 2005 to discuss the issue and recommend further activities to meet the need. The consultants, representing a broad cross section of experts active in the international fuel development community, determined that preparation of a document providing a common definition of qualification and outlining good practices in developing and qualifying new RR fuels would provide valuable information for fuel developers and qualifiers, fuel manufacturers, fuel users, and regulatory bodies. Subcommittees of the consultants were established to prepare drafts of specific parts of the document. The consultants also met to discuss the content of the document: in Sophia (April 2006), in Cape Town (November 2006), in Lyon (March 2007), and finally in Prague (September 2007). At the Prague meeting, a relatively complete draft of the document was reviewed. The document, that will be issued as a Nuclear Energy Series Report is now being finally edited by the IAEA and publication is expected by end of 2008 or beginning of 2009. In addition to recommending good practices to any organization undertaking a fuel development programme in the future, this document will bring RR fuel manufacturers, fuel users, and regulatory bodies up to date on the information expected to be available to support licensing of newly developed fuels for conversion of RRs from the use of HEU fuels to the use of LEU fuels and for use in new reactors.

2.1.2.3 Conversion of Miniature Neutron Source Reactors

The Chinese-built Miniature Neutron Source (MNSR, 30 kW) reactors (four in China, five abroad) are low-power, neutron source RRs used primarily for neutron activation analysis, education, and training. These reactors have cores consisting of about 1 kilogram of HEU, enriched to 90% or greater. The China Institute of Atomic Energy (CIAE) has designed a new MNSR using LEU to operate in hospitals and has been studying conversion of the existing MNSR cores to LEU. China has also designed and built, with commissioning expected in 2008, a large 60MW RR that will have LEU fuel. It is generally accepted that conversion of the MNSRs is feasible and it is likely that China will be able to produce LEU cores for the MNSR reactors in the near future. A technical meeting regarding the conversion of SLOWPOKE and Miniature Neutron Source Reactors (MNSR) was held on 23-25 May 2005. Participants from Canada, China, France, Ghana, Jamaica, Nigeria, Pakistan, Syria and the U.S., participated in the meeting. The participants of the Technical Meeting agreed that conversion to LEU has been clearly demonstrated for the SLOWPOKE, and based on initial analysis, appears to be feasible for the MNSRs. However, it was agreed that additional analysis, including various calculations, would have to be made in order to confirm that the MNSRs can be converted. Following recommendations of the Technical Meeting, the IAEA initiated a Coordinated Research Project (CRP) in June 2006 to assist in the conversion of MNSRs to LEU fuel. with the following objectives:

- To assist institutions in Member States with MNSR reactors with HEU cores to convert to LEU fuel with minimal reduction of the utilization capacity of the reactors;
- To establish a common approach for the conversion to LEU of the existing MNSR reactors through a comparative analysis of the feasibility of conversion;
- To provide the basis for individual MNSR reactors to safely convert to qualified LEU fuel;
- To carry out calculations and conduct studies necessary to plan and implement MNSR conversion to LEU; and
- To disseminate information on the various technical and other steps necessary to safely convert MNSR reactors to LEU fuel.

Institutions in China (3), Ghana, Iran, Nigeria, Pakistan, and Syria are participating as contract holders in this CRP. The U.S. (Argonne National Laboratory) is an agreement holder. At the end of the CRP, it is expected that all of the participants will have acquired an appropriate understanding of the technical and other steps necessary as well as the documentation that will be required in order to meet national regulatory requirements to carry out the conversion of their HEU-fuelled MNSR reactors to LEU cores. Information acquired through the CRP will be published by the Agency in the form of a technical publication.

At a Trilateral Meeting (CIAE – IAEA – U.S/DOE) held in Beijing on April 2008 a road map for the MNSR conversion process was agreed upon. Key elements of the devised MNSR conversion process include carrying out critical experiments at CIAE to determine the number of LEU pins in the core and measure core parameters at zero power. Transient experiments in the LEU Hospital Irradiator reactor to be constructed at CIAE in 2008 will be used to demonstrate the inherent safety of the 4 mk ramp insertion. Step reactivity insertions will be addressed by validating computer codes and models for the HEU MNSR core during the IAEA CRP and using these validated codes and models to calculate these transients for use in the LEU safety analysis. Experiments for the 4 mk ramp reactivity insertion and for step reactivity insertions will be performed during the commissioning process of the MNSR LEU core.
At the 2nd Research Coordination Meeting (RCM) of the CRP, held in Vienna on May 2008, it was agreed that on the basis of conversion studies performed by the participants in the CRP that conversion of the MNSR reactors to LEU fuel is feasible without any compromise to safety and performance. The specifications of the projected conversion fuel and selected reactor components were also agreed upon.
At the end of the CRP, it is expected that all of the participants will have acquired an appropriate understanding of the technical and other steps necessary as well as the documentation that will be required in order to meet national regulatory requirements and to safely proceed with the conversion of their HEU-fuelled MNSR reactors to LEU. Information acquired through the CRP will be published by the Agency in the form of a technical report.

2.1.2.4 Use of LEU in Accelerator Driven Subcritical Assemblies

An Accelerator Driven Sub-critical Assembly system (ADS) is composed of a sub-critical assembly and an accelerator. In such a system, the accelerator provides a charged particle beam for generating a neutron source to drive the sub-critical assembly. The sub-critical assembly of the ADS includes nuclear fuel, coolant and reflector. In principle, HEU or LEU can be used for the sub-critical assembly fuel.

At a Technical Meeting held in Vienna from 10-12 October 2005 and attended by 15 experts from 13 Member States, it was recommended that a CRP or an international collaborative work on the use of LEU in ADS systems be organized. In November 2006, with financial support from US-DOE-GTRI, the Agency organized a Technical Meeting with the purpose of establishing the working plan for the proposed collaborative work intended to study the feasibility of using LEU in ADS systems. Seven facilities were included in the working plan: Yalina-Thermal (Belarus); Yalina-Booster (Belarus), with 3 possible configurations; Kharkov Facility (Ukraine); ADS IPEN/MB-01 (Brazil), with 2 possible configurations; RC-1 TRIGA Casaccia (Italy); H5B (Serbia), and AHWR (India). For each facility the participants defined its area of interest and proposed a number of supporting activities. The work methodology adopted consists in carrying out benchmark studies on the use of LEU in ADS systems within the scope of the collaborative work as described above. Organizations in developing countries work under specific IAEA contracts entailing some financial support, while institutions in industrialized countries contribute their work at no cost for the Agency.
The second Technical Meeting of the collaborative work was held in Rome, from 12 to 16 November 2007 and attended by 40 experts from 18 Member States. At the meeting, participants provided technical presentations describing the research activities carried out during 2007, discussed results obtained and established the work plan for 2008. There was broad consensus that results obtained so far show encouraging perspectives for the use of LEU in ADS systems. It was recommended to extend the collaborative work, originally meant to finish by end of 2008, to end of 2009. Additional funds to cover this extension has been provided by US-DOE-GTRI. The third Technical Meeting is planned to be held early in 2009 in Vienna.
The output of the collaborative work will be in the form of an IAEA technical document with the summary of the results of the work done, and a description of the work developed by each participating organization. It will also identify open issues for future R&D activities, and indicate a possible role for the Agency in the subject. It is expected that such document be a driving force to consider utilization of LEU in all future ADS designs.

2.1.2.5 Assessing Facilities Utilizing HEU for Possible Future Conversion Efforts

There is a pressing need for an enhanced data and information collection effort to develop a comprehensive international inventory of civilian nuclear research facilities and other activities possessing inventories of HEU. The development of such an inventory would permit a more comprehensive examination of the technical and other requirements for an expanded international effort to convert all civilian nuclear facilities now possessing HEU to LEU. To contribute to this data collection and information assessment efforts a Consultancy Meeting was held in Vienna, from 8 to 10 February 2006. The main objective of this consultancy was to present, compare, discuss and review available data regarding international civilian facilities operating with HEU. The consultants compiled a list considering all RRs that, according to the individual knowledge of the participants, make use of HEU. This list is considered a reference to be used in activities related to assessment of HEU facilities for future conversion efforts.

2.1.2.6 Technical Workshop and International Symposium on Minimization of HEU in the Civilian Nuclear Sector

The "Technical Workshop on HEU Minimization", held on 17-18 June 2006, as well as the "International Symposium on Minimization of HEU in the Civilian Nuclear Sector", which followed the technical workshop on 19-20 June, were organized by the Government of Norway in cooperation with the IAEA. The IAEA was integrally involved in the organization of the meeting, especially regarding the development of the programme and the recruitment of speakers. More than 100 experts from 41 countries participated in the Technical Workshop and around 130 participants from 45 countries in the International Symposium. The goal of the Technical Workshop was to review and discuss technical issues related to HEU minimization, and to achieve a hoped-for consensus on the technical feasibility of eliminating HEU from civil uses, which would be communicated to the International Symposium. The objective of the latter was to formulate concrete policy options for advancing the goal of HEU minimization.
Participants in the Technical Workshop concluded that virtually all RRs can use LEU fuel without a significant penalty to their educational, scientific, technical, and industrial applications. Several presentations made by users of reactors that have already converted to LEU clearly demonstrated that any "flux penalty" that resulted from the conversion can be managed and compensated by other measures so as not to affect the performance of the reactor. There was broad consensus that the production of Mo-99 from LEU is technically feasible, and that future new producers of Mo-99 should do so from LEU only. There was also consensus that the only significant obstacles to conversion to LEU of the present major Mo-99 production facilities are economic, financial, and political. It was agreed that the RERTR programme and the related RR spent fuel "take-back" programmes have made significant progress in HEU minimization, and that there is substantial and successful international collaboration in this area. The workshop called for these efforts to be enhanced and expanded on the basis of voluntary decisions by states interested in converting reactors or shipping spent fuel. The positive role of the IAEA in these efforts was highlighted, and there was broad consensus that the IAEA should expand its relevant activities, including the promotion of cooperation between and international sharing of RR facilities.
The International Symposium was marked by broad political discussions placing this subject within the context of the global nuclear disarmament debate, especially regarding the differing obligations of Nuclear Weapons States and Non-Nuclear Weapons States under the Nuclear Non Proliferation Treaty (NPT). However, there was consensus that activities related to the minimization of HEU in the civil sector should proceed on the basis of voluntary requests by national authorities, in the context of available donor funding and international technical assistance.

2.1.2.7 Assessment of the Status of Pulse Reactors and Critical Assemblies

A Consultancy Meeting was held on the Status of Pulse Reactors (PRs)and Critical Assemblies (CAs) in January 2008 at IAEA Headquarters. Discussions took place regarding future uses of PRs and CAs, optimization of existing facilities, proposals for international user centres, and possibilities for conversion of such facilities to LEU. Both PRs and CAs offer unique features in support of advanced nuclear

research. CAs have been historically used to determine the physics properties of proposed reactor-core designs. Typical ongoing uses include mock-ups for different types of reactors and to examine core concepts for future reactors. Most PRs were designed to determine the effects of neutron bursts on different materials and systems. Both CAs and PRs typically have lifetime cores, often fuelled by uranium enriched above 20% (HEU) or in some cases plutonium. Both types of facilities have been used for both civil and military applications and they will possibly have a role in advanced reactor development. Modern computer simulations are becoming increasingly popular options for some of these applications. It was discussed that there are a significant number of existing facilities worldwide which are under-utilized in national programmes. Approximately ten facilities have been closed worldwide in the past few years. It is expected that more facilities will be closed and decommissioned in coming years. During the meeting, it was stated that some facilities in different countries are being examined for possible closure. It was recommended that, in cases where the use of HEU or Pu is indispensable to accomplish scientific objectives, these activities be carried out in international user facilities and centres of excellence for PRs and CAs. Any such international centres using HEU or Pu should be highly secured, employing best practices of nuclear security and physical protection.

2.2. Support to the Research Reactor Fuel Take Back Programmes

The IAEA has been an active supporter of the effort(s) to return RR fuel to the country of origin.

2.2.1 U.S. Take Back Programme

In 1986, to further encourage foreign RR operators to convert to LEU fuel, the U.S. Department of Energy DOE "Off-Site Fuels Policy" was extended to include the acceptance of foreign spent nuclear fuel containing uranium enriched in the United States. The U.S. accepted foreign RR spent nuclear fuel until the programme expired (in 1988 for HEU fuels and 1992 for LEU fuels). A number of urgent “relief” shipments of spent fuel of U.S. origin did continue to take place, however.

During the period following the expiration of the U.S. Off Site Fuels programme (which coincided with the creation of the RR fuels programme in the IAEA Department of Nuclear Energy), the IAEA was involved as an observer in many of the meetings of the "ad hoc" group of RR operators, known as the Edlow/Egan Group. Beginning in January 1992 this Group kept up pressure on the U.S. DOE to accept US-origin spent fuel from foreign RRs.

Toward the same end, then Director General of the IAEA, Dr. Hans Blix, wrote letters to Secretary O'Leary of the US DOE (1 July 1993) and Mr. Victor Michailov, Minister of Atomic Energy of the Russian Federation, (2 February 1995) suggesting that these major partners in RERTR could facilitate the non-proliferation goal of RERTR by taking back foreign RR fuel.

A Record of Decision was published by DOE on May 13, 1996 to re-start the U.S. Foreign Research Reactor Spent Nuclear Fuel (FRR SNF) Acceptance Programme with a deadline of May 13, 2006 for eligible fuel to be discharged from reactors and a deadline of May 13, 2009 for fuel to be received in the U.S.

With the re-initiation of the U.S. take-back programme, the IAEA began a number of activities to assist member states eligible to ship spent RR fuels back to the U.S. The IAEA convened experts to develop guidance for Member States in this regard, which produced a Guidelines Document on Preparatory Work Prior to Return of Spent Fuel of US-Origin from Foreign Research Reactors", Draft IAEA-TECDOC (June 1996). (Note: These documents and lectures from the training courses, below, are available on the ANL/RERTR website at http://www.td.anl.gov/Programs/RERTR/RERTR.html).

In response to a request from the US Government the IAEA organized two interregional training courses on the "Technical and Administrative Preparations Required for Shipment of Research Reactor Spent Fuel to its Country of Origin," in cooperation with the Government of the United States through Argonne National Laboratory. The first course was held at Argonne in January 1997 and the second in May 1999, also at Argonne. These courses included participants from Russian RRs.

The purpose of the courses was to provide participants with the technical, organizational and administrative information needed to prepare irradiated RR fuel for shipment to its country of origin, in this case, the United States.

The aforementioned guidelines were later revised and expanded in scope into a "Guidelines document on Technical and Administrative Preparations Required for Shipment of Research Reactor Spent Fuel to Its Country of Origin, Draft IAEA-TECDOC (March 1999).
The U.S. announced in April 2004 that the U.S. take-back programme would be consolidated with DOE support for the Russian RR spent fuel return programme.

A Technical Meeting on "National Experiences on Return of Research Reactor Spent Fuel to the Country of Origin" was held in Vienna in August 2006. The TM was attended by 46 experts from 27 Member States. The meeting was convened with the aim of collecting the information accumulated worldwide on the subject and consolidating it in an IAEA publication. The Technical Meeting allowed operators and managers of RRs that have successfully shipped RRSNF back to the country of origin describe their experiences, exchange information and transfer lessons learned to managers and operators of RRs that have not make any shipment yet but are considering the return of their RRSNF in the future.
The main outcome of the meeting is IAEA TECDOC 1593, "Return of research reactor spent fuel to the country of origin: national experiences and requirements for technical and administrative preparations".
This publication gathers, in one single IAEA document, the requirements for technical and administrative preparations for shipment of Research Reactor Spent Fuel to its country of origin, updating the 1997 document that has become obsolete, and an important number of national experiences in shipping back fuel to the country of origin. The main purposes of the publication are to disseminate information on good practices on the subject and make available to operators and managers of RRs orientation on the basic methods and activities that serve as the preparatory framework for implementing the shipments, and to capture the lessons learned from previous successful shipments of RR spent fuel to the U.S. and Russia. The publication is divided in two parts, the first one includes a document covering generic issues to be used by countries interested in shipping spent fuel within the framework of the FRRSNF acceptance programme and an update of the well established "APPENDIX A" including instructions on how to complete it. These documents provide key information for planning and conducting shipments of RR spent nuclear fuel back to the country where it was originally enriched. It is intended for use by all parties involved in the planning, preparations, coordination and operations associated with returning spent nuclear fuel to the country of origin. The second part, based on the papers presented during the Technical Meeting, captures almost all the experience accumulated so far worldwide and identifies and discusses the basic methods and activities that serve as the preparatory framework for implementing the shipments. TECDOC 1593 will be issued in fall 2008.
By request of Portugal and the U.S. Foreign Research Reactor Spent Nuclear Fuel (FRRSNF) acceptance programme the IAEA initiated a bidding process for the return to the U.S. of spent and fresh HEU fuel from the Portuguese RR. The Agency prepared the Scope of Work for this procurement, in consultation with Portugal and the FRRSNF acceptance programme. An evaluation group of international expert consultants was convened in January 2008 at IAEA Headquarters, Vienna, for the purpose of review and technical evaluation of the bids submitted in response to this IAEA procurement. A contract with the preferred tender was finalized and a purchase order timely issued. The HEU fuel was safely shipped back to the U.S. in July 2008.

2.2.2 Russian Take-Back Programme

At the IAEA General Conference in September 1999, U.S. Energy Secretary Bill Richardson announced that the U.S. was prepared to work with Russia and the IAEA to manage and dispose of Russian-origin HEU RR fuel remaining in a number of countries.
On 14-15 December 1999 the IAEA convened the first Ad Hoc Tripartite Meeting on the possible management and disposition of Russian origin fuel currently at foreign RRs. The meeting reviewed the situation regarding fresh and spent Russian origin RR fuel in various locations around the world, Russian experience in regard to spent fuel transport, legal, policy and safeguards issues, criteria for prioritising sites; scenarios for a demonstration shipment and action plan, as well as financial issues.
The Second Tripartite Meeting was held 27-29 March 2000 in Vienna, which included a presentation of the data and information collected by the IAEA, discussions of the IAEA role in the programme as well as applicable Russian laws, regulations, and policies. It was decided that the IAEA should send a letter to

targeted member states to assess their interesting in participating in a fuel return programme. It was also decided that the site for a first demonstration shipment would be decided based on the responses to the letter, and the U.S. would provide funding for the shipment.

IAEA Director General Mohamed ElBaradei sent a letter on 29 September 2000 to sixteen countries with inventories of Russian RR fuel (Belarus, Bulgaria, China, Czech Republic, Egypt, Germany, Hungary, Kazakhstan, Latvia, Libya, Poland, Romania, Ukraine, Uzbekistan, Vietnam, and Yugoslavia). There were thirteen responses, all positive (one with reservations) and three did not reply (one of these, Libya, later shipped fresh fuel to Russia in 2004, see below).

The third and fourth Tripartite Meeting were held in April and September 2001, which requested and reviewed fact-finding missions to Ukraine, Uzbekistan, and Yugoslavia to begin detailed planning for eventual spent fuel shipments. Additional Tripartite meetings were held in November 2001, July 2002, and January 2003, the last of which included a report on the Vinca fresh fuel shipment which had taken place the previous August (though not a Tripartite shipment), progress on a possible fuel shipment from Uzbekistan, as well as for additional fact-finding missions to Latvia, Czech Republic, Romania, and Kazakhstan. The last fact finding missions to Poland, Hungary, Bulgaria and Belarus were implemented in 2003 and 2004.

From 2002 to 2007 under contracts arranged by the IAEA, 13 shipments representing a total amount of about 450 kilograms of fresh HEU fuel were returned to the Russian Federation (Table 1).

Country	Amount of HEU, kg	Date of Removal
Yugoslavia (Serbia)	48.0	08/2002
Romania	14.0	09/2003
Bulgaria	17.0	12/2003
Libya	17.0	03/2004
Czech Republic	6.0	12/2004
Uzbekistan	3.0	09/2004
Latvia	3.0	05/2005
Czech Republic	14.0	09/2005
Libya	3.0	07/2006
Poland	40.0	08/2006
Germany	268.0	12/2006
Poland	8.8	08/2007
Vietnam	4.5	09/2007

Table 1. Fresh HEU Fuel Returned to Russia under IAEA Contracts

In 2006, the IAEA procured ten high capacity dual purpose spent fuel casks to directly assist the Russian Research Reactor Fuel Return Programme (RRRFR) under a 4 million euro contract. The IAEA prepared the Scope of Work for this procurement, in consultation with the RRRFR Programme, coordinated the technical evaluation of cask systems proposals from six (6) international cask vendors and implemented the contract awarded to the preferred tender. In addition, the IAEA supported shipments of spent HEU fuel from Uzbekistan, Czech Republic, Latvia, Bulgaria and Hungary. The shipment from the Czech Republic in November 2007 was the first where the high capacity casks purchased by the IAEA in 2006 were used.

The IAEA is also supporting the RRRFR through the organization of meetings, workshops, training and publication of guidelines to facilitate operator's/institutions participation in future spent fuel shipments. The IAEA made available in February 2007 to all potential participants in the RRRFR the document on "Technical and Administrative Preparations for Shipment of Russian-Origin Research Reactor Spent Fuel to the Russian Federation (a Guideline Document)". The document is based on material presented and discussed at different meetings and workshops and is expected to help interested Member States plan their shipments of spent fuel to the Russian Federation and have an important impact on future spent fuel shipments to that country.

The IAEA has been provided funds by the Nuclear Threat Initiative (NTI) to proceed with the planning and implementation of the safe removal of the spent RR fuel from the Vinča Institute in Serbia. In addition, supplementary funds have been committed from the US-DOE. With such financial support, several studies of the spent fuel stored at Vinča have been carried out, as well as other activities to

improve the spent fuel storage conditions. In 2005 the IAEA solicited bids from qualified firms to remove the spent nuclear fuel from the Vinča Institute for reprocessing at the PO Mayak facility in the Russian Federation. Bids were evaluated by a group of international experts and a preferred tender was selected. In October 2006, through its technical cooperation programme, the IAEA concluded a US $4.3 million contract with a Russian consortium and Serbia to start the work, which initially involves repackaging about 8000 TVR-S fuel elements for transportation. With additional funds, received from the European Union, another contract of nearly $5.5 million to cover transport and related tasks will be implemented. This project is financially the largest ever involving the IAEA technical cooperation programme. Since signature of the contract, on-site operations at Vinca were effectively managed by all stakeholder organizations and are progressing smoothly and on schedule.

3. A Look into the Future

The IAEA will continue to support GTRI, specifically the RERTR programme and the programmes to return fresh and spent HEU fuel to the country of origin. The 2010-2011 IAEA Programme and Budget, which is currently in the final stages of development before presentation to and review by member states, includes activities specifically designed to assist Member States in their efforts to minimize and eventually eliminate civilian uses of HEU.
Main activities to be carried out in the triennium 2009-2011 are listed below:

- Under the IAEA initiative on Research Reactor Coalitions and Centres of Excellence, the IAEA will encourage and coordinate cooperative work among operators of similar type of HEU operated reactors to study and develop prototypical approaches for conversion from HEU to LEU;
- The IAEA will continue maintaining and improving the list of RRs using HEU including subcritical and critical facilities and pulse reactors;
- The IAEA will publish a technical document on “Conversion of MNSR RRs” after completion of the related CRP;
- The IAEA will publish a document on “Use of LEU in Accelerator Driven Subcritical Systems after completion of the related international collaborative work;
- The IAEA will extend for another three years, starting in 2009, the CRP on “Developing techniques for small-scale indigenous production of Mo-99 from LEU or Neutron Activation” and publish a technical document on the subject when the CRP is completed
- The IAEA will initiate a new CRP on “Feasibility Evaluation of the Use of LEU Fuelled Homogeneous Aqueous Solution Nuclear Reactors for the Production of Short lived Fission Product Isotopes”;
- The IAEA will prepare a comprehensive technical publication on high density U-Mo fuels and evaluate the convenience of holding a training course on the subject; and
- The IAEA will promote the concept of regional shared RRs and centres of excellence to substitute the present fleet of ageing and many times underutilized RRs.

4. Conclusions

The IAEA will continue contributing to international non-proliferation efforts in connection with HEU minimization by supporting RERTR and the programmes of return of RR fuel to the country of origin. Important progress has been achieved in the period 2005-2008 in the expanded set of new HEU minimization activities initiated in 2005.
To assist Member States and the international initiatives in their efforts to reduce and eventually eliminate the use of HEU, the Agency offers all mechanisms available through its Regular Agency Programme and Technical Cooperation Programme.
Agency’s involvement is not limited to supporting and conducting HEU minimization activities. Due consideration is also being given to support RR sustainability in the post conversion and post return of spent fuel phases, through initiatives like the new project on RR coalitions and centres of excellence.
The IAEA encourages Member States to contact pertinent departments at the Agency to seek assistance and make suggestions for new activities in relation with RR and target conversion and fuel return issues.