THE U.S. RERTR PROGRAM
STATUS AND PROGRESS*

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ABSTRACT

The progress of the Reduced Enrichment Research and Test Reactor (RERTR) Program since its inception in 1978 is described. A brief summary of the results which the RERTR Program had achieved by the end of 1996 in collaboration with its many international partners is followed by a detailed review of the major events, findings, and activities of 1997.

Significant progress has been made during the past year.

In the area of U.S. acceptance of spent fuel from foreign research reactors, several shipments have taken place and additional are being planned.

Intense fuel development activities are in progress, including procurement of equipment, screening of candidate materials, and production of microplates. Irradiation of the first series of microplates began in August 1997 in the Advanced Test Reactor, in Idaho.

Progress has been made in the Russian RERTR program, which aims to develop and demonstrate within five years the technical means needed to convert Russian-supplied research reactors to LEU fuels**.**

The study of an alternative LEU core for the FRM-II design has been extended to address, with favorable results, controversial performance issues which were raised at last year's meeting.

Progress was also made on several aspects of producing molybdenum-99 from fission targets utilizing LEU instead of HEU. Various types of targets and processes are being pursued, with FDA approval of an LEU process projected to occur within two years.

The feasibility of LEU fuel conversion for three important DOE research reactors (BMRR, HFBR, and HFIR) has been evaluated by the RERTR program.

In spite of the many momentous events which have occurred during the intervening years, and the excellent progress achieved, the most important challenges that the RERTR program faces today are not very different in type from those that were faced during the first RERTR meeting. Now, as then, the most important task is to develop new LEU fuels satisfying requirements which cannot be satisfied by any existing fuel. These new advanced fuels will enable conversion of the reactors which cannot be converted today, ensure better efficiency and performance for all research reactors, and allow the design of more powerful new advanced LEU reactors.

As in the past, the success of the RERTR program will depend on free exchange of ideas and information, and on the international friendship and cooperation that have been a trademark of the RERTR program since its inception.

INTRODUCTION

This is the twentieth time that specialists from all over the world have gathered under the aegis of the Reduced Enrichment for Research and Test Reactor (RERTR) Program to exchange information about their activities, to coordinate their efforts, to make new friendships, and to renew old ones.

The RERTR Program was established in 1978 at the Argonne National Laboratory (ANL) by the Department of Energy (DOE), which continues to fund the program and to manage it in coordination with the Department of State (DOS), the Arms Control and Disarmament Agency (ACDA), and the Nuclear Regulatory Commission (NRC). The primary objective of the program is to develop the technology needed to use low-enriched uranium (LEU) instead of high-enriched uranium (HEU) in research and test reactors, and to do so without significant penalties in experiment performance, economic, or safety aspects of the reactors. Research and test reactors utilize nearly all the HEU that is used today in civil nuclear programs.

Close cooperation with international organizations has been the cornerstone of the RERTR Program since its beginning. This cooperation and the high quality of the technical contributions which many partners have brought to the overall effort are to be credited for much of the progress which the program has achieved.

In many ways, this meeting is a historic event for the RERTR program, as attested by the very large number of attendees and by the extensive number of papers to be presented -- greater by far than at any previous RERTR meeting. It is an appropriate time for taking stock of what we have been able to do, of what has happened in the world since the program began, and of what our future goals should be.

Holding this meeting in Jackson Hole will facilitate, I hope, this process of review, self-examination, and planning. In many ways, it is as if a cycle had been concluded, with this meeting occurring in the United States, as was the first. This time, however, the meeting is being held close to the Western site of Argonne National Laboratory, as a complement to the Eastern site where the first meeting was held. As in 1978, you will be able to visit the facilities that are being equipped for the development of advanced new LEU fuels, and to hear about a recently started irradiation program. There are many similarities, but also very important differences. I will review some of these differences and similarities in the sections that follow, and will describe, in particular, the most important events of last year.

I hope that, having attended our annual RERTR meetings in many other regions of the United States, you will take this opportunity for enjoying the majestic beauty of the American West and of its Mountain States. The great mountains which surround us, their unique formation, their wildlife, and the attitudes of the people who inhabit them, are an integral and unforgettable part of the American landscape. I hope that you will take pleasure in sharing them with us.

OVERVIEW OF THE PROGRAM STATUS

The group of scientists, managers, fuel developers, and fuel fabricators who met at Argonne National Laboratory in October 1978, on the occasion of the first International RERTR Meeting, faced an unusual set of problems. The main task was to find technical solutions that would make it possible to use LEU fuels in the research reactors that were then operating with HEU fuels. But little was known about the new fuels that needed to be developed, about the performance and safety characteristics resulting from the use of the new fuels, and even about the reactors for which the new fuels were to be developed.

By October 1996, when the last International RERTR Meeting was held[1], many important results had been achieved in the fuel development area:

(a) The qualified uranium densities of the three main fuels which were in operation with HEU in research reactors when the program began (UAl_x-Al with up to 1.7 g U/cm^3; U_3O_8-Al with up to 1.3 g U/cm^3; and $UZrH_x$ with 0.5 g U/ cm^3) had been increased significantly. The new qualified uranium densities extended up to 2.3 g U/cm^3 for UAl_x-Al, 3.2 g U/cm^3 for U_3O_8-Al, and 3.7 g U/cm^3 for $UZrH_x$. Each fuel had been tested extensively up to these densities and, in some cases, beyond them. All the data needed to qualify these fuel types with LEU and with the higher uranium densities had been collected.

(b) For U_3Si_2-Al, after reviewing the data collected by the program, the U.S. Nuclear Regulatory Commission (NRC) had issued a formal approval[2] of the use of U_3Si_2-Al fuel in research and test reactors, with uranium densities up to 4.8 g/cm^3. A whole-core demonstration using this fuel had been successfully completed in the ORR using a mixed-core approach. Plates with uranium densities of up to 6.0 g/cm^3 had been fabricated by CERCA with a proprietary process, but had not yet been tested under irradiation.

(c) For U_3Si-Al, miniplates with up to 6.1 g U/cm^3 had been fabricated by ANL and the CNEA, and irradiated to 84-96% in the Oak Ridge Research Reactor (ORR). Postirradiation examinations of these miniplates had given good results, but had shown that burnup limits would need to be imposed for the higher densities. Four full-size plates fabricated by CERCA with up to 6.0 g U/cm^3 had been successfully irradiated to 53-54% burnup in SILOE, and a full-size U_3Si-Al (6.0 g U/cm^3) element, also fabricated by CERCA, had been successfully irradiated in SILOE to 55% burnup. However, conclusive evidence indicating that U_3Si became amorphous under irradiation had convinced the RERTR Program that this material as then developed could not be used safely in plates beyond the limits established by the SILOE irradiations.

(d) Limited work had been accomplished to develop methods for producing plates with much higher effective uranium loadings. The effort to develop new advanced LEU fuels had been restarted after a pause of about six years,

Important results had been obtained also in other areas. Reprocessing studies at the Savannah River Laboratory had concluded that the RERTR fuels could be successfully reprocessed at the Savannah River Plant and DOE had defined the terms and conditions under which these fuels would be accepted for reprocessing. These results had been rendered moot, however, by DOE's decision to phase out reprocessing at the Savannah River Plant and by the expiration of the Off-site Fuel Policy at the end of 1988. An Environmental Impact Statement and a related Record of Decision had been completed in May1996 for a new DOE policy allowing, over a period of 13 years, the return of spent research reactor fuel elements of US origin to be irradiated during the next 10 years.

An analytical/experimental program was in progress to determine the feasibility of using LEU instead of HEU in fission targets dedicated to the production of ^{99}Mo for medical applications. Procedures had been developed for dissolution and processing of both LEU silicide targets and LEU metal foil targets. These procedures were ready for demonstrations on full-size targets with prototypic burnups.

Extensive studies had been conducted, with favorable results, on the performance, safety, and economic characteristics of LEU conversions. These studies included many joint study programs, which were in progress for about 29 reactors from 18 different countries. A study to assess the feasibility of using LEU in the fuel of a modified version of the FRM-II reactor, which was being designed with HEU at the Technical University of Munich, had stimulated spirited discussions.

Coordination of the safety calculations and evaluations was continuing for the U.S. university reactors planning to convert to LEU as required by the 1986 NRC rule. Nine of these reactors had been converted, four other safety evaluations had been completed, and calculations for four more reactors were in progress.

Much technical change had occurred since the inception of the RERTR program. Many important events had also changed the geopolitical landscape in which the program operates. As a result of the former Soviet Union moving from a centrally planned economy to a market-oriented economy, U.S. reprocessing of research reactor fuels had come to an end, but a new cooperation with Russian institutes had become possible with the goal of converting to LEU many Russian-designed research reactors still operating with HEU. With the waning of the bipolar tension between nuclear superpowers, international attention had become increasingly focused on the dangers of nuclear proliferation and had resulted in increased support for the goals of the RERTR program. The events of the Gulf War intensified this support, especially after it became known that Iraq had been on the verge of acquiring and using a nuclear weapon built from research reactor fuels containing HEU.

LEU fuels were planned for the new Jules Horowitz Reactor in France and the new China Advanced Research Reactor in China. However, there was increasing pressure for HEU use in new research reactors pushing the limits of current technology. The Advanced Neutron Source Reactor had been discontinued by the U.S. Congress, but the FRM-II reactor in Germany was still designed with HEU fuel, and so was the PIK reactor in Russia. New and better LEU fuels were needed, not only to convert existing reactors, but also to encourage the use of LEU fuels in the research reactors of the future.

PROGRESS OF THE RERTR PROGRAM IN 1997

The main events, findings, and activities of the RERTR Program during the past twelve months are summarized below.

1. After publication of the Final Environmental Impact Statement[3] for the return of spent research reactor fuel and of the related Record Of Decision[4] (February 1996 and May 1996, respectively), four spent research reactor fuel shipments containing about 900 fuel assemblies have been completed to the Savannah River Site (SRS). These shipments, along with planned shipments to the Idaho National Engineering and Environmental Laboratory (INEEL), are expected to eliminate, over a thirteen-year period, the large inventories of spent fuel which currently fill the pools and storage facilities of many research reactors. The process is consistent with U.S. policy[5] and will resolve urgent operational problems of the reactor sites while, at the same time, eliminating a serious proliferation concern. Two sessions of this meeting are dedicated to this important topic.

2. The fuel development effort has started in earnest at both Argonne-East and Argonne-West. New equipment needed for this activity is being procured and installed[6]. Several fuel types which appeared to be good candidates for high-density applications were evaluated and tested out of pile[7, 8]. A series of microplates comprising the most promising materials, including dispersion fuels formed with U-Mo and U-Zr-Nb alloys, in addition to other uranium compounds, in combination with various matrix materials were fabricated[9]. The fabricated microplates were inserted for irradiation[10] in the Advanced Test Reactor. The irradiation is currently in progress in Idaho, not far from Jackson Hole.

3. Cooperation with the Russian RERTR program has continued. The main Russian organizations taking part in this effort include the Research and Development Institute for Power Engineering (RDIPE), the Institute for Inorganic Materials (VNIINM), the Novosibirsk Chemical Concentrates Plant (NZChK), and the RRC “Kurchatov Institute.” The purpose of the activity is to conduct the studies, analyses, fuel development, and fuel tests needed to establish the technical and economic feasibility of converting Russian-supplied research and test reactors to the use of LEU fuels. An important component of this effort is the development of computer models to interpret and predict the behavior of various fuels that might be irradiated in Russian-designed reactors, as well as in other reactors. The models are being developed through a joint effort between Argonne and VNIINM scientists[11]. Other results obtained by the Russian laboratories will be presented and discussed at this meeting by our Russian colleagues.

4. The study of an alternative LEU core which could provide the same experiment performance and the same fuel lifetime as the HEU core currently planned for the FRM-II has continued, in order to address technical issues that were raised at the 1996 RERTR meeting in Seoul and in other fora. The results of these extended studies, addressing fluxes at experimental facilities in HEU and LEU designs for the FRM-II, will be presented at this meeting.[12]

5. Progress was also achieved during the past year on several aspects of producing ^{99}Mo from fission targets utilizing LEU instead of HEU. The goal is to develop and demonstrate during the next few years one or more viable technologies compatible with the processes currently in use with HEU at various production sites throughout the world. This

activity is conducted in cooperation with several other laboratories including Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL), the University of Illinois, the University of Texas, and the Indonesian National Atomic Energy Agency (BATAN). Targets comprising a UO_2 LEU layer have been fabricated at LANL and are planned for irradiation in the Annular Core Research Reactor at SNL in late spring 1998, to be followed by processing through acidic dissolution. FDA certification of this process is expected to follow one year later. Another method, for UO_2-Al LEU dispersions to be processed through alkaline dissolution, is under study[13]. Finally, a second series of LEU metal-foil targets was irradiated in the RSG-GAS research reactor at BATAN, and a third series is being prepared for irradiation to begin in early 1998. These tests are to optimize the design of LEU metal-foil targets, which can be processed either through acidic or alkaline dissolution. The chemical processes to be used in combination with the LEU metal foils are being refined and tested[14], and an improved method to apply fission recoil barriers to the foils is being developed[15].

6. In the Reactor Analysis area, results of the RELAP5/MOD3 and PARET/ANL codes were compared with experimental transient data from the SPERT-IV D-12/25 Series to assess their applicability to midrange and more severe transients[16]. A method was developed to derive the kinetic parameters of research reactors without using perturbation codes.[17]

7. As part of a task assigned by the Department of Energy, the RERTR program began to assess the feasibility of converting to LEU each of the DOE facilities which currently use HEU fuel. In particular, conversion feasibility studies were completed for the Brookhaven Medical Research Reactor (BMRR) [18], for the High Flux Beam Reactor (HFBR) [19], and for the High Flux Isotope Reactor (HIFR) [20].

8. During the past year, the IAN-R1 reactor in Colombia was converted from HEU MTR-type fuel to LEU TRIGA fuel; the Slowpoke reactor at the Ecole Polytechnique in Montreal, Canada, was converted to LEU UO_2 Slowpoke fuel; and the first LEU fuel elements were inserted into the BER-II reactor at the Hahn-Meitner Institute in Berlin, Germany. The foreign reactors that have been fully converted to LEU fuels include ASTRA, DR-3, FRG-1, JMTR, NRCRR, NRU, OSIRIS, PARR, PRR-1, RA-3, R-2, and THOR, while the domestic reactors include FNR, RPI, OSUR, WPIR, ISUR, MCZPR, UMR-R, RINSC, and UVAR. Two foreign reactors, IEA-R1 and SSR, have been partially converted, and three more, GRR-1, HOR, and JRR-4, have fabricated or ordered LEU cores. Approximately 60% of the work required to eliminate use of HEU in U.S.-supplied research reactors has been accomplished.

PLANNED ACTIVITIES

In some ways, the tasks that the program faces today remind us of those that had to be faced in 1978. Entirely new fuels need to be developed, and new equipment and procedures need to be established. The characteristics of new reactor types need to be studied, including performance, safety, and fuel requirements.

There are also major differences. Our expertise in fuel development is much greater than in 1978, but the properties required for the new fuels are also much more demanding. Our ability to predict the characteristics of converted reactors has much improved and the number of the reactors that need to be evaluated is much smaller.

The major activities which the RERTR Program plans to undertake during the coming year to face these challenges are described below.

1. Complete procurement and installation of fuel fabrication equipment needed to develop advanced fuels.

2. Begin producing a second series of microplates, including samples of the main materials of interest for the advanced fuel development.

3. Continue out-of-pile tests on some of the fuel materials, to assess their properties and likely performance.

4. Continue irradiation testing of microplates in the ATR.

5. Perform postirradiation examination of the first series of microplates.

6. In collaboration with the Russian RERTR program, continue to implement the studies, analyses, fuel development, and fuel tests needed to establish the technical and economic feasibility of converting Russian-supplied research and test reactors to the use of LEU fuels.

7. Continue LEU conversion feasibility studies for U.S. reactors. Continue calculations and evaluations about the technical and economic feasibility of utilizing reduced-enrichment fuels in reactors that require such assistance, and in reactors of special interest.

8. Continue development of one or more viable processes, based on LEU, for the production of fission ^{99}Mo in research reactors.

9. Complete the testing, analysis, and documentation of LEU fuels which have already been developed, support their implementation, and transfer their fabrication technology to countries and organizations which require such assistance.

SUMMARY AND CONCLUSION

The RERTR program has made significant progress during the past year.

(a) In the area of **U.S. acceptance of spent fuel** from foreign research reactors, four shipments have taken place, and additional shipments are being planned.

(b) In the area of **advanced fuel development**, fuel development activities are in progress, including procurement of equipment, screening of candidate materials, and production of microplates. Irradiation of the first series of microplates is in progress in the Advanced Test Reactor, in Idaho.

(c) Significant progress has been achieved in the **Russian RERTR program**, which aims to develop and demonstrate within five years the technical means needed to convert Russian-supplied research reactors to LEU fuels.

(d) The study of an alternative LEU core for the **FRM-II design** has been extended to address, with favorable results, controversial performance issues which were raised at last year's meeting.

(e) Significant progress was made on several aspects of producing **molybdenum-99** from fission targets utilizing LEU instead of HEU. Various types of targets and processes are being pursued, with FDA approval of an LEU process projected to occur within two years.

(f) In the area of **conversion of DOE research reactors**, the feasibility of converting three important DOE reactors (BMRR, HFBR, and HFIR) has been evaluated by the RERTR program.

The type of problems that we are facing today, as we gather for the twentieth International RERTR Meeting, are not very different from that which we faced during the first meeting. Now, as then, our most important task is to develop brand new LEU fuels satisfying requirements which cannot be satisfied by any existing fuel.

These new advanced fuels will enable conversion of the reactors which cannot be converted today, ensure better efficiency and performance for all research reactors, and allow the design of more powerful new advanced LEU reactors. Because of the provision of the Atomic Energy Act, as amended in 1992,[21] it also satisfies one of the conditions that would enable the U.S. to export HEU for the operation of those reactors which require it.

As in the past, our success will depend on free exchange of ideas and information. Once more, I ask for the international friendship and cooperation that have been a trademark of the RERTR program since its inception.

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