STATUS AND PROGRESS OF THE RERTR PROGRAM *

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ABSTRACT

The progress of the Reduced Enrichment Research and Test Reactor (RERTR) Program is described. The major events, findings, and activities of 1996 are reviewed after a brief summary of the results which the RERTR Program had achieved by the end of 1995 in collaboration with its many international partners.

Significant progress has been made during the past year in each of the three areas that the delegates to last year's RERTR meeting chose to address, in their letter to President Clinton, as requiring special attention.

(1) In the area of U.S. acceptance of spent fuel from foreign research reactors, a second shipment of 99 urgent-relief spent fuel elements was completed. The Final Environmental Impact Statement was published in February 1996, and the Record of Decision was published in May 1996. The first shipments under the Record of Decision, containing 280 spent fuel elements, were received at the Savannah River Site in September 1996.

(2) In the area of advanced fuel development, adequate funding and guidance were received by the RERTR program in March 1996. Fuel development activities are now in progress, including procurement of equipment, screening of candidate materials, and preparations for the production of a first series of microplates. The first irradiations are planned to begin in the Advanced Test Reactor. in Idaho, during April 1997.

(3) In the area of conversion of DOE research reactors, the RERTR program has been tasked by the Department of Energy to assess the feasibility of converting to LEU fuel each of the DOE research reactors which currently use HEU fuel. A preliminary assessment will be presented at this meeting.

Significant progress has been made by the Russian RERTR program, which aims to develop and demonstrate within the next 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 excellent results, several controversial performance and safety questions which were raised at last year's meeting.

Substantial accomplishments were made on the development of a process to produce ^{99}Mo from fission targets utilizing LEU instead of HEU. In particular, LEU metal-foil target prototypes were irradiated and, after irradiation, were easily extracted from other target materials for separate dissolution and processing.

We owe a debt of gratitude to the U.S. Department of Energy for responding as it did to some of our most pressing needs. Once more, I ask for the international friendship and cooperation that have been a trademark of the RERTR program since its inception.

INTRODUCTION

Last year, at the conclusion of the 1995 International Meeting in Paris, the 200 delegates who attended that meeting from approximately 30 countries asked the Secretary of the meeting to send a letter to President Clinton expressing their concern about some problems facing the RERTR program, and recommending the adoption of three steps which could alleviate those problems. The three recommended steps included

a) U.S. acceptance of spent fuel from foreign research reactors;

b) resumption of RERTR fuel development; and

c) conversion of DOE research reactors.

I am happy to report that great progress has been made in all the three areas of concern to last year's meeting, and that the RERTR program is again whole, vibrant, and eager to face, with your help, the challenges ahead so that we can attain together President Clinton's goal to minimize and eventually eliminate the use of highly-enriched uranium in civil nuclear programs.

The Reduced Enrichment Research and Test Reactor (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-Enrichment Uranium (LEU) instead of High-Enrichment 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 in civil nuclear programs.

Close cooperation with international organizations has been the cornerstone of the RERTR Program since its inception. 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.

Cooperation between the RERTR program and the Korean Atomic Energy Research Institute (KAERI) dates back to many years ago, when the Korean Multipurpose Research Reactor (KMRR), now called HANARO, was still on the drawing boards. Scientists from KAERI visited Argonne frequently, sometimes for several months, working with us at the development of silicide fuels, and scientists from Argonne visited KAERI on many occasions. From those interactions emerged a very original and important contribution of KAERI to RERTR effort: the process to produce atomized particles of uranium silicide, which promises significant improvements over the classic comminution process. We are expanding this cooperation to include the development of new advanced fuels and the development of LEU-based processes for the production of ^{99}Mo.

I am very grateful to KAERI for hosting this nineteenth International RERTR Meeting. The beauty and hospitality of the Republic of Korea are well known and will be very much appreciated by all of us, especially by those who are visiting Korea for the first time. I am very much impressed by the thoroughness with which the meeting was organized, and I look forward to a

series of exciting and productive sessions, to visiting the HANARO and other KAERI facilities in Taejon, to renew old friendships, and to make new ones.

OVERVIEW OF THE PROGRAM STATUS

In September 1995, when the last International RERTR Meeting was held[1], the main results achieved in the fuel development area were:

(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. Irradiation of several plates with 5.8 g/cm^3 and 6.0 g/cm^3 was to begin in SILOE during 1995, and irradiation of two elements with 5.8 g/cm^3 was to begin in OSIRIS during 1996.

(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). PIE 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 done to develop methods for producing plates with much higher effective uranium loadings.

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 extensive Draft Environmental Impact Statement had been completed for a new DOE policy allowing the return of spent research reactor fuel elements of US origin. After resolution of significant legal obstacles, 153 urgent-relief elements from several European countries had been received at the Savannah River Plant under the provisions of an Environmental Assessment published in April 1994. Implementation of the new DOE policy was contingent on publication of a Final Environmental Impact Statement and of a Record of Decision.

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 US 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. After a pause of six years, the US administration had decided that the RERTR program should resume development of advanced LEU research reactor fuels, but had not yet provided the funding needed for it.

PROGRESS OF THE RERTR PROGRAM IN 1996

The activities and accomplishments of the RERTR Program during the past twelve months have corresponded closely to the plans outlined at last year's meeting in Paris. [1] The main events, findings, and activities are summarized below.

1. A second urgent-relief shipment of 99 spent fuel elements from Greece and Switzerland was received at the Savannah River Plant in November 1995 under the provisions of the Environmental Assessment. Publication of the Final Environmental Impact Statement[3] for the return of spent research reactor fuel occurred in February 1996 and was followed, on May 13, 1996, by publication of the related Record of Decision.[4] These documents, and the favorable conditions which they established for the return of spent research reactor fuel, paved the way for a great number of fuel shipments which 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. This action will resolve urgent operational problems of the reactor sites while, at the same time, eliminating a serious proliferation concern. The first shipments under this Record of Decision, containing 280 spent research reactor fuel elements coming from reactors in Germany, Switzerland, Sweden, Chile, and Colombia, were received at the Savannah River Site during September 1996.

2. Near the end of March 1996, after a pause of over six years during which no fuel development could be pursued by the RERTR program, the US Department of Energy provided both the funding and the guidance needed by the program to resume the development of advanced LEU fuels to improve the options and performance of research reactors undergoing conversions. The DOE action, which provided $1.4 million for fiscal year 1996, was supplemented by a $1.5 million contribution from the US Department of State. DOE plans to support this effort with $3.0 million in fiscal year 1997 and has committed itself, in written testimony to Congress, to continue to support the fuel development effort for several years until its objectives are met.

   As a result of these events, the RERTR program is now deeply involved, for the first time in many years, in fuel development activities. The first and foremost task is to reestablish a cadre of skilled fuel developers building on the expertise of the previous fuel development

effort. Two groups with complementary strengths have been formed for this purpose, one at the Argonne-East site in Illinois and the other at Argonne-West in Idaho. Orders have been placed to procure new equipment, several uranium-bearing materials have been evaluated for their potential application in high-density fuels, and a preliminary plan has been developed for the initial phase of the fuel development effort.[5] Initial efforts will be concentrated on the production of microplates containing dispersion fuels formed with U-Mo and U-Zr-Nb alloys, in addition to other uranium compounds, in combination with various matrix materials. Irradiation of the first microplates is planned to begin in the Advanced Test Reactor (ATR), in Idaho, during April 1997.

3. Cooperation with the Russian RERTR program has continued and was strengthened by a new agreement, signed in May 1996, which modified the intellectual property rights of the pre-existing agreement. The main Russian organizations which take part in this effort include the Research and Development Institute for Power Engineering (RDIPE), the Novosibirsk Chemical Concentrates Plant (NZKhK), the Institute for Inorganic Materials (VNIINM), 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. Calculations are planned at ANL to study the applicability of the new LEU fuels to be developed under this activity to the operation of various Russian-design research reactors currently using HEU. A theoretical study has addressed the irradiation behavior of high-density UO_2 dispersion fuel, whose development is currently the focus of the Russian RERTR effort.[6] The 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 an effort to resolve the technical issues and discussions which took place at the 1995 RERTR meeting in Paris.[7,8] The results of these extended studies, addressing both the performance and the safety of the proposed alternative LEU core, will be presented at this meeting.[9]

5. Significant progress was achieved during the past year on several aspects of producing ^{99}Mo from fission targets utilizing LEU instead of HEU. [10, 11, 12, 13] 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 the University of Illinois and the Indonesian National Atomic Energy Agency (BATAN). For the first time, LEU metal-foil target prototypes were irradiated and, after irradiation, were easily extracted from other target materials for separate dissolution and processing. This constituted a very important milestone in the development of a viable process based on the use of LEU metal-foil targets.

6. Existing fuel data were analyzed and interpreted to derive a better understanding of the behavior of dispersion fuels under irradiation. In particular, the results of some HFIR irradiation tests of very small silicide fuel particle clusters, performed in 1995, were analyzed to assess the limits which very high levels of power density, temperature, uranium density, and fission density may pose on the applicability of U_3Si_2-Al dispersion fuels.[14]

7. In the Reactor Analysis area, the reactivity effects of the most important uranium compounds considered in the fuel development effort were evaluated, to derive a realistic assessment of

the advantages that could be derived from the development of the various types of high-density fuels.[15] The results of the PARET/ANL code were compared with those of RELAP5/MOD3 for a number of IAEA benchmark transients, to assess the validity of thermal-hydraulic calculations obtained from each code. [16]

8. Design and safety analyses were performed for reactors undergoing or considering LEU conversions within the joint study agreements which are in effect between the RERTR Program and several international research reactor organizations. For the first time, during the past year the RERTR program was tasked by the Department of Energy to assess the feasibility of converting to LEU each of the DOE facilities which currently use HEU. A preliminary assessment resulting from this study will be presented at this meeting.[17]

9. The main radiological characteristics of spent research reactor nuclear fuel were evaluated,[18] in direct support of the DOE policy to accept spent nuclear fuel from foreign research reactors for disposition in the U.S.

10. The list of the fully-converted research reactors which used to require HEU supplies of US origin has not changed since last year: The foreign reactors 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. Three foreign reactors, including IEA-R1, SSR, and TR-2, have been partially converted, and two more, GRR-1 and HOR, have fabricated LEU cores. Approximately 60% of the work required to eliminate use of HEU in US-supplied research reactors has been accomplished.[1]

PLANNED ACTIVITIES

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

1. Complete the orders for the new fuel fabrication equipment needed to develop advanced fuels, and set up the fuel fabrication laboratory at ANL-W.

2. Produce a first series of microplates, including samples of the main materials of interest for the advanced fuel development.

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

4. Begin irradiation testing of microplates in the ATR.

5. 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.

6. 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.

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

8. Complete testing, analysis, and documentation of the 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

Significant progress has been made during the past year in each of the three areas that the delegates to last year's RERTR meeting chose to signal, in their letter to President Clinton, as requiring special attention.

(a) In the area of **U.S. acceptance of spent fuel** from foreign research reactors, a second shipment of 99 urgent-relief spent fuel elements was completed. The Final Environmental Impact Statement was published in February 1996, and the Record of Decision was published in May 1996. The first shipments under the Record of Decision were received at the Savannah River Site in September 1996.

(b) In the area of **advanced fuel development**, adequate funding and guidance were received by the RERTR program near the end of March 1996. Fuel development activities are now in progress, including procurement of equipment, screening of candidate materials, and preparations for the production of a first series of microplates. The first irradiations are planned to begin in the Advanced Test Reactor, in Idaho, during April 1997.

(c) In the area of **conversion of DOE research reactors**, the RERTR program has been tasked by the Department of Energy to assess the feasibility of converting to LEU fuel each of the DOE research reactors which currently use HEU fuel. A preliminary assessment resulting from this study will be presented at this meeting.

Important advances have been made also in other areas.

(d) The Russian RERTR program, which aims to develop and demonstrate within the next five years the technical means needed to convert Russian-supplied research reactors to LEU fuels, has made significant progress**.**

(e) The study of an alternative LEU core for the FRM-II design has been extended to address, with excellent results, several controversial performance and safety questions which were raised at last year's meeting.

(f) Significant progress was made on several aspects of producing ^{99}Mo from fission targets utilizing LEU instead of HEU. In particular, LEU metal-foil target prototypes were irradiated and, after irradiation, were easily extracted from other target materials for separate dissolution and processing. This was an important milestone in the development of a viable process based on the use of LEU metal-foil targets.

The most important issues that I have addressed are unquestionably those related to the return of the spent fuel and to the advanced fuel development.

The Record of Decision, and the successful completion of the first related shipments, brings to an end a long period of concern for many research reactors. However, it must be noted that the U.S. spent fuel acceptance policy is valid only for ten more years of operation. Reactor operators would be wise to plan now for the final disposition of their spent fuel when the ten years have elapsed.

Resumption of advanced fuel development means that new fuels can be developed to enable conversion of the reactors which cannot be converted today, to ensure better efficiency and performance for all research reactors, and to allow the design of more powerful new advanced LEU reactors. Because of the provision of the Atomic Energy Act, as amended in 1992,[19] it also satisfies one of the conditions that would enable the U.S. to export HEU for the operation of those reactors which need it. The U.S.

Department of Energy has had a leading role in the successful resolution of these serious and long-standing problems. We owe a debt of gratitude to the Department for acting forcefully on our behalf, frequently overcoming significant obstacles in terms of funding, effort, aggravation, and legal harassment. I am especially grateful towards the U.S. Government representatives who have attended our meetings and been able to bring forcefully our message to the highest levels of the agencies for which they work.

We are beginning our new tasks in earnest. Old agreements are been renewed, and new ones are being forged. Especially in the fuel development area, our success will depend, as in the past, on cooperation and 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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