THE RERTR PROGRAM STATUS AND PROGRESS*

A. Travelli

Argonne National Laboratory
Argonne, Illinois 60439-4841 USA

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A. Travelli
Argonne National Laboratory
Argonne, Illinois, USA

ABSTRACT

The progress of the Reduced Enrichment Research and Test Reactor (RERTR) Program is described. The major events, findings, and activities of 1995 are reviewed after a brief summary of the results which the RERTR Program had achieved by the end of 1994 in collaboration with its many international partners.

The revelation that Iraq was on the verge of developing a nuclear weapon at the time of the Gulf War, and that it was planning to do so by extracting HEU from the fuel of its research reactors, has given new impetus and urgency to the RERTR commitment of eliminating HEU use in research and test reactors worldwide.

The Draft Environmental Impact Statement on the DOE policy for managing spent nuclear fuels from foreign research reactors was published on schedule. A Record of Decision is due in December 1995. After much legal debate, a first shipment of 153 urgent-relief elements took place, and another 151 elements became eligible for shipment.

Development of advanced LEU research reactor fuels is scheduled to begin in October 1995, after DOE funding is received. Funding for equipment needed to begin this activity was provided by the US Department of State, and procurement of the equipment is in progress.

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, is now in operation. A Statement of Intent was signed by high US and Chinese officials, endorsing cooperative activities between the RERTR program and Chinese laboratories involved in similar activities.

Joint studies of LEU technical feasibility were completed for the SAFARI-1 reactor in South Africa and for the ANS reactor in the US. The ANS project was later canceled for budgetary and nonproliferation reasons. A new study has been initiated for the FRM-II reactor in Germany.

Significant progress was made on several aspects of producing ^{99}Mo from fission targets utilizing LEU instead of HEU. A cooperation agreements is in place with the Indonesian BATAN. The first prototypical irradiation of an LEU metal-foil target for ^{99}Mo production was accomplished in Indonesia.

The TR-2 reactor, in Turkey, began conversion. SAPHIR, in Switzerland, was shut down. LEU fuel fabrication has begun for the conversion of two more US reactors. Twelve foreign reactors and nine domestic reactors have been fully converted. Approximately 60% of the work required to eliminate the use of HEU in US-supplied research reactors.

International friendship and cooperation has been and will continue to be essential to the achievement of the common goal.

INTRODUCTION

During 1995, the US administration continued to assign a high priority to the issue of proliferation of weapons of mass destruction and has acted in accord with President Clinton's announcement, in his 1993 speech to the United Nations General Assembly, that he intended "*to minimize the use of highly-enriched uranium in civil nuclear programs*". This goal has been shared and pursued by our international RERTR program for many years, and is the goal that brings us here today.

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 most of the HEU that is used in civil nuclear programs.

Close cooperation with the many international organizations represented at this meeting has been the cornerstone of the RERTR Program since its beginning seventeen years ago. 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 to date.

We have had a long a fruitful collaboration with the Commissariat à l'Énergie Atomique (CEA). The CEA was one of the first organizations in the world to espouse the principle of converting HEU research reactors to the use of LEU fuels, and its conversion of the OSIRIS reactor actually predated the early efforts of the RERTR program. It would take a long time to list the many ways in which CERCA, a world-renowned fabricator of research reactor fuels, and SILOE, another CEA reactor, have supported the RERTR program. And it was in Paris that the first RERTR meeting ever to be held abroad took place, in 1979. I am very grateful to the CEA for hosting this RERTR meeting in Paris for the second time. I look forward to a series of exciting and productive sessions, and to the beauty and culture that are and always will be the mark of the Ville Lumière.

OVERVIEW OF THE PROGRAM STATUS

In September 1994, 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 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 US. 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 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). PIE of these miniplates had given good results, but had shown that some burnup limits might 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.

In other important program 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. A new DOE policy had been proposed for the return of spent research reactor fuel elements of US origin and an Environmental Impact Statement was being prepared. Legal obstacles were still preventing implementation of emergency-relief shipments that were addressed in the Environmental Assessment published in April 1994.

A new analytical/experimental program had begun to determine the feasibility of using LEU instead of HEU in fission targets dedicated to the production of ^{99}Mo for medical applications. A procedure for basic dissolution and processing of LEU silicide targets had been developed and was ready for demonstration on a full-size target with prototypic burnup.

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 joint study to assess the feasibility of using reduced uranium enrichments in the fuel of the Advanced Neutron Source, which was under design at Oak Ridge National Laboratory (ORNL), had identified several low- and medium-enrichment options [3,4,5].

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 already been converted, four other safety evaluations had been completed, and calculations for four more reactors were in progress. DOE guidance received at the beginning of 1990 had redirected the efforts of the US RERTR Program away from the development of new and better fuels, toward the transfer of already developed fuel technologies, and toward providing assistance to reactors undergoing conversion. The US administration had decided in favor of resuming development of advanced LEU research reactor fuels, but had not yet provided the funding needed for it.

PROGRESS OF THE RERTR PROGRAM IN 1995

At the beginning of August 1995, with the defections from Iraq of Lt. Gen. Hussein Kamel Hassan and Lt. Col. Saddam Kamel Hassan, the world came to know how a nightmare had almost become reality. According to the newest revelations, shortly before the 1990 invasion of Kuwait, Saddam Hussein had given the order to produce, within six months, **a nuclear weapon using the highly enriched uranium contained in research reactor fuel held in Iraq**. The amount of HEU in Iraq was sufficient to manufacture a nuclear weapon, even considering only the material which did not require radiological protection. Had the order been issued earlier, or the Gulf War started later, the world might have faced an unspeakable horror. The fact that we came so close to it confirms the validity and the urgency of our mission, and must intensify our commitment to eliminate the use of HEU in civil nuclear programs worldwide.

During the past twelve months the RERTR Program has moved aggressively to implement the plans which were outlined at last year's meeting in Williamsburg.[1] The main events, findings, and activities are summarized below.

1. After much legal debate, 153 urgent-relief elements from Austria, Denmark, The Netherlands, and Sweden were received at Savannah River, and another 151 elements from Germany, Greece, and Switzerland became eligible for shipment. The "Draft Environmental Impact Statement on a Proposed Nuclear Weapon Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel"[6] was published by DOE on schedule, in March 1995, and was distributed for public comment in April 1995. A Record of Decision, defining which option will be chosen to implement the policy, is due in December 1995. The status of this important activity will be presented at this meeting.[7] The proposed DOE spent nuclear fuel policy was formulated in response to proliferation concerns and to the needs of foreign research reactor operators. The RERTR program has contributed to the overall effort in several ways, one of which will be discussed at this meeting.[8]

2. Activities related to the development of LEU fuels with uranium density greater than the 4.8 g/cm^3, which last year were expected to start at the beginning of 1995, had to be postponed because of budgetary restrictions which occurred during 1995. Funding for this activity is now included in the DOE budget for the fiscal year beginning in October 1995. Furthermore, the US Undersecretary of Energy has assured Congress that *"DOE is committed to fully fund the advanced fuel development program until its objectives*

are met [9]. *To* prepare for the beginning of this activity, the US Department of State has received Congressional approval to fund procurement of the equipment that needs to be installed at Argonne for this purpose, beginning in August 1995. Preparation of the specifications and purchase orders for the equipment is now ongoing.

3. Significant progress was achieved by the Russian RERTR program, which comprises several major Russian institutes including 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 objective of this program is to develop and demonstrate within the next five years the technical means needed to convert from HEU to LEU fuels approximately 27 research reactors designed and supplied by institutes of the Russian Federation. Our Russian colleagues will describe their activities and plans in several papers that will be presented at this meeting.[10, 11, 12, 13, 14, 15] With their assistance, the scope of the RERTR program has been expanded to address the problems created by use of HEU in civil nuclear programs in many parts of the world which in the past had been outside its reach.

4. On 23 February 1995, the US Secretary of Energy and the President of the China Atomic Energy Authority of the People's Republic of China signed a Statement of Intent endorsing cooperative activities between the RERTR program and Chinese laboratories involved in similar activities. It is hoped that this will lead soon to a Chinese RERTR program that would make the RERTR program global.

5. Studies related to the utilization of LEU fuels in advanced research reactor concepts have continued. Studies were performed to assess the feasibility of using new LEU advanced fuels of the Advanced Neutron Source, which was under design at Oak Ridge National Laboratory (ORNL).[16] However, the results of these studies were rendered moot by the cancellation of the project *"for budgetary and nonproliferation reasons."*

   Another very important reactor design in this category is that of the FRM-II reactor, which is under design at the Technical University of Munich, in Germany. Preliminary calculations comparing the performance and requirements of an HEU design with those of alternative LEU designs have been performed and will be presented at this meeting.[17]

6. Significant progress was achieved during the past year on several aspects of producing ^{99}Mo from fission targets utilizing LEU instead of HEU.[18, 19, 20, 21, 22, 23] 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). A first prototypic irradiation of an LEU metal-foil target was accomplished in Indonesia.

7. 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. In particular, a study of the technical feasibility of converting the SAFARI-1 reactor to LEU fuel was completed with excellent results, in cooperation with personnel from the Atomic Energy Corporation (AEC) of South Africa.[24] A study of the economic feasibility of the conversion is currently in progress at the AEC.

8. Existing fuel data were analyzed and interpreted to derive a better understanding of the behavior of dispersion fuels under irradiation, with particular regard for the fuel porosity and for the thermal conductivity of the fuel meat.[25, 26]

9. Computer codes have been modified and upgraded to improve our capability to analyze the performance and safety characteristics of research reactors utilizing LEU fuels. In particular, a Supercell Option was added to the WIMS-D4 code.[27]

10. The TR-2 (5 MW) in Çekmece, Turkey, began conversion by loading the first LEU elements in 1994. The SAPHIR reactor (10 MW) in Würenlingen, Switzerland, was shut down in 1994 before completing the conversion process which had been in progress for several years. The list of the fully-converted foreign reactors which used to require HEU supplies of US origin stands at twelve reactors: ASTRA, DR-3, FRG-1, JMTR, NRCRR, NRU, OSIRIS, PARR, PRR-1, RA-3, R-2, and THOR. As illustrated in Fig. 1, approximately 60% of the work required to eliminate use of HEU in US-supplied research reactors has been accomplished.[1]

11. Among the US. university reactors, which are considered separately because they do not require HEU exports, fuel fabrication has begun for the GTRR, at Georgia Tech, and for the ULR, at the University of Lowell. A significant upgrade is being pursued for the FNR, which was one of earliest conversions.[28] The total number of US converted reactors stands at nine (FNR, RPI, OSUR, WPIR, ISUR, MCZPR, UMR-R, RINSC, and UVAR). Safety documentation is either complete or nearly complete for four other plate-type reactors. Work is in progress on the four TRIGA reactors which use HEU fuel.

PLANNED ACTIVITIES

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

1. Place the orders for the new fuel fabrication equipment needed to develop advanced fuels, and install the equipment. Resume high-density fuel development as soon as guidance and funding for this activity are received from DOE.

2. 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.

3. 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, such as the FRM-II.

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

5. 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

The revelation that Iraq was on the verge of developing a nuclear weapon at the time of the Gulf War, and that it was planning to do so by extracting HEU from the fuel of its research reactors, gives new impetus and urgency to the RERTR commitment of eliminating HEU use in research and test reactors worldwide.

Several important events have marked the progress of the RERTR Program during the past year.

(a) A first shipment of 153 urgent-relief spent fuel elements took place, and another 151 spent fuel elements became eligible for shipment. The Draft Environmental Impact Statement on a US policy for managing spent nuclear fuels from foreign research reactors was published, on schedule, in March 1995. A Record of Decision is due in December 1995.

(b) Development of advanced LEU research reactor fuels is scheduled to begin around the end of 1995, after DOE funding is received. Funding for equipment needed to begin this activity was provided by the US Department of State, and procurement is in progress.

(c) 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, is now in operation.

(d) A Statement of Intent was signed by high US and Chinese officials, endorsing cooperation between the RERTR program and Chinese laboratories involved in similar activities.

(e) Joint LEU feasibility studies were completed for the SAFARI-1 and ANS reactors. The ANS project was later canceled for budgetary and nonproliferation reasons. A new study has been initiated for the FRM-II reactor.

(e) Significant progress was made on several aspects of producing ^{99}Mo from fission targets utilizing LEU instead of HEU. A cooperation agreement is in place with the Indonesian BATAN. The first irradiation of an LEU metal-foil target for ^{99}Mo production was completed in Indonesia.

(f) LEU conversion began at the TR-2 reactor, in Turkey. SAPHIR, in Switzerland, was shut down for financial reasons. Fabrication of LEU fuel for the conversion of two more US reactors has begun. The number of converted foreign reactors stands at twelve, and the number of converted US reactors stands at nine. Approximately 60% of the work required to eliminate the use of HEU in US-supplied research reactors has been accomplished.

The most important current issues are related to the imminent resumption of advanced fuel development and to finding an acceptable solution for the back end of the fuel cycle. The new fuels can ensure better efficiency and performance for all research reactors, can enable conversion of the reactors which cannot be converted today, and can allow the design of more powerful new advanced LEU reactors. We are very excited at the prospect of this task and eager to begin. The problems concerning the back end of the fuel cycle are much more complex, but we hope that an acceptable solution will be found. Once more, I ask for the international friendship and cooperation that have been a trademark of the RERTR program since its inception, seventeen years ago.

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FIG. 1 PROGRESS TOWARD CONVERSION OF US-SUPPLIED RESEARCH AND TEST REACTORS