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THE RERTR PROGRAM: A STATUS REPORT*

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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 1991 are reviewed after a brief summary of the results which the RERTR Program had achieved by the end of 1990 in collaboration with its many international partners.

The RERTR Program has concentrated its efforts on technology transfer and implementation activities consistent with the guidance received from the Department of Energy at the end of 1990.

Postirradiation fuel data have continued to be analyzed and interpreted to gain a better understanding of the behavior of research reactor fuels under irradiation. Final reports of the Oak Ridge Research Reactor (ORR) Whole-Core Demonstration and of the Ford Nuclear Reactor (FNR) Whole-Core Demonstration were published, and a final report on RERTR fuel development activities is at the final draft stage. Several computer codes for the analysis of research reactors were successfully converted to run on SUN workstations. Final contributions to the IAEA Safety and Licensing Guidebook for Core Conversions were completed. Analyses, calculations, and safety evaluations were conducted to support both US and foreign research reactors in converting to the use of low enrichment uranium.

Six additional reactors that used to need HEU exports have become fully converted to LEU fuels, bringing to nine the total of such reactors. Two more U.S. university reactors were also fully converted, bringing their total to five. An approximate quantitative evaluation shows that the midpoint of the road to conversion of all reactors which used to require HEU exports has been passed, and last year's progress is consistent with the projection that most reactors which do not require development of new fuels could be converted within three years. The major current program goal is to work closely with the various reactor and fuel fabrication organizations, so that this projection becomes reality. International cooperation continues to be essential to the achievement of this goal.

INTRODUCTION

Recent disclosures about nuclear activities in Iraq have heightened new concerns about nuclear proliferation and the dangers inherent in the international traffic of highly-enriched uranium (HEU). Reduction and possibly elimination of this traffic has been from the beginning the goal of the Reduced Enrichment Research and Test Reactor (RERTR) Program and of all the international organizations associated with it. The recent events underscore the importance and timeliness of our task, and reinforce our determination to succeed.

The RERTR Program was established in 1978 by the Department of Energy (DOE), which continues to fund and manage the program in coordination with the Arms Control and Disarmament Agency (ACDA), the Department of State (DOS), 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 in the research and test reactors whose fuel requirements cause most of the HEU traffic, and to do so without significant penalties in experiment performance, economics, or safety aspects of the reactors.

Close cooperation with the many organizations represented at this meeting has been the keystone of the RERTR Program since its beginning, and is to be credited for much of the excellent progress which the program has achieved to date.

It is appropriate to make a special mention, on the occasion of this meeting, of the cooperation between the RERTR Program and the National Atomic Energy Agency of Indonesia (BATAN). This cooperation began in 1981, when two BATAN scientists visited ANL for several months using fellowships provided by the International Atomic Energy Agency (IAEA) and analyzed with RERTR personnel the features and characteristics of various research reactor designs that were being considered by BATAN. That early effort culminated, within a short time, in the selection and acquisition by BATAN of a beautiful new facility whose focal point is the RSG-GAS reactor (or MPR-30), a modern 30 MW research reactor which uses LEU fuel.

As the new BATAN facility progressed from design to construction and to operation, also the BATAN/RERTR cooperation continued and grew, with exchanges of technical data, computer codes, and technical visits. The areas of cooperation include neutronics, thermal-hydraulics, safety issues, fuel fabrication, postirradiation examinations, and fuel qualification -- in short, nearly every technical area in which the RERTR Program is involved.

The RERTR Program is looking forward to continued cooperation with BATAN and we are grateful to BATAN for hosting this conference in Jakarta. We eagerly anticipate exchanging technical data and news with our many colleagues; enjoying the beauty and hospitality of Indonesia; visiting a first-class new research facility; and seeing how well one of the early fuels developed by the RERTR Program is utilized in a modern, advanced research reactor design.

OVERVIEW OF THE SEPTEMBER 1990 PROGRAM STATUS

By September 1990, 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 U.S. Nuclear Regulatory Commission (NRC) had issued a formal and generic 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.

(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 beyond the limits established by the SILOE irradiations.

(d) Two concepts based on hot-isostatic pressing (HIP) procedures had been developed for LEU silicide fuels with the potential of holding effective uranium densities much greater than 4.8 g U/cm^3. One of the concepts was based on a composite structure of U_3Si wires and aluminum (up to 12.9 g U/cm^3), while the other was based on a U_3Si_2-Al dispersion structure (up to 10.2 g U/cm^3). Sample miniplates had been produced for both concepts.

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 will be accepted for reprocessing.

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 28 reactors from 17 different countries.

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. Three of these reactors had already been converted, three other safety evaluations had been completed, and calculations for six more reactors were in progress.

New guidance received from DOE around 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.

PROGRESS OF THE RERTR PROGRAM IN 1991

The activities of the RERTR Program during the past year have been consistent with the guidance provided by DOE at the beginning of 1990. That guidance, which was described in detail at the last International RERTR meeting in Rhode Island, directed the RERTR Program to focus on the conversion of research reactors using the low-enrichment fuels which the program had already developed, and to concentrate program efforts on technology transfer and analytical assistance related to such conversions. These activities were envisioned to continue through 1994, when it was estimated that most of the research reactors now fueled with HEU would have been able to convert to low-enrichment fuels.

The main accomplishments of the program during 1991 are listed below.

1. The results of postirradiation examinations of dispersion fuels were further studied to derive a better understanding of the irradiation behavior, safety characteristics, and applicability of these fuels[3]. Whenever needed, the results were transmitted to the operators of reactors preparing for conversion, so that they could be taken into account in the required safety evaluations.

2. A final, comprehensive report of the ORR whole-core demonstration with silicide fuel was completed and published[4]. A final, comprehensive report of the Ford Nuclear Reactor (FNR) whole-core demonstration with LEU aluminide fuel was also published[5]. It is expected that both reports will be of considerable assistance in the planning and safety evaluations of research reactors considering either gradual or single-step conversions.

3. The final draft stage was reached in the preparation of a report that will condense in a single document all the information accumulated by the RERTR Program on the fabrication of new LEU fuels[6].

4. Several computer codes which can be used to analyze the performance and safety characteristics of research reactors operating with LEU fuels were successfully converted to run on SUN workstations. In combination with those previously converted to run on microcomputers,[7] these codes are expected to improve significantly the computational capabilities of organizations with limited access to mainframe computers. The codes converted to run on SUN workstations are PLTEMP, NATCON, PARET, DIF3D, and REBUS. The codes converted to run on microcomputers are PLTEMP, NATCON, PARET, UM2DB, LEOPARD, and LYNX.

5. Final contributions were made to the "Safety and Licensing Guidebook for Core Conversions from HEU to LEU Fuels", to be published by the IAEA.

6. Analyses, calculations, and safety evaluations were conducted to support US research reactors in their efforts to convert to LEU fuels as required by the US Nuclear Regulatory Commission. Some results of this work are included in one of the papers presented at this meeting[8].

7. Analyses, calculations, and safety evaluations were performed also for reactors undergoing or considering conversions outside the US, within the joint study agreements which are in effect between the RERTR Program and several international research reactor organizations. An important contribution of the RERTR Program in this area is reported at this meeting.[9]

8. Calculations were performed for advanced compact-core designs and concepts, to define their limits and to investigate the feasibility of using reduced-enrichment fuels in their cores. Also reported at this meeting are the preliminary results of a promising method which uses linear programming to optimize the core design of an advanced research reactor concept with LEU fuel.[10]

I reported last year[1] on the overall progress toward conversion which had been achieved by the end of 1990 toward the conversion to LEU fuels of all the research reactors which required HEU exports when the program began, and which were still in operation without imminent plans of being shut down. It is of interest to revisit the situation of these reactors today, and to see how much new progress has been accomplished during the intervening year.

The research reactors of interest for this review are the forty-two[1] research reactors with power of at least one megawatt which used to import HEU either from the United States or from other Western sources. Several reactors among this group have made very important recent strides toward conversion. Listed below are the major accomplishments of which we have become aware since the previous report was prepared:

1. The DR-3 reactor (12 MW), at RISØ, Denmark, was completely and successfully converted to the use of LEU silicide fuel fabricated at RISØ.

2. The RA-3 reactor (2.8 MW), at the CNEA, Argentina, was completely and successfully converted to the use of LEU oxide fuel fabricated at the CNEA.

3. The FRG-1 reactor (5 MW), at GKSS, Germany, was completely and successfully converted to the use of LEU silicide fuel fabricated at CERCA.

4. The ASTRA reactor (8 MW), at ÖFZS, Austria, completed a gradual conversion to the use of LEU elements of various types, fabricated by NUKEM and CERCA.

5. The NRCRR reactor (5 MW), at AEOI, Iran, was converted to the use of LEU fuel fabricated by the CNEA.

6. The PARR reactor (5 MW), at PAEC, Pakistan, was converted to the use of LEU fuel.

7. The R2 reactor (50 MW), at Studsvik, Sweden, began conversion by gradually loading about 36 LEU silicide fuel elements fabricated by CERCA.

8. Five other reactors placed orders for fabrication and/or materials of LEU elements: HOR (Netherlands), GRR-1 (Greece), TR-2 (Turkey), JMTR (Japan), and SSR (Romania).

With these changes the list of the fully-converted reactors, which last year included only three reactors (OSIRIS, THOR, and PRR-1), has grown to include nine reactors.

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[1]Forty-three such reactors were identified to belong to this group last year. The change was motivated by two reasons: (a) one reactor was added (SCARABEE, France) and two were removed because both DIDO and PLUTO, in the United Kingdom, were permanently shut down in 1991 after long and fruitful service.

Significant progress has been achieved also in the completion of intermediate steps leading to conversion. As detailed in Ref. 1, the six important steps which many reactors may be expected to take on their way toward conversion are:

1. Determine feasibility of conversion.

2. Develop conversion plan.

3. Begin irradiation of prototype elements.

4. Order LEU elements for conversion.

5. Load first LEU elements in the core.

6. Unload last HEU elements from the core.

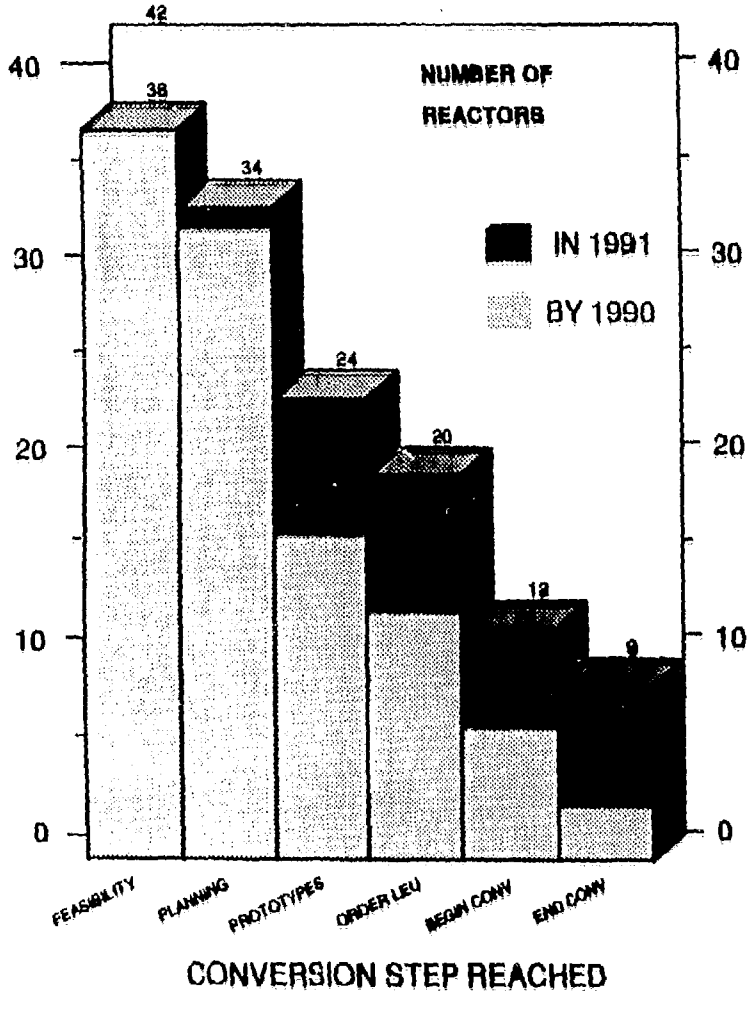
The forty-two operating reactors which required HEU exports when the RERTR Program began can be subdivided in seven categories according to the most advanced step which they have achieved. The two graphs of Fig. 1 illustrate the distributions of the numbers of the reactors, and of the average number of kilograms of ^{235}U yearly exported for use in their fuels, among the various categories. Both diagrams would be blank if no progress toward reduction of HEU exports had been achieved, and would be fully shadowed if total success had been achieved and no further HEU exports were to be required. The lighter areas correspond to the progress achieved by the end of 1990 and reported at the last meeting, and the darker areas correspond to the incremental progress achieved during 1991. If each new step achieved is assumed to correspond approximately to equivalent progress, the percentage of each diagram which is shadowed corresponds to the percentage of the overall goal which has been accomplished, either in terms of reducing the number of reactors requiring HEU exports or in terms of reducing the yearly exports of ^{235}U. These percentages are now 54.4% for the number of reactors and 54.8% for the yearly ^{235}U exports, while they were, respectively, 44.1% and 47.9% last year.[2] Therefore, the progress which has been achieved collectively by the international RERTR effort has passed the midpoint of the road leading to the ultimate goal.

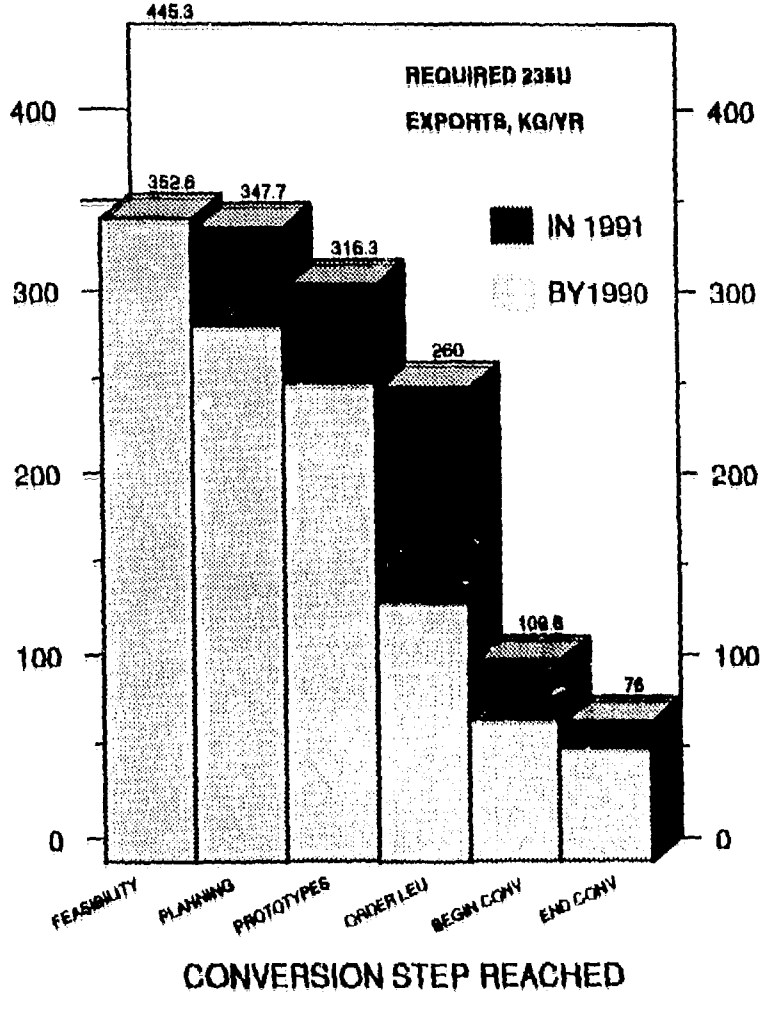
Last year it was noted that, since U_3Si_2-Al LEU fuel was fully qualified for use in research reactors in 1986, the progress achieved by the end of 1990 appeared to indicate that most of the remaining conversion work could be accomplished by the end of 1994. The progress achieved during the past year is in line with that projection and confirms that our collective goal can be achieved.

Comparable progress has been attained also by the U.S. university reactors, which are considered separately because they do not require HEU exports. Two additional reactors of this

[2]The values cited last year were slighuly different, 43.8% and 47.4%, because of the different base.

Fig.1 PROGRESS TOWARD CONVERSION OF RESEARCH REACTORS REQUIRING HEU EXPORTS





group were converted to LEU fuels, bringing the total number of such converted reactors to five. One additional conversion order was issued by the NRC. Safety documentation was completed for another reactor and is in progress for four more reactors.

The RERTR Program has contributed to this progress and plans to continue to do so to the best of its ability. However, it is the individual reactor organizations which shoulder the responsibility for the reactors, their operation, and their safety. They must carry on most of the work required for the conversions, and deserve most of the credit for the progress which has been achieved. We look forward to working with them towards our common goal in the coming years, as we have in the past.

PLANNED ACTIVITIES

The future activities which the RERTR Program plans to undertake are consistent with the recent DOE guidance and with the plan outlined at last year's international meeting. The major elements of this plan are described below.

1. Complete testing, analysis, and documentation of the fuels which have already been developed, and support their implementation.

2. Transfer LEU fuel fabrication technology to countries and organizations which require such assistance.

3. Perform calculations and evaluations for reactors planning to undergo conversion, to assist in improving performance and in resolving safety issues.

4. Within the available budget, develop a viable process, based on LEU, for the production of fission ^{99}Mo in research reactors.

SUMMARY AND CONCLUSION

Consistent with recent DOE guidance and with a reduced but stable budget projection, the RERTR Program has concentrated its efforts on the following activities:

1. Existing fuel data were analyzed and interpreted to derive a better understanding of the behavior of dispersion fuels under irradiation.

2. Final reports of experiments and analyses were prepared. Final reports of the ORR Whole-Core Demonstration and of the FNR Whole-Core Demonstration were completed, and will assist most research reactors planning to convert to LEU fuel either gradually through a succession of mixed-cores or in a single step, with a uniform core. A final report on RERTR fuel development activities is at the final draft stage.

3. A series of computer codes for the analysis of research reactors operating with LEU fuels were successfully converted to run on SUN workstations, in addition to those already converted to run on microcomputers. This work is expected to improve the applicability and usefulness of the codes.

4. Final contributions were completed for the IAEA Safety and Licensing Guidebook for Research Reactor Core Conversions from HEU to LEU Fuels.

5. Analyses, calculations, and safety evaluations were conducted to support both US and foreign research reactors in their activities related to core conversions to LEU fuels.

Six additional reactors that formerly required HEU exports have fully converted to the use of LEU fuels during the past year, bringing to nine the number of such full conversions. Two more U.S. university reactors have also converted, bringing their total to five. An approximate quantitative evaluation of the overall LEU conversion progress has shown that more than half of the work required to eliminate the need for further HEU exports has been accomplished. The incremental progress achieved during the past year is well in line with the projection that the conversion process of the reactors which do not require development of new fuels can be accomplished during the next three years. The primary program goal is to work as closely as possible with the various reactor and fuel fabrication organizations, and to spare no effort to ensure that this projection materializes. As in the past, international cooperation will be essential to the achievement of our common goal.

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