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THE RERTR PROGRAM: A PROGRESS REPORT

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ABSTRACT

The progress of the Reduced Enrichment Research and Test Reactor (RERTR) Program is described. After a brief summary of the results which the RERTR Program, in collaboration with its many international partners, had achieved by the the end of 1985, the activities, results, and new developments which occurred in 1986 are reviewed. The second miniplate series, concentrating on U_3Si_2-Al and U_3Si-Al fuels, was expanded and its irradiation continued. Postirradiation examinations of several of these miniplates and of six previously irradiated U_3Si_2-Al full-size elements were completed with excellent results. The whole-core ORR demonstration with U_3Si_2-Al fuel at 4.8 g U/cm^3 is well under way and due for completion before the end of 1987. DOE removed an important barrier to conversions by announcing that the new LEU fuels will be accepted for reprocessing. New DOE prices for enrichment and reprocessing services were calculated to have minimal effect on HEU reactors, and to reduce by about 8-10% the total fuel cycle costs of LEU reactors. New program activities include preliminary feasibility studies of LEU use in DOE reactors, evaluation of the feasibility to use LEU targets for the production of fission-product ^{99}Mo, and responsibility for coordinating safety evaluations related to LEU conversions of U.S. university reactors, as required by NRC. Achievement of the final program goals is projected for 1990. This progress could not have been achieved without close international cooperation, whose continuation and intensification are essential to the achievement of the ultimate goals of the RERTR Program.

INTRODUCTION

The Reduced Enrichment Research and Test Reactor (RERTR) Program was established in 1978 by the Department of Energy (DOE). Its primary objective 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, economics, or safety aspects.

Excellent progress has been made toward the achievement of this objective through the close cooperation which has existed since the beginning between the program and the many organizations represented at this meeting. In particular, the cooperation of Oak Ridge National Laboratory (ORNL) has been vital to the progress of the program. All the RERTR miniplate irradiations, and many of the full-size element irradiations, have taken place in the Oak Ridge Research Reactor (ORR). Many of the postirradiation examinations and fission-product release tests have also taken place at ORNL. And it is in the ORR that the whole-core demonstration of U_3Si_2 fuel, which we will have an opportunity to view on the final day of this meeting, is now taking place. Therefore, it gives me special pleasure to report here, in close proximity to Oak Ridge National Laboratory, on the status of the RERTR Program, on last year's progress, and on our plans for the future.

OVERVIEW OF THE OCTOBER 1985 PROGRAM STATUS

The main results achieved in the fuel development area by October 1985, at the time of the last International RERTR Meeting,[1] 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 significantly increased. 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, but some supplementary activities were still in progress.

b) For U_3Si_2-Al, miniplates with up to 3.8 g U/cm^3 had been fabricated by ANL and irradiated to 90-96% burnup in the ORR with excellent PIE results.

   Four full-size plates with up to 5.4 g U/cm^3 had been irradiated to an estimated 59% average burnup in the SILOE reactor at CENG, France, with excellent results.

   A full-size element, fabricated by CERCA with 5.2 g U/cm^3, was planned to begin irradiation soon, also in SILOE.

   Six full-size elements with 4.8 g U/cm^3 had been fabricated in equal numbers by NUKEM, CERCA, and B&W, and irradiated in the ORR. Of the two elements fabricated by each fuel vendor, one was estimated to have reached ~50% average burnup and the other ~75% average burnup. All visual and dimensional tests of these elements, and the PIE which had been completed for one element with ~41% average burnup, had given excellent results.

A whole-core demonstration was due to start soon in the ORR. Orders had been placed for 100 standard fuel elements with U_3Si_2-Al at 4.8 g U/cm^3, and for 12 control elements with U_3Si_2-Al at 3.5 g U/cm^3.

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% burnup in the 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 43-54% burnup in SILOE.

Irradiation testing of a full-size U_3Si-Al (6.0 g U/cm^3) element, fabricated by CERCA, was in progress in SILOE with good preliminary results.

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. This conclusion was an important prerequisite for a DOE economic study to define the terms and conditions under which spent LEU fuels from research and test reactors might be accepted for reprocessing.

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 28 reactors from 17 different countries.

The scope and relevance of these activities depended, to some extent, on the outcome of three important pending decisions by U.S. Agencies. These decisions concerned (1) the pricing policy of DOE enrichment services, (2) DOE terms and conditions for reprocessing of LEU research reactor fuels, and (3) a proposed rule by the Nuclear Regulatory Commission (NRC) requiring use of LEU fuels in NRC-licensed non-power reactors.

PROGRESS OF THE RERTR PROGRAM IN 1986

Fuel Development

In the fuel development area, the efforts of the RERTR Program during 1986 have concentrated on materials which show promise for utilization in fuels with uranium densities in excess of 4.8 g U/cm^3. A large number of miniplates have been fabricated and irradiated as part of the second series of miniplate irradiations[2] in the ORR. Forty of these miniplates are still under irradiation, and seventy-two have been irradiated and are either cooling or undergoing examination.

The principal materials used in the second series, and included in approximately 80% of the miniplates, are:

U_3Si_2-Al	35 miniplates with densities up to 5.7 g U/cm^3 and enrichments up to 93%;
$U_3Si_{1.5}$-Al	7 miniplates with densities up to 6.0 g U/cm^3 and enrichments up to 40%;
U_3Si-Al	34 miniplates with densities up to 7.2 g U/cm^3 and enrichments up to 93%;
U_3SiCu-Al	12 miniplates with densities up to 7.0 g U/cm^3 and enrichments up to 40%.

Each of these materials has some properties which make it interesting or promising as a research reactor fuel. The miniplates cover a wide range of densities, thicknesses, and enrichments. In addition, they include some special features to investigate or expand their range of applicability. For instance, several U_3Si_2-Al and U_3Si-Al miniplates include burnable poisons in their fuel meat.

The first three materials are variations of fuels which have already been tested by the RERTR Program, and the results obtained so far from the new miniplates are consistent with expectations.[3] U_3Si_2-Al continues to exhibit extremely stable behavior under irradiation, even with high enrichments. U_3Si-Al offers the advantage of a higher uranium density but tends to approach breakaway swelling at high burnups. $U_3Si_{1.5}$-Al is a mixture of U_3Si_2-Al and U_3Si-Al, and offers a combination of the advantages and disadvantages of both. The data from the miniplates will make it possible to quantify these general trends. It is hoped that the addition of a small amount of Cu to U_3Si-Al, as in U_3SiCu-Al, will increase its stability under irradiation; however, the results from the irradiations are not yet available.

The remaining 24 miniplates of the second series are meant to provide additional general information on the behavior of dispersion fuels under irradiation. In particular, several miniplates of $U_6Mn_{1.3}$-Al with densities up to 7.0 g U/cm^3 are being irradiated to test a theory related to the fundamental irradiation behavior of intermetallic fuel compounds.

Other efforts in the fuel fabrication area are directed at

a) developing an effective and economical comminution process for silicides;

b) investigating the feasibility of improving the fabrication process of silicide fuels by using vapor deposition to coat the compacts with aluminum; and

c) investigating some other very speculative fuel types which, in theory, could reach up to 9.0 g U/cm^3.

Fuel Demonstration

In the area of fuel demonstration, program efforts have centered on U_3Si_2-Al with 4.8 g U/cm^3. It is believed that this fuel will receive very wide application, both in the United States and abroad, because:

a) its maximum practical uranium density is adequate for most research and test reactors considering utilization of LEU fuels,

b) it is relatively simple and inexpensive to fabricate, and, especially,

c) it exhibits excellent behavior under irradiation.

Postirradiation examinations of the six prototype elements which were irradiated in the ORR during previous years are complete,[4] with excellent results.

Currently, the principal effort in the demonstration area is focused on the whole-core demonstration[5] in the Oak Ridge Research Reactor (ORR), which began in December 1985. Extensive measurements were performed around that time to characterize the HEU core. The first three LEU elements were introduced in the ORR core at the beginning of January. After that, at every cycle, three or four additional LEU elements were inserted while an equivalent number of HEU elements were discharged. The ORR normal procedure is to operate with two cores which alternate between the reactor and the pool. At this moment each core contains 21 LEU elements and 4 LEU shim assemblies, corresponding to approximately 80% of the fuel content of the core. The highest burnup of the LEU elements is greater than 40%, and the cores are scheduled to be fully loaded with LEU around the end of the year.

The demonstration has two fundamental goals. The first goal is to prove that it is possible to predict accurately the properties of the many mixed cores which are used in a gradual conversion of this type. Mixed cores are likely to be the most demanding, from a safety point of view, and it is important to establish their safety margins and the accuracy with which their properties can be predicted.

The second goal is to establish a statistically significant database on the irradiation behavior of the silicide fuel fabricated under commercial conditions. Three international fuel vendors have contributed to the fabrication of LEU elements for the ORR demonstration. Sixty elements and twelve shim assemblies were fabricated by Babcock & Wilcox, and twenty elements each were fabricated by CERCA (France) and NUKEM (F.R.G.). A program goal is to achieve successful irradiation to normal burnup of approximately twenty elements from each fuel vendor.

A serious budgetary problem developed during the summer of 1986, threatening achievement of this goal and receiving wide exposure both in the technical and non-technical press. The DOE Fusion Program, which has provided for several years the bulk of the ORR operating funds, concluded that their experiments would be run more efficiently in the High Flux Isotope Reactor (HFIR) and shifted their support to that facility. Left without a major component of the ORR operating funds, ORNL announced that the ORR would be shut down on August 1, 1986. This announcement caused much concern about the fate of the ORR demonstration, both within the RERTR Program and within some of its partners whose activities depend on the results of the demonstration. However, a solution was found within DOE which allowed the ORR to continue to operate past August 1. It is now virtually certain that the ORR will continue to operate at least until the end of September 1987. This extension is estimated to be sufficient for the achievement of a statistically significant number of spent LEU fuel elements from each fabricator.

The goal of confirming the validity of calculations related to the ORR demonstration is well on its way to being achieved.[6,7] Extensive measurements are performed at the end of each ORR cycle. They include flux mapping of the entire core, gamma scanning of the elements, control rod worth and β_{eff}/ℓ measurements. The results of these measurements are compared with calculations within a very short time. So far, the agreement between calculations and measurements is excellent for most parameters.

A document summarizing all the available data on the behavior of U_3Si_2-Al fuel is being prepared and is scheduled for submission to the NRC before the end of 1986. It is hoped that the the NRC, after reviewing this document, will conclude that the fuel can be safely utilized in research reactors.

Generic Analysis and Specific Support

In the analytical area, contributions to the IAEA Guidebook on Safety and Licensing Aspects of HEU-to-LEU Core Conversions are nearly complete. Analyses of the feasibility to convert the many reactors with which the RERTR Program has joint study agreements have continued. Some of these studies concern high-power, high-performance reactors like the HFR-Petten (The Netherlands), the BR-2 (Belgium)[8], and the RHF (France), which require special considerations and methods. The results obtained to date are generally positive, and it is expected that LEU prototype elements will soon begin to be tested in some of these reactors.

A new pricing policy for enrichment services was adopted by the Department of Energy in October 1986. Shortly thereafter, in a Federal Register Notice[9], the Department of Energy announced also that LEU fuels such as those developed by the RERTR Program will be accepted for reprocessing. The Federal Register Notice also defined, for both LEU and HEU fuels, the terms and conditions under which such reprocessing will occur.

In addition to removing a fundamental obstacle to the implementation of LEU fuels, these announcements have altered the cost differential of operating a research reactor with HEU or LEU fuels, which is extremely important to many research reactors contemplating conversions. Economic evaluations[10] by the RERTR Program indicate that the new price scales tend to leave the total HEU fuel cycle costs essentially unchanged while decreasing the total LEU fuel cycle costs by about 8-10%. This means that for many research reactors the new price scales improve the economic feasibility of LEU conversions.

In addition to these activities, which correspond to a continuation or extension of similar activities in progress during the preceding years, some new significant activities were initiated during the past year.

a) An analytical/experimental program was begun, under sponsorship by the Department of Energy, to determine the feasibility of using LEU, instead of HEU, in targets dedicated to the production of fission-product ^{99}Mo for medical applications. Some initial results from this activity are reported at this meeting.[11]

b) At the request of DOE, a preliminary study has been initiated to assess the feasibility of utilizing LEU in all the reactors operated by DOE which can be classified as civilian thermal research and test reactors. Approximately fifteen reactors are considered to satisfy this definition.

c) In support of the DOE effort to assist in the implementation of the new NRC rule[12] requiring LEU usage, whenever possible, in all NRC-licensed research and test reactors, the RERTR Program has assumed the responsibility of coordinating the safety calculations and evaluations for the U.S. university reactors planning LEU conversion. Calculations for several of these reactors[13] have already begun.

   Several reactor operators consider the required LEU conversion as an opportunity to enhance the performance and utilization of their facilities. DOE strongly favors use of a standard plate in most reactors, to minimize refueling costs. The RERTR Program is actively assisting in the pursuit of these goals within the framework of NRC's requirements. No significant safety problem has been encountered so far, and the outcome of this effort is foreseen to result in the extensive utilization of a standard fuel plate (U_3Si_2-Al, ~3.5 g U/cm^3) and in a significant upgrading of several facilities accompanying the enrichment reduction.

FUTURE PROGRAM TRENDS

The good irradiation behavior which continues to be observed in U_3Si_2-Al and U_3Si-Al LEU fuels mandates that most of the Program's fuel development and demonstration future efforts concentrate on the testing and refinement of these fuel types.

The major goals will be:

a) to increase as much as possible the practically usable uranium density of the silicide fuels, so that their range of applicability is extended beyond 4.8 g U/cm^3;

b) to improve the fuel cycle economy of these research reactor fuels by modifying, when desirable and feasible, the fuel element design; and

c) to accumulate a large database on fuel performance under irradiation, which will facilitate licensing.

Consistent with these goals, the major planned activities of the RERTR Program are:

1. Complete the current miniplate fabrication campaign, concentrating on U_3Si_2-Al and U_3Si-Al fuels, and continue irradiation of the miniplates.

2. Continue postirradiation examinations of the miniplates of the second series, and expand them as more irradiated miniplates become available.

3. Conclude, within 1987, the ORR whole-core demonstration with U_3Si_2-Al fuel at 4.8 g U/cm^3.

4. Fabricate and irradiate test and prototype elements with U_3Si_2-Al, U_3Si-Al, or intermediate compositions beyond 4.8 g U/cm^3. The specifications for these elements are to be selected using the data on optimal fabrication procedures and burnup potential provided by the irradiations and examinations of the second miniplate series. Consistent with the schedule of miniplate irradiations and examinations and with current budget requirements, the bulk of this activity is now scheduled to begin at the end of 1987.

5. Continue efforts to develop better comminution processes, better compact forming procedures, and innovative fuel designs.

6. Continue to concentrate analysis on safety, economics, and performance evaluations. Study in greater detail some special aspects typical of very high performance reactors or of very low power lifetime cores. Continue efforts to define generic envelopes of safety limits for possible use in licensing reviews.

The current schematic schedule of the RERTR Program fuel development and demonstration activities is illustrated in Figure 1, using the same format as that used at the 1985 International RERTR Meeting.[1] The main differentiating feature is the postponement of U_3Si-Al element fabrication, mentioned earlier, and a correspondingly later date for final U_3Si-Al qualification. Conclusion of the RERTR Program is now projected to occur in 1990. By that time, it is anticipated that most research and test reactors now operating with HEU will be able to utilize the new LEU fuels without significant penalties.

SUMMARY AND CONCLUSION

The RERTR Program and its international partners have made significant progress in 1986 towards their common goals.

The second miniplate series, initiated during the previous year and concentrating on U_3Si_2-Al and U_3Si-Al, has been expanded and its irradiation has continued. Postirradiations have confirmed anticipated fuel behavior both for the miniplates and for the six full-size U_3Si_2-Al elements whose irradiation had been previously completed. The whole-core ORR demonstration of U_3Si_2-Al fuel with 4.8 g U/cm^3 is well under way, with excellent results.

Three major actions by U.S. Agencies have been announced, with significant implications on program activities. These actions concern (a) DOE pricing policy for enrichment services, (b) DOE terms and conditions for reprocessing LEU fuels, and (c) NRC rule for LEU conversion of NRC-licensed research and test reactors.

The first two DOE actions were evaluated to have minimal effect on HEU reactors, and to reduce by about 8-10% the fuel cycle costs of LEU reactors. As a consequence of the third action, the RERTR Program assumed the responsibility for coordinating the safety evaluations of U.S. university reactors converting to LEU.

Other new activities of the RERTR Program include an experimental/analytical program to evaluate the feasibility of replacing with LEU the HEU currently used in targets for the production of fission-product ^{99}Mo for medical applications, and a preliminary study of the feasibility of converting to LEU the civilian thermal research and test reactors which are currently operated by DOE with HEU fuel.

The RERTR Program schedule has undergone a small readjustment, with qualification of the most advanced fuel currently considered, U_3Si-Al with ~7.0 g U/cm^3, now projected for 1990.

The overall progress which has been achieved in the area of reduced enrichment fuels for research and test reactors would not have been possible without active international cooperation among fuel developers, commercial vendors, and reactor operators. Continued and intensified cooperation will be essential to the achievement of our common long-term goal.

REFERENCES

1. A. Travelli, "The U.S. RERTR Program: Overview, Status and Plans," Int'l. Mtg. on Reduced Enrichment for Research and Test Reactors, Petten, The Netherlands, October 14-16, 1985, D. Reidel Publ. Co., pp.9-19.

2. J. L. Snelgrove, "RERTR Program Fuel Development and Testing — The Past Year and the Next", these proceedings.

3. G. L Hofman, "Swelling and Microstructure of Uranium Silicide - Aluminum Dispersion Fuel", these proceedings.

4. G. L. Copeland, G. L. Hofman, and J. L. Snelgrove, "Irradiation Performance of Experimental U3Si2 Elements in the Oak Ridge Research Reactor," these proceedings.

5. R. W. Hobbs, "The Transition Phase of the Whole-Core Demonstration at the ORR", these proceedings.

6. M. M. Bretscher, "Analytical Support for the Whole-Core LEU Fuel Demonstration in the ORR," these proceedings.

7. R. J. Cornella, "Comparison of Calculated and Experimental Wire Activations," these proceedings.

8. J. R. Deen and J. L. Snelgrove, "Preliminary LEU Fuel Cycle Analysis for the Belgian BR2 Reactor", these proceedings.

9. Department of Energy,"Receipt and Financial Settlement Provisions for Nuclear Research Reactor Fuels," Federal Register/Vol. 51, No. 32/ Tuesday, February 18, 1986/Notices.

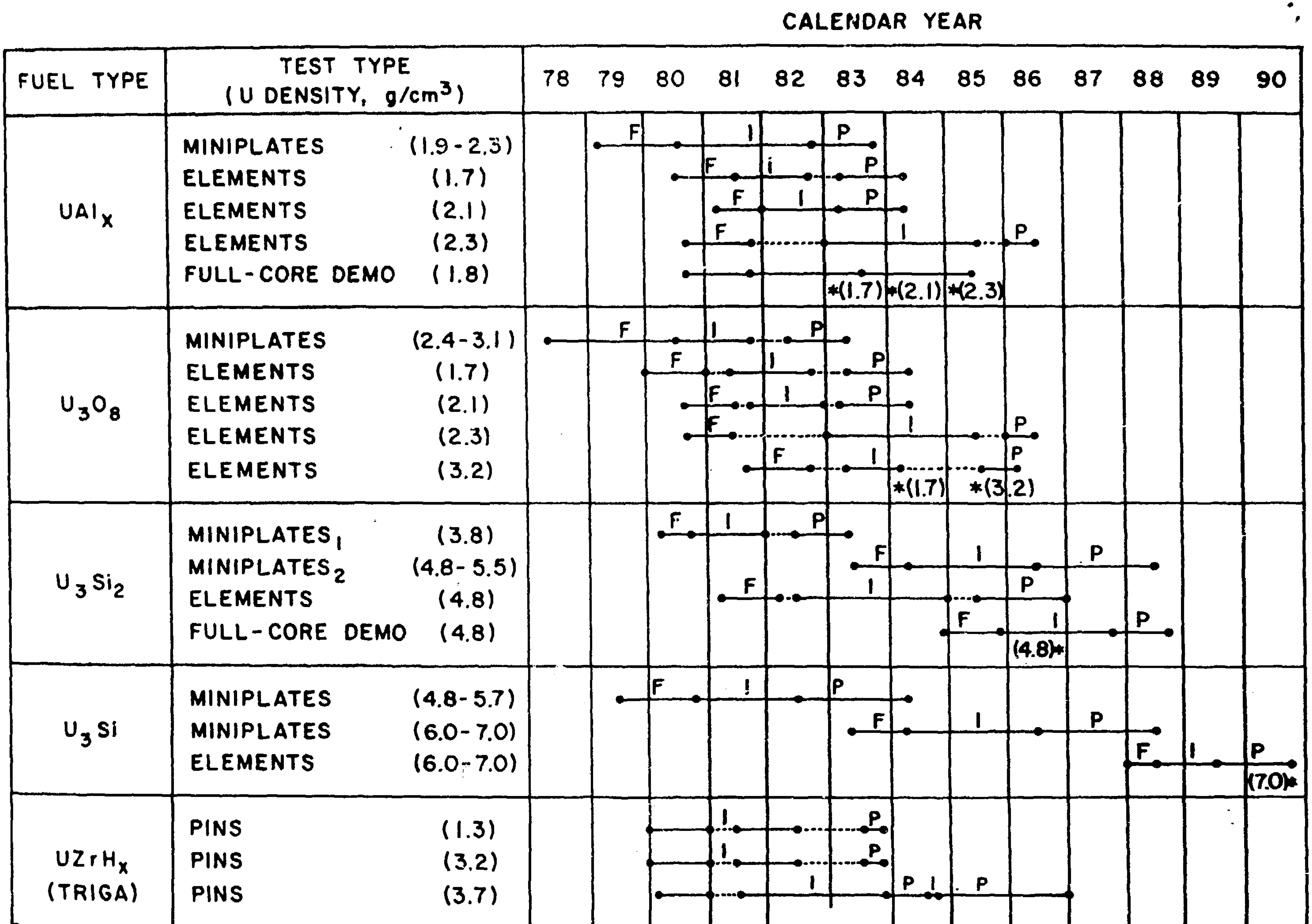
10. J. E. Matos, "Effect of Changes in DOE Pricing Policies for Enrichment and Reprocessing on Research Reactor Fuel Cycle Costs," these proceedings.

11. D. R. Vissers and G. F. Vandegrift, "Preliminary Investigations for Technology Assessment of 99Mo Production from LEU Targets," these proceedings.

12. Nuclear Regulatory Commission, 10 CFR Part 50, "Limiting the Use of Highly Enriched Uranium in Domestically Licensed Research and Test Reactors," Federal Register/Vol. 51, No. 37/Tuesday, February 25, 1986/Rules and Regulations.

13. H. H. Young, J. E. Matos, and K. R. Brown, "Conversion and Standardization of University Reactor Fuels Using Low-Enrichment Uranium - Pl.ans and Schedules," these proceedings.

Fig. 1. Schematic Schedule for RERTR Fuel Development and Demonstration Activities.



A = ANALYSIS; F = FABRICATION; I = IRRADIATION; P = POST-IRRADIATION EXAMINATION; * = QUALIFICATION DATE