STATUS REPORT ON THE CONVERSION OF THE RHODE ISLAND NUCLEAR SCIENCE CENTER REACTOR

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ABSTRACT

The 2 MW Rhode Island Atomic Energy Commission reactor is required to convert from the use of High Enriched Uranium (HEU) fuel to the use of Low Enriched Uranium (LEU) fuel using a standard LEU fuel plate which is thinner and contains more U-235 than the current HEU plate. These differences, coupled with a desire to upgrade the characteristics and capability of the reactor, have resulted in core design studies and thermal hydraulic studies not only at the current 2 MW but also at the maximum power level of the reactor, 5 MW. In addition, during 25 years of operation, it has become clear that the main uses of the reactor have been neutron scattering and neutron activation analysis. The requirement to convert to LEU presents an opportunity to optimize the core for the utilization and to restudy the thermal hydraulics using modern techniques. This paper presents a status report on the conversion.

INTRODUCTION

The Rhode Island Atomic Energy Commission operates an open pool, MTR type research reactor in Narragansett, Rhode Island. While the reactor has a maximum design power level of 5 MW, current, licensed operation is at a power level of 2 MW.

The reactor was designed by General Electric in the late 1950's with construction beginning in late 1962. The reactor went critical in 1964, to a power level of 1 MW in 1965 and to a power level of 2 MW in 1968.

Before presenting this status report on the conversion of the reactor to LEU, it will be useful to describe those aspects of the utilization, duty cycle, and original design of the facility which have influenced the approach taken for conversion. A detailed description of the reactor was presented at the 1987 RERTR meeting in Buenos Aires and only a synopsis will be presented here/1/.

REACTOR DESCRIPTION, UTILIZATION AND DUTY CYCLE

The reactor is a typical swimming pool research reactor utilized primarily for neutron scattering at three beam ports and research programs which require neutron activation analysis as an analytical tool-including small sample analysis-utilizing five irradiation facilities. At one beam port, the University of Rhode Island has installed the only polarized neutron, small angle scattering spectrometer currently operating in the United States.

The normal, equilibrium operating HEU core consists of 30 fuel elements each containing 18 plates and a U-235 content of 124 grams when new. These elements sit on a grid plate in a grid box with permanently installed shrouds in which the boral control rods or blades move. The reactor has been reflected by graphite and the grid contains sufficient spaces for a boral regulating rod and several irradiation baskets. This arrangement is shown in Figure 1.

Note that the four boral control blades move in permanently fixed shrouds and these shrouds cannot easily be relocated. The boral regulation rod is also fixed in the reflector region of the 30 element core but its relocation is possible. For clarity, some of the grid positions are shown vacant. During operation, however, each grid position must contain a fuel element, a reflector piece, an irradiation basket or a plug. Otherwise the coolant flow will by-pass the core through the vacant grid position.

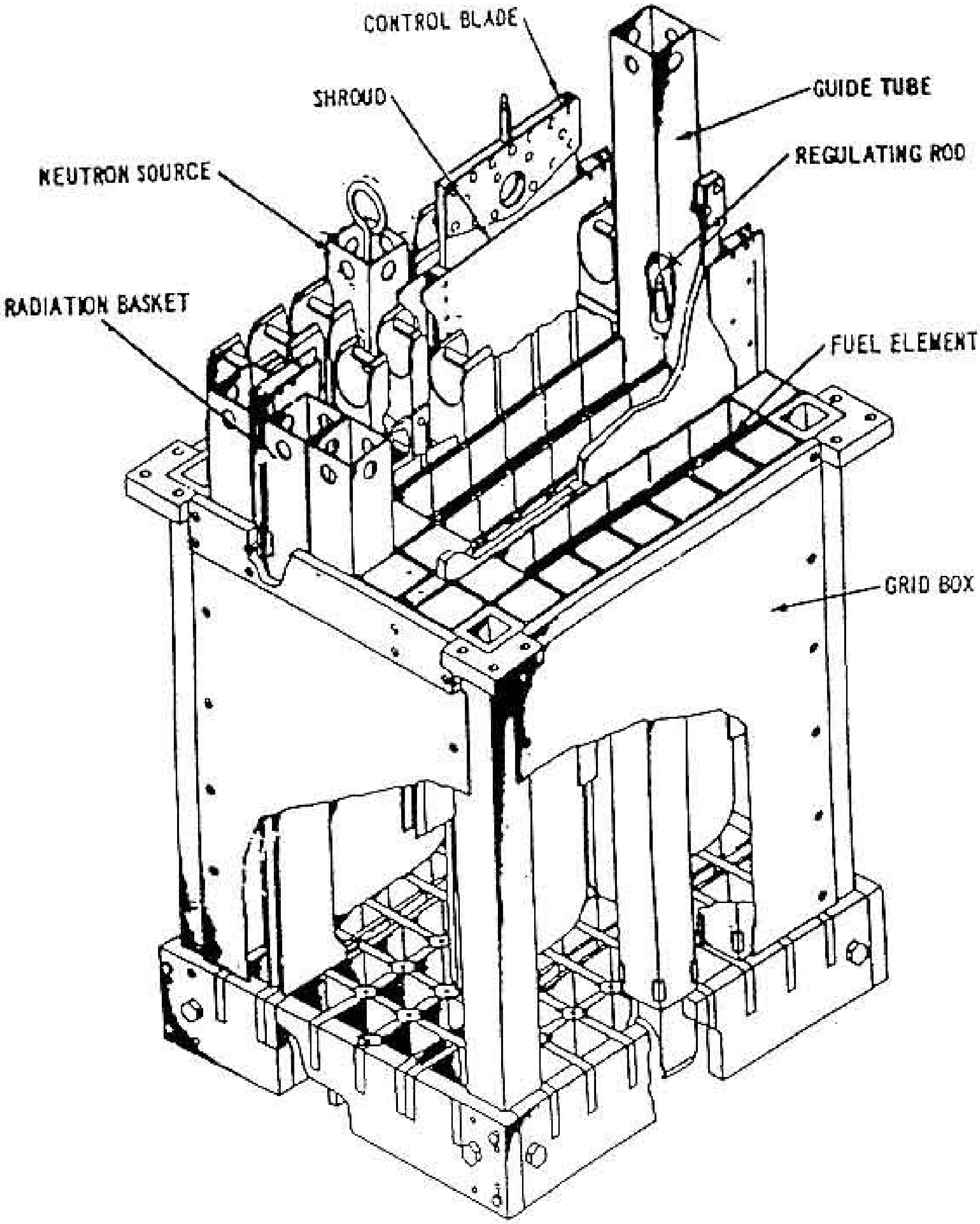


Figure 1: Core Arrangement

Figure 2 is a schematic representation of the HEU core showing 30 fuel elements surrounded by graphite reflectors and a row of irradiation baskets. The control blades are labeled 1, 2, 3 and 4 and the regulating rod is in position D1. This figure also shows the location of the beam tubes and the terminals of the pneumatic systems. Note that the large beam tubes and the pneumatic irradiation systems terminate outside the grid box at row 5, in the center of the grid box. The neutron flux in this position is representative of the flux available to the beam ports. Also note that there is a radiation basket in position D9. Positions A5 and D9 have been used for flux comparisons between HEU and LEU cores.

Another consideration important to the LEU conversion is the decision by the Department of Energy to produce a standard fuel plate for use in all university plate type reactors for which they provide fuel cycle assistance. This fuel plate is slightly thinner than the current plate and contains about 80% more U-235.

The existing core may be characterized as large with a very low power density resulting in a low thermal flux per unit power. It utilizes lightly loaded fuel elements to make the core large enough to encompass the control blades. Even with extraordinary techniques, the maximum burn-up achievable is about 14% and this burn-up is only possible because we are a one shift operation and do not have to contend with equilibrium xenon.

The reactor has operated for 25 years with an 8 hour on - 16 hour off, 5 day per week duty cycle. There are no plans to change this duty cycle. This duty cycle allows for operation with an excess reactivity less than that required for continuous operation. Because of the control blade configuration, this duty cycle also requires special start-up considerations when converting to a compact LEU core.

30 Fuel and 23 Graphite Reflector Elements

Approx. U-235 Loadings, g per Element

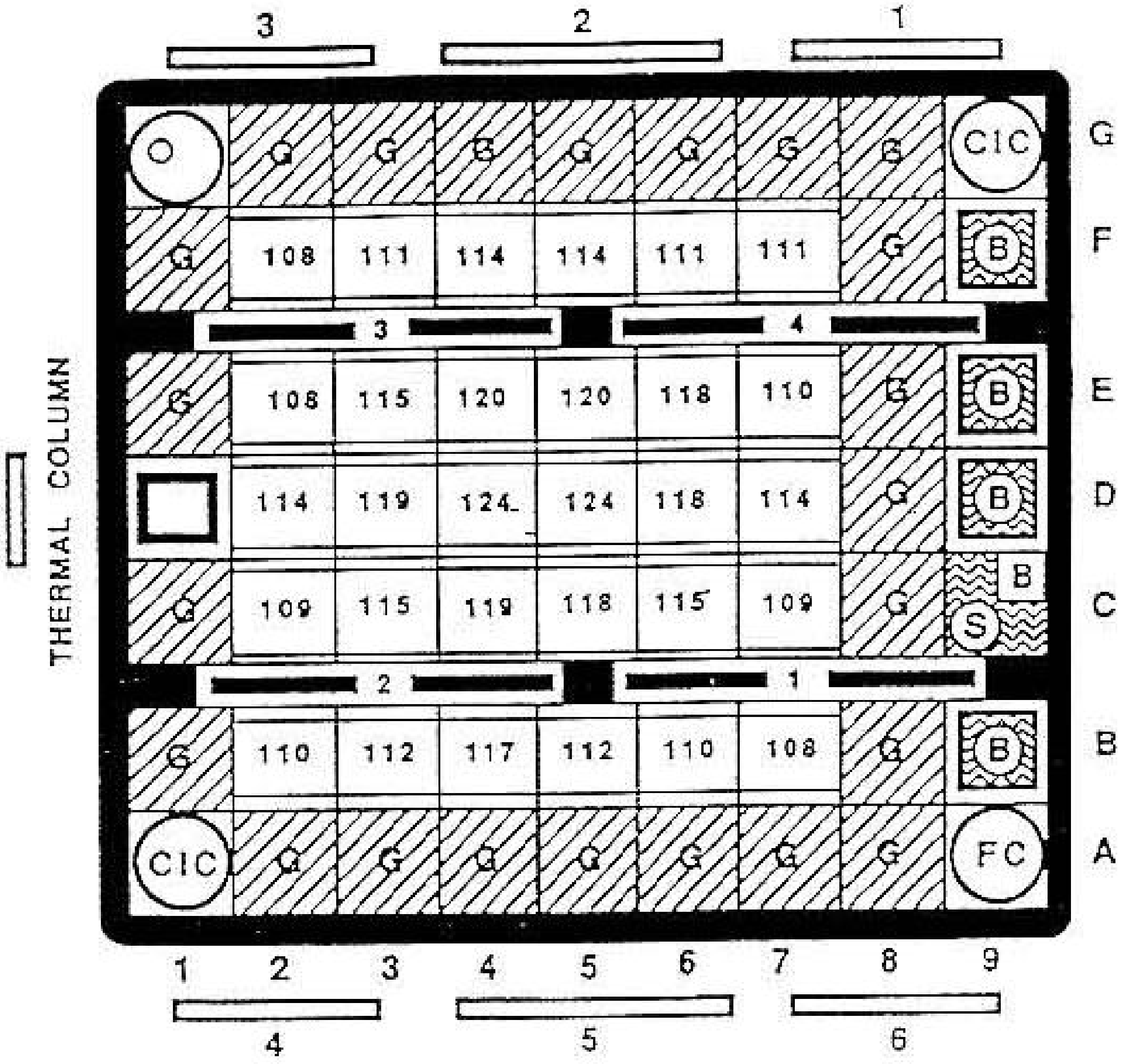


Figure 2: Typical 30 Element HEU Core

CONVERSION OBJECTIVES

There are six basic objectives of the LEU conversion program. These are:

1. Convert the reactor to the use of LEU without requiring the fabrication of additional HEU fuel.

2. Design a LEU core and an operating scheme to achieve burn-ups greater than the current 14%. This is especially important for anticipated higher power operation.

3. Design a LEU core which will optimize the neutron flux in the beam tubes and will allow for future improvements.

4. Design a reactor core with a flux trap for small sample neutron activation analysis.

5. Design a reactor core which can be operated at power levels up to 5 MW with the appropriate primary coolant flow.

6. Design a LEU core whose initial cost will be about the same as the cost of 30 HEU fuel elements since that is the amount allocated for the core by the Department of Energy.

During extensive scoping studies many core configurations were examined/1/. Incorporating all of the information gathered during these scoping studies and remembering our six objectives, a preferred core design has emerged. The general neutronic and thermal hydraulic characteristics of this LEU core have been presented at the 1989 RERTR meeting in Berlin/2/. This paper will discuss the techniques which will be utilized in achieving an equilibrium core, scheduling, and future improvements.

LEU NEUTRONIC CORE DESIGN

Figure 3 presents the start-up version of this prefered core which consists of 14 fuel elements. The elements now contain 22 standard plates with a total of 275 grams of U-235 per element. A central beryllium piece with a 38mm hole is incorporated as a flux trap. The regulating rod has been changed to stainless steel and moved one grid position so as to be adjacent to this smaller core.

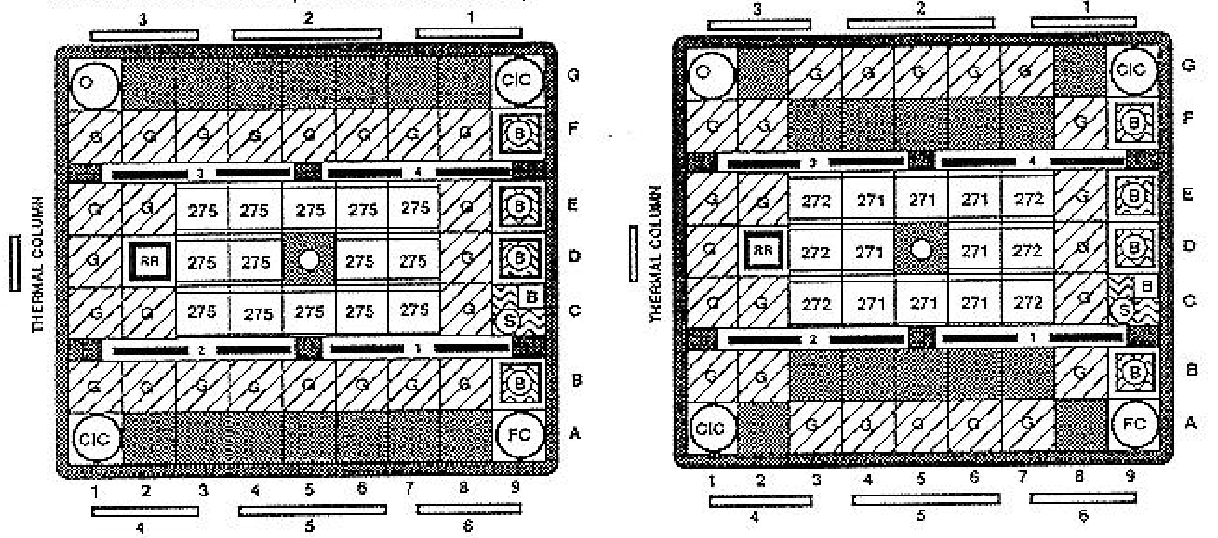
The core is graphite and beryllium reflected, with an excess reactivity of about 3 % Δk/k, a regulating rod worth of .44%, a shutdown margin with blade 3 stuck out of 6.4% and a total power peaking factor of 2.64. This design allows the use of the existing 24 graphite reflector pieces and requires the acquisition of 14 fuel elements and 16 beryllium reflector pieces for the equilibrium core. This meets one of the conversion objectives since the cost of a beryllium reflector piece is less than the cost of an LEU fuel element.

Because of the one shift operation, the xenon behavior is cyclical and this core can be operated as long as it is possible to operate on Friday morning. Using computer simulation, this core has been "run down" until a Friday morning start-up is no longer possible. The reactivity balance is shown in Table 1.

Table 1. Reactivity Balances on the Friday Morning of the Last Week of Operation for the Startup and Transition Cores.

	Startup % ?k/k	Core 2 % ?k/k	Core 3 % ?k/k
Fresh Cold Clean,	**3.0**	**5.1**	**6.9**
Reactivity Losses,			
Burnup	**0.3**	**1.8**	**3.2**
Xe	**1.5**	**1.5**	**1.5**
Sm	**0.6**	**0.7**	**0.7**
Long-Lived F.P.	**0.1**	**0.6**	**1.0**
Cold-Hot Swing	**0.3**	**0.3**	**0.3**
Control	**0.2**	**0.2**	**0.2**
	3.0	**5.1**	**6.9**

Fig. 3. Startup, Transition, and Equilibrium Cores
(Lifetimes Based on Operation for 8 Hr/D, 5 D/Wk)



STARTUP CORE

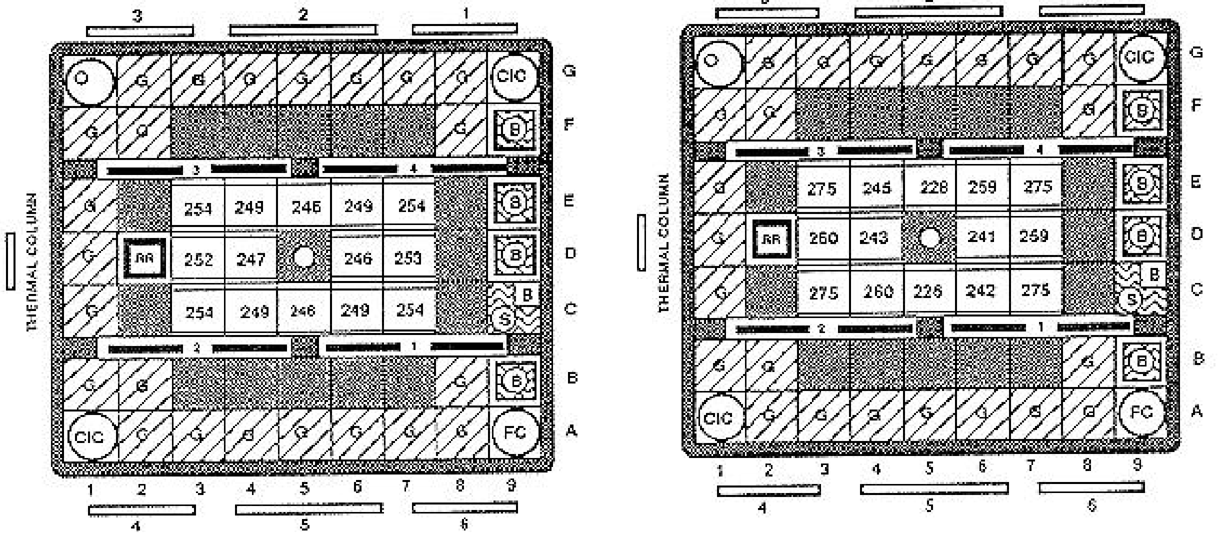
Excess Reactivity = 3.0 % Δk/k

Core Lifetime: ~ 14 Wks (~ 560 Full Power Hours)

CORE 2

Excess Reactivity = 4.1 % Δk/k

Core Lifetime: ~ 70 Wks (~ 2800 Full Power Hours)



CORE 3

Excess Reactivity = 3.7 % Δk/k

Core Lifetime: ~ 60 Wks (~ 2400 Full Power Hours)

EQUILIBRIUM CORE

Core Lifetime: ~ 57 Wks (~ 2300 Full Power Hours)

The reactivity requirements for Xe, Sm, long lived fission products, control, and the cold-hot swing is approximately 3 % which will allow for approximately 14 weeks of operation before it will not be possible to start up on Friday morning.

After this initial operation, ten beryllium and ten graphite reflector pieces will be reconfigured to provide additional reactivity. Figure 3 also presents this second core showing the fuel remaining in each fuel element after the initial 14 weeks of operation. The reactivity balance is shown in Table 1 and it allows for an additional 70 weeks of operation.

Following this second phase of operation, the graphite and beryllium reflectors will again be reconfigured. This third core is shown in Figure 3 which also shows the fuel in each element at the start of this phase. Table 1 again presents the reactivity balance which now allows for an additional 60 weeks of operation.

Note that the core is now almost completely beryllium reflected. The core has operated for about 3 years and refueling is now required.

Refueling consists of removing the four elements with the most burn-up, placing four fresh elements in the core corner positions, and placing the remaining used fuel elements in the remaining positions with those elements containing the least fuel nearest the center of the core. This process provides the flatest flux and greatest neutron leakage. Eventually an equilibrium core will be reached.

Figure 3 presents this eventual equilibrium core where the four elements with the most burn-up have been discharged and four fresh elements have been added to the edge of the core. The average discharge burn-up for this equilibrium core is about 21 %, which is 50 % more burn-up than in the current HEU core.

The cyclical behavior of the xenon receives considerable attention when a reactor of significant power is operated regularly for a single shift. If, however, the reactivity requirements for Friday morning start-up are examined, the samarium and long-lived fission products as well as the xenon are important. Figure 4 presents the individual Friday morning reactivity losses as a function of time.

Note that while the xenon loss is the dominant factor for relatively fresh fuel, it is always about 1.5 %. In the long term, burnup provides the greatest reactivity loss, followed by xenon, long-lived fission products, and samarium. The behavior shown is for the time period before refueling.

The thermal flux available to the beam tubes has previously been examined for the cores presented above/2/. This examination has shown that while the total of the 7 group fluxes are only somewhat increased over the thirty element HEU core, the sum of the three thermal group fluxes shows a 40 % increase in the LEU cores. In addition, it has been shown that as these changes in graphite and beryllium reflectors are made, the thermal fluxes at the beam tubes do not substantially change/2/.

THERMAL HYDRAULIC STUDIES

The thermal hydraulic characteristics of these cores have been studied and previously reported/2/. These studies have shown that operation at 2 MW with these LEU cores is acceptable with the current primary coolant flow. of 386 M^3/hr. These studies have also shown that operation at 3 and 5 MW will require a primary flow rate greater than previously expected.

DESIGN BASIS ACCIDENT

The design basis accident for this reactor has been a loss of coolant accident with the water draining through a beam port containing no plugs. Recall that the core sits in a grid box and draining of this box is through a 1.25 cm hole drilled in the bottom. Because of this, about 35 minutes is required to complete the draining, after which, the bottom 18 cm of fuel remains in water. It has been possible to show that the low power density HEU core will not melt after this hypothetical loss of coolant accident.

The LEU core has a higher power density than the HEU core. Using the same accident sequence and calculations which were used for the HEU core, it is not possible to conclude that the LEU core will not suffer some melting following a loss of coolant accident. Studies are in progress to refine the design basis accident sequence and calculations. In addition, the design of an emergency core cooling system is proceeding. Such a system is simplified because of the grid box.

FUTURE IMPROVEMENTS

All work on LEU conversion has proceeded so as not to preclude future improvements after LEU conversion has been achieved. These improvements include operation at the maximum design power level of 5 MW and further modifications in the core region to enhance the beam port fluxes.

Because of the grid box design, the beam tubes cannot easily be extended to the LEU compact core to take full advantage of the flux increase. In the future, it will be possible to discard the graphite reflectors and relocate the existing beryllium reflectors from in front of the active beam tubes. In front of the active beam tubes, new beryllium reflectors which contain an air void in the center will be installed. This will be equivalent to moving the end of the beam tube to a position closer to the core resulting in an increased flux available to experimenters. Eventually, this process will also lead to a fully beryllium reflected core.

SCHEDULE

The fuel element re-design, and the beryllium reflector and flux trap design are completed. Design of an emergency core cooling system is underway. The safety analysis report is scheduled for submission to the Nuclear Regulatory Commission by January, 1991.

Because of funding limitations, fuel fabrication is scheduled for 1992 allowing almost one year for NRC review. If the schedule is maintained, the conversion should be completed by 1993. Fabrication of additional HEU fuel is not required.

CONCLUSION

In conclusion, the redesign of the Rhode Island Atomic Energy Commission research reactor is nearing completion and the preparation of the safety analysis report for conversion to LEU is progressing. The redesign will not only accomplish conversion but will also improve the reactor characteristics for the utilization.

REFERENCES

/1/ DiMeglio, A.F., Matos, J.E., and Freese, K.E.: Conversion, Core Redesign and Upgrade of the Rhode Island Atomic Energy Commission Reactor, Proceedings of the 1987 International Meeting on Reduced Enrichment for Research and Test Reactors, Buenos Aires, Argentina, 28 Sept.-10 October, in press.

/2/ DiMeglio, A.F., Matos, J.E., Freese, K.E, and Spring, E.F:..The Conversion of the 2 MW Reactor at the Rhode Island Nuclear Science Center. Proceedings of the 1989 International Meeting on Reduced Enrichment for Research and Test Reactors, Berlin, West Germany, September,.in press.