ANALYSIS FOR CONVERSION OF THE GEORGIA TECH RESEARCH REACTOR FROM HEU TO LEU FUEL*

J.E. Matos, S.C. Mo, and W.L. Woodruff

Argonne National Laboratory
Argonne, Illinois 60439-4841 USA

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ABSTRACT

The 5 MW Georgia Tech Research Reactor (GTRR) is a heterogeneous, heavy water moderated and cooled reactor, fueled with highly-enriched uranium aluminum alloy fuel plates. The GTRR is required to convert to low enrichment (LEU) fuel in accordance with USNRC policy. Results of design and safety analyses performed by the RERTR Program at the Argonne National Laboratory for LEU conversion of the GTRR are summarized. Only those parameters which could change as a result of replacing the fuel are addressed. The performance of the reactor and all safety margins with LEU fuel are expected to be about the same as those with the current HEU fuel.

INTRODUCTION

The results of design and safety analyses performed by the RERTR Program at the Argonne National Laboratory for conversion of the Georgia Tech Research Reactor from the use of HEU fuel to the use of LEU fuel are presented. The objectives of this work were to: (1) maintain or improve upon the present reactor performance and margins of safety, (2) maintain as closely as possible the technical specifications and operating procedures of the present HEU core, and (3) utilize a proven fuel assembly design that is economical to manufacture.

The GTRR core contains provisions for up to 19 fuel assemblies spaced 6 inches apart in a triangular array. The fuel is centrally located in a six-foot diameter aluminum vessel which provides a two-foot thick D_2O reflector completely surrounding the core. The vessel is surrounded radially and beneath by an additional two-foot thick graphite reflector. The reactor is controlled by means of four cadmium shim-safety blades that swing downward through the core between adjacent rows of fuel assemblies and one cadmium regulating rod that moves vertically in the radial D_2O reflector. The reactor is equipped with 22 horizontal and 23 vertical experimental facilities for extracting neutron beams and performing irradiations. A shielded room (10 feet by 12 feet inside) for biomedical research is located at the side of the reactor.

The reactor performance objectives and design constraints that were addressed in designing the LEU fuel assembly are discussed in Ref. 1. The LEU fuel assembly has the same overall design as the present HEU fuel assembly, except that it contains 18 fueled plates with LEU U_3Si_2-Al fuel and two non-fueled plates instead of 16 fueled plates with HEU U-Al alloy fuel and 2 non-

fueled plates. Each HEU assembly contains 188 g ^{235}U and each LEU assembly contains 225 g ^{235}U. The LEU core will use the same control system, heat removal system, and auxiliary systems as the current HEU core.

Reactor Models

A detailed Monte Carlo model of the reactor was constructed including all beam tubes, experiment penetrations, the bio-medical facility, shim-safety blades, and regulating rod in order to obtain absolute excess reactivities and shutdown margins for comparison with limits specified in the Technical Specifications. The diffusion theory model did not include the control absorbers or the various experiment facilities. A simplified Monte Carlo model similar to the diffusion model was constructed to verify that the diffusion theory model was correct. Nuclear cross sections in seven energy groups were calculated using standard methods for use in the diffusion theory calculations.

Critical Experiment

In 1974, a critical experiment was built using 9 fresh HEU fuel assemblies. The core was made critical at different shim-safety blade positions with the regulating rod nearly fully-withdrawn and nearly fully-inserted. The excess reactivities calculated for these critical configurations using the detailed Monte Carlo model were -0.91 ± 0.20% Δk/k and -1.22 ± 0.22% Δk/k, respectively. The reactivity bias of about -1.0 ± 0.3% Δk/k in the calculations is attributed to uncertainties in the nuclear cross sections and uncertainties in the reactor materials.

NEUTRONIC PARAMETERS

Excess Reactivity

Calculated excess reactivities (including reactivity bias) for fresh HEU and LEU cores with 17 fuel assemblies are shown in Table 1. The Technical Specifications limit the excess reactivity to a maximum of 11.9% Δk/k. The LEU core is expected to satisfy this requirement.

Table 1. Excess Reactivities of HEU and LEU Cores with 17 Fresh Fuel Assemblies

	Calculated Excess React.[1], % Δk/k (±1σ)	
	Fresh HEU Core	Fresh LEU Core
Detailed Monte Carlo Model	11.7 ± 0.4	9.4 ± 0.4
Simplified Monte Carlo Model[2]	16.8 ± 0.4	14.3 ± 0.4
Diffusion Theory Model[2]	16.6	14.6

[1] The reactivity bias of -1.0 ± 0.3% Δk/k was added to calculated values. [2] Detailed Monte Carlo model without experiment penetrations, shim-safety blades, and regulating rod.

The reactivity effect of replacing all air-filled experiment facilities in the detailed Monte Carlo model with D_2O or graphite was calculated to be 4.5 ± 0.3% Δk/k. Replacing the control absorbers in their fully-withdrawn position with D_2O gave a worth consistent with zero. Thus, the simplified Monte Carlo and diffusion theory models are consistent with the detailed Monte Carlo model if the reactivity worth of the experiment facilities is accounted for.

Fuel Lifetimes

Burnup calculations v·ere run for HEU and LEU cores with 17 fuel assemblies to estimate fuel lifetimes. Reactivity profiles (including the 1% Δk/k reactivity bias) are shown in Fig. 1 over a limited burnup range. The dashed lines show the end-of-cycle excess reactivity range that accounts for reactivity losses due to experiment facilities (4.5 ± 0.3% Δk/k), cold-to-hot swing (~0.3% Δk/k), and control provision (~0.5% Δk/k) that are not included in the diffusion theory model. Reactivity losses due to equilibrium Xe and Sm are included in the curves. The results show that the HEU and LEU cores will have about the same lifetime.

Fig. 1. Burnup Reactivity Profiles
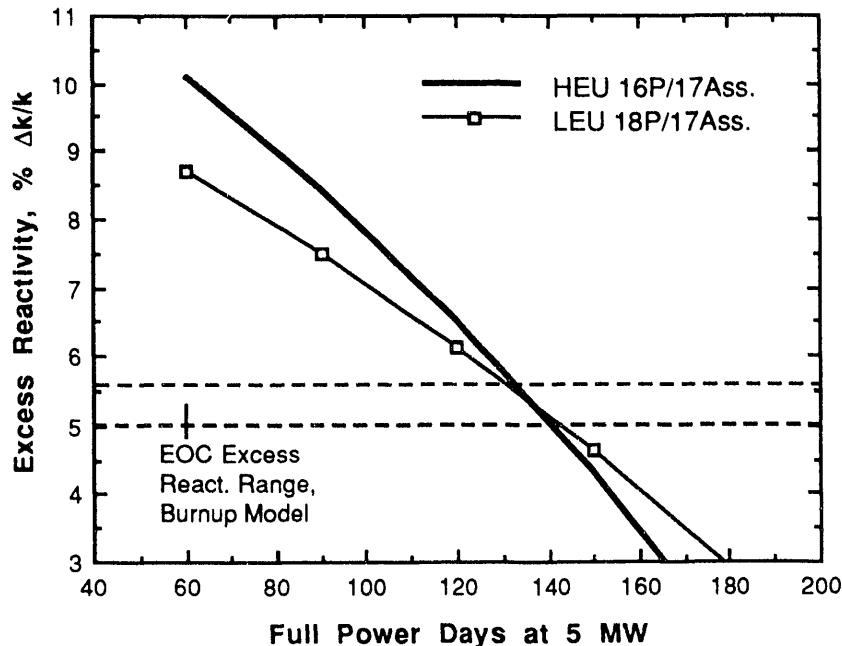
Power Distributions and Power Peaking Factors

Power distributions and nuclear power peaking factors were calculated to be very similar in HEU and LEU cores with 14 and 17 fresh fuel assemblies.

Temperature Coefficients and Kinetics Parameters

Reactivity coefficients for the coolant and the fuel Doppler were computed as functions of temperature for fresh HEU and LEU cores with 14 and 17 fuel assemblies. Also computed were the void coefficient, the whole-reactor isothermal temperature coefficient, and the prompt neutron lifetime. Fresh cores were calculated because they are limiting cores. As fuel burnup increases, the neutron spectrum becomes softer and the reactivity coefficients become more negative. Key temperature coefficients and kinetics parameters are summarized in Table 2.

Table 2. Reactivity Coefficients (% Δk/k/°C at 45°C) and Kinetics Parameters

	HEU		LEU	
	14 Ass.	17 Ass.	14 Ass.	17 Ass.
Coolant	-0.0076	-0.0069	-0.0067	-0.0066
Fuel Doppler	~0.0	~0.0	-0.0017	-0.0020
Whole Reactor Isothermal[1]	-0.0224	-0.0201	-0.0232	-0.0215
Void Coefficient[2]	-0.0383	-0.0392	-0.0333	-0.0350
l_p[3], μs	780	704	745	695
β_{eff}	0.00755[4]	0.00755[4]	0.0075 - 0.0076[5]	

[1] Includes fuel, coolant, inter-assembly water, and reflector. [2] % Δk/k/% Void. Uniform voiding of coolant in all fuel assemblies. [3] Calculated prompt neutron lifetime. [4] Measured effective delayed neutron fraction. [5] Estimated value.

Shutdown Margins

The Technical Specifications require that the reactor have a shutdown margin of at least 1% Δk/k with the most reactive shim-safety blade (blade #3) and the regulating rod fully withdrawn. Shutdown margins calculated using the detailed Monte Carlo model gave - 7.1 ± 0.2% Δk/k for an HEU core and - 8.8 ± 0.2% Δk/k for an LEU core with 17 fresh fuel assemblies. Both cores satisfy the shutdown margin requirement.

In addition to the automatic protective systems, manual scram and reflector drain provide backup methods to shut the reactor down by operator action. Results of Monte Carlo calculations with shim-safety blade positions that would bring the reactor near critical are shown in Table 3. These results show that the top reflector worth of the LEU core is slightly larger than that of the HEU core.

Table 3.   Calculated Top Reflector Worths (% Δk/k) of HEU and LEU Cores with 17 Fuel Assemblies and Control Blades near Critical Positions

Top D$_2$O Reflector	HEU Core	LEU Core
D$_2$O 1" Above Fuel Meat	- 2.58 ± 0.29 (1σ)	- 2.73 ± 0.31 (1σ)
D$_2$O 2" Above Fuel Meat	- 2.05 ± 0.28	- 2.42 ± 0.30

THERMAL-HYDRAULIC SAFETY PARAMETERS

Thermal-hydraulic safety limits and safety margins calculated using the PLTEMP code[2] for the LEU core with 14 fuel assemblies were compared with the thermal-hydraulic safety parameters used as bases for the current Technical Specifications. ANL analyses for the LEU core used a combined multiplicative and statistical treatment of a revised set of engineering uncertainty factors. Results for the HEU core obtained using ANL's statistical treatment agree well with the original analyses performed by Georgia Tech. The modified Wheatherhead correlation[3] was used for departure from nucleate boiling (DNB), the Forgan-Whittle correlation[4] was used for flow instability, and the Bergles and Rohsenow correlation[5] was used for onset of nucleate boiling (ONB).

Safety Limits

Calculated reactor power limits based on DNB and flow instability are shown in Table 4 for 14-assembly HEU and LEU cores with the minimum coolant flow of 1625 gpm and with the coolant lowflow limit of 760 gpm. Power limits based on the flow instability criterion are adequate to ensure the safety of the facility. The main reason for differences between the HEU and LEU cores is that the manufacturing specifications for LEU silicide dispersion fuel plates contain a factor of 1.2 for homogeneity of the fuel distribution while the HEU alloy fuel has a corresponding factor of 1.03.

Table 4. Reactor Power Limits (MW) in 14-Assembly Cores Based on DNB and Flow Instability for a Maximum Inlet Temperature of 50.5°C .

| Reactor Coolant | GTRR-HEU | | ANL-LEU | |
Flow, gpm	DNB	Flow Instability	DNB	Flow Instability
760	5.5	5.3	5.3	5.0
1625	11.5	10.6	10.8	10.6

Safety limits for the reactor inlet temperature were calculated at the maximum reactor power of 5.5 MW and the minimum coolant flow of 1625 gpm. The results are shown in Table 5. A safety limit for the reactor outlet temperature was then established by adding the average temperature rise across the core to the limiting inlet temperature. These results show that the HEU and LEU cores have nearly identical safety limits on the reactor inlet and oulet temperatures.

Table 5. Safety Limits on Reactor Inlet and Outlet Temperatures.

Parameter	GTRR-HEU DNB	ANL-LEU DNB	Flow Instability
Limiting Reactor Inlet Temp., °C	77.8	77.2	76.7
Ave. Coolant Temp. Rise across Core, °C	8.9	9.4	9.4
Limiting Reactor Outlet Temp., °C	86.7	86.6	86.1

Safety System Trip Settings

The safety system trip settings in the current GTRR Technical Specifications for power levels >1 MW and the nominal value for each parameter are shown in Table 6.

Table 6. Current Safety System Trip Settings for Power Levels >1 MW.

Parameter	Trip Setting	Nominal Value
Thermal Power, MW	5.5	5.0
Reactor Coolant Flow, gpm	1625	1800
Reactor Outlet Temperature, °C	59.4	54.4

These settings are based on a criterion that there shall be no incipient boiling during normal operation. The criterion is applied in GTRR by ensuring that the surface temperature at any point on a fuel assembly does not exceed the coolant saturation temperature at that point. This criterion

is conservative because there is an additional margin of ~14°C between the D_2O saturation temperature and the temperature at which onset of nucleate boiling occurs.

Combinations of reactor power, coolant flow rate, and reactor inlet temperature that were calculated to have zero subcooling (fuel surface temperature = coolant saturation temperature) for HEU and LEU cores with 14 fuel assemblies are shown in Table 7. Underlined values for the HEU core correspond with the trip settings shown in Table 6. Corresponding underlined values for the LEU core were determined to be more conservative than those for the HEU core. Thus, the current trip settings for the HEU core can also be used for the LEU core.

Table 7. Parameter Combinations for Zero Subcooling with 14-Assembly Cores

	HEU Core			LEU Core		
Reactor Power, MW	5.5	5.0	5.0	5.6	5.0	5.0
Coolant Flow Rate, gpm	1800	1625	1800	1800	<1625	1800
Reactor Inlet Temp., °C	45.6	45.6	50.5	45.6	45.6	53.3
Temp. Rise Across Core, °C	8.9	8.9	8.9	9.4	9.4	9.4
Reactor outlet Temp., °C	54.4	54.4	59.4	55.0	55.0	62.7

The results in Table 8 show that the degree of subcooling (ΔT_{sub}) at the hottest spot of the limiting fuel assembly under nominal operating conditions is expected to be 6.1°C in the LEU core and 4.4°C in the HEU core. Both of these margins are adequate. Another criterion that is often used in research reactors is that the margin to onset of nucleate boiling (ONB) should be equal to or greater than 1.2. ONB occurs at a temperature of about 118.9°C, which is ~14°C above the D_2O saturation temperature of 104.4°C. The margin to ONB in the LEU core was computed by increasing the reactor power until ONB occured and dividing by the nominal reactor power of 5 MW. These margins are adequate to ensure that the LEU core can be operated safely at a power levels of 1-5 MW.

Table 8. Margins to D_2O Saturation Temperature and ONB for 14-Assembly Cores

Parameter	GTRR-HEU	ANL-LEU
Thermal Power, MW	5.0	5.0
Reactor Coolant Flow, gpm	1800	1800
Reactor Inlet Temp., °C	45.6	45.6
ΔT_{sub}, °C	4.4	6.1
Margin to ONB	-	1.44
Limiting Power Based on ONB, MW	-	7.2

ACCIDENT ANALYSES

A spectrum of accident scenarios was evaluated by Georgia Tech in its safety documentation for 5 MW operation using HEU fuel. These scenarios were thoroughly reviewed and only those that could be affected by changing the fuel assemblies from HEU to LEU were addressed.

Startup Accident

The worst case for a possible startup accident in the current HEU core was determined to result from the simultaneous withdrawal of one shim blade and the regulating rod. Calculations were done using the PARET code[6] for the HEU and LEU cores with 14 fuel assemblies in which reactivity was added at a rate of 0.005 $\Delta k/k$ per second starting from a power level of 5 MW. Both the HEU and LEU cores were scrammed by the overpower trip at 5.5 MW. A time delay of 100 ms was assumed between introduction of the scram signal and release of the shim-safety blades. Both cores reached a peak power of 5.9 MW at a time of 0.335 s after the transient was initiated. Peak surface cladding temperatures of 80.6°C and 77.8°C were reached in the limiting fuel assembly of the HEU and LEU cores, respectively. The peak power is well below the safety limits of 11.5 MW in the HEU core and 10.6 MW in the LEU core. The peak surface cladding temperatures are far below the solidus temperature of 660°C in the 1100 Al cladding of the HEU core and far below the solidus temperature of 582°C in the 6061 Al cladding of the LEU core. Thus, no damage to the fuel and no release of fission products is expected.

Inadvertent Reactivity Insertions Due to Experiment Failure (with Scram)

The Technical Specifications limit the magnitude of the reactivity worth of each unsecured experiment to 0.4% $\Delta k/k$ and the reactivity worth of each secured removable experiment to 1.5% $\Delta k/k$. The objective of these specifications is to prevent damage to the reactor and to limit radiation dose to personnel and the public in event of experiment failure.

The PARET code was used to calculate the consequences of inadvertent step reactivity insertions of 0.4% $\Delta k/k$ and 1.5% $\Delta k/k$ in HEU and LEU cores with 14 fuel assemblies. The model and methods that were used for analysis of the SPERT-II BD-22/24 HEU core[7,8] were also used to analyze the HEU and LEU cores of the GTRR. Temperature coefficients included contributions from only the coolant and the fuel. Calculations were performed with the reactor at nominal operating conditions of 5 MW power, a coolant flow rate of 1800 gpm, and a reactor inlet temperature of 45.6°C. A scram signal was initiated when the reactor power reached the safety system overpower trip setting of 5.5 MW. A time delay of 100 ms was assumed between introduction of the scram signal and release of the shim-safety blades. The results of these calculations are shown in Table 9.

Table 9. Results of Assumed Step Reactivity Insertions Due to Experiment Failure (with Scram)

Parameter	HEU Core		LEU Core	
Step Reactivity Insertion, % $\Delta k/k$	0.4	1.5	0.4	1.5
Asymptotic Period, s	0.18	0.05	0.18	0.05
Peak Power, MW	7.4	27.5	7.4	27.2
Peak Surface Cladding Temp., °C	84.4	136.1	81.7	130.6

A positive step reactivity change less than 0.4% $\Delta k/k$ caused by the ejection or insertion of experiments would result in transient behavior that would not exceed the safety limits for the HEU or LEU cores. The peak power of 7.4 MW in both cores is well below the safety limits of 11.5 MW in the HEU core and 10.6 MW in the LEU core.

Step reactivty insertions of 1.5% $\Delta k/k$ would result in peak surface cladding temperatures that are far below the solidus temperature of 660°C in the 1100 Al cladding of the HEU core and far below the solidus temperature of 582°C in the 6061 Al cladding of the LEU core. Thus, no damage to the fuel and no release of fission products is expected.

Maximum Positive Reactivity Insertion Without Scram

The Technical Specifications limit the potential reactivity worth of each secured removable experiment to 1.5% $\Delta k/k$. The purpose of this analysis is to show that there is a sufficient margin between the maximum allowable reactivity worth of a single experiment and the maximum step reactivity insertion that can be tolerated without fuel damage, assuming failure of reactor scram systems.

Analysis for the current HEU core used SPERT-II experimental data[8] as a basis for estimating the step reactivity insertion that would result in the onset of steam blanketing in the GTRR. In the present analysis, the PARET code was used to compute the step reactivity insertion required to initiate steam blanketing (film boiling) in both the SPERT-II B22/24 core and 14-assembly GTRR cores with HEU and LEU fuel. Key kinetics parameters and results are shown in Table 10. Power peaking factors are similar in the SPERT-II and GTRR cores. The inverse period corresponding to onset of steam blanketing as determined from the SPERT data is about 13 s^{-1}. The PARET code predicts onset of film boiling for a step insertion of $2.0 (1.5% $\Delta k/k$) with an inverse period of 12 s^{-1}, in good agreement with experiment.

Table 10. Comparison of Kinetics Parameters and Onset of Steam Blanketing Results

	SPERT-II B-22/24	14 Assembly GTRR	
		HEU	LEU
Prompt Neutron Generation Time, μs	660	780	745
Beta Effective	0.0075	0.00755	0.00755
Coolant Temperture Coeff., $/°C	-0.00867	-0.00874	-0.00689
Void Coefficient, $/% Void	-0.0729	-0.0509	-0.0442
Doppler Coefficient, $/°C	~0.0	~0.0	-0.00096
Operating Pressure, kPa	122	127	127
Step Reactivity Insertion, $ (% $\Delta k/k$)	2.00	1.99	1.95
Inverse Period, s^{-1}	12	19	19
Energy/Plate at t_m, kWs	31.8	31.2	32.0
Peak Cladding Temp at Peak Power, °C	204	218	225
Peak Cladding Temperature at Onset of Steam Blanketing, °C	252	257	257

The same methodology was used to compute GTRR cores with 14 fuel assemblies. The step insertions needed to initiate film boiling (~$2.0) and the peak surface cladding temperatures (250-260°C) at the onset of steam blanketing are nearly the same. At the time of peak power, the energy deposited per plate is about the same in the SPERT and GTRR cores. The peak surface cladding temperature at the time of peak power is about 220°C in the GTRR cores and about 204°C in the SPERT core.

The SPERT-II B22/24 tests[8] indicate that even more extensive film boiling (or steam blanketing) does not result in temperatures that exceed the solidus temperature of the cladding. The most extreme case in the test series with a reactivity insertion of $2.95 (2.2% Δk/k) resulted in a peak surface cladding temperature of 337°C, a temperature far below the solidus temperature of 582°C for 6061 Al cladding. The GTRR SAR also notes that the maximum temperature for large insertions is primarily limited by the energy deposited in the plate with very little effect from the boiling heat transfer.

Since the behavior of the SPERT-II B22/24 and GTRR 14-assembly cores is very similar, a step reactivity insertion greater than 2.2% Δk/k would be required to initiate melting of the GTRR LEU core. The margin of at least 0.7% Δk/k above the maximum allowed reactivity worth of 1.5% Δk/k for a single experiment is sufficient to ensure that the facility is safe in the unlikely event that the maximum allowed reactivity were inserted in a step and the reactor scram system failed to function.

Design Basis Accident

The Design Basis Accident for the HEU core in the GTRR safety documentation is the melting and release of the fission products from one fuel assembly into the containment atmosphere. This accident was assumed to occur during a fuel transfer operation in which an irradiated fuel assembly was being moved from the core to the fuel storage area using a shielded transfer cask. Fuel assemblies are not normally discharged from the reactor until at least 12 hours after reactor shutdown. This ensures that sufficient fission product decay heat has been removed from the assembly and that the surface temperature of the fuel plates will not reach 450°C when the assembly is moved into the cask.

In spite of administrative controls, it is conceivable that a fuel assembly could be withdrawn from the reactor prior to a 12 hour cooldown period. Some or all of the fuel plates within the assembly could then melt and release some of their fission products into the containment atmosphere. In the current GTRR SAR, the source term for evaluating the radiological consequences of this accident was obtained by assuming that an HEU fuel assembly with equilibrium burnup was removed from the core before the 12 hour cooldown period. All of the plates in the fuel assembly melt and the isotopes of iodine, krypton, and xenon were released to the containment. The limiting dose is the thyroid dose from the iodine isotopes.

Since the HEU and LEU cores operate at 5 MW, neutron flux levels and equilibrium concentrations of iodine, xenon, and krypton will be about the same in the two cores. From burnup calculation results shown in Fig. 1, it was concluded that the lifetimes of the HEU and

LEU core will be about the same. As a result, concentrations of the other fission products in the LEU and HEU fuel assemblies will be very similar. The exception is that the LEU assembly will contain larger concentrations of plutonium isotopes. Reference 9 contains a detailed analysis comparing the radiological consequences of a hypothetical accident in a generic 10 MW reactor using HEU and LEU fuels. This analysis concluded that the buildup of plutonium in discharge fuel assemblies with [235]U burnup of over 50% does not significantly increase the radiological consequences over those of HEU fuel. Because fission product concentrations in the GTRR HEU and LEU cores are expected to be comparable, the thyroid dose shown in the GTRR SAR for HEU fuel will be the limiting dose for both cores.

COOLING TIME REQUIREMENTS

The primary coolant pumps must be operated for 8 hours following operation at power levels of more than 1 MW to preclude the possibility of fuel plate melting in the event of a loss-of-coolant accident following reactor shutdown. In addition, a minimum cooldown time of twelve hours is required before fuel assemblies are transferred out of the reactor. A limit of 450°C was set in the Technical Specifications as the upper limit for a fuel plate temperature to preclude melting of the plates.

The analysis method followed the superposition technique used in the GTRR safety documentation for the HEU core, with modification of the input parameters appropriate for the LEU fuel assembly design. The most important modification was that the maximum power per fuel plate in the LEU assembly was reduced by a factor of 16/18 since an HEU assembly contains 16 fueled plates and an LEU assembly contains 18 fueled plates. A standard 3-week operating history consisting of 4.3 days at full power of 5 MW and 2.7 days shutdown was used for 14 assembly cores with HEU and LEU fuel.

The results for loss-of-coolant from the reactor vessel after eight hours of cooling gave a maximum plate temperature of 425°C in the HEU core and 400°C in the LEU core. The maximum temperature occurred 45 minutes after loss-of-coolant in the HEU core and 50 minutes after loss-of-coolant in the LEU core. Thus, the current Technical Specification requirements on cooling times are more conservative for the LEU core than for the HEU core.

FUEL HANDLING AND STORAGE

The objective of the Technical Specifications that apply to the handling and storage of fuel assemblies is to prevent inadvertent criticality outside of the reactor vessel and to prevent overheating of irradiated fuel assemblies.

Irradiated fuel assemblies are stored in aluminum racks fastened to the side walls of a light water pool. There is one rack along each of the two walls and each rack can accomodate up to 20

assemblies in a linear array. The center-to-center spacing of the assemblies is six inches and the separation between assemblies is about three inches.

A systematic nuclear criticality assessment[10] been done for infinite-by-infinite arrays of fresh LEU fuel assemblies with ^{235}U contents between 225 and 621 grams using the ORR fuel storage rack spacing specifications[11] of 0.7 inch assembly separation and 6.8 inch row separation. An assembly similar to the GTRR LEU assembly with a ^{235}U content of 225 grams gave a k_{eff} of 0.72, well below the maximum k_{eff} of 0.85 needed to ensure an adequate margin below criticality for storage of irradiated fuel assemblies. The GTRR storage configuration discussed above will have k_{eff} less than 0.72.

Currently, no more than four unirradiated HEU fuel assemblies can be together in any one room outside the reactor, shipping container, or fuel storage racks. Calculations of HEU and LEU cores indicate that a grouping of four LEU assemblies will be less reactive than the same configuration of HEU assemblies. Thus, the current specification will also hold for LEU fuel.

CONCLUSION

Conversion of the GTRR core from HEU to LEU fuel is feasible utilizing an LEU assembly containing 18 DOE standard silicide fuel plates (for university MTR-type reactors) as a replacement for the current HEU assembly with 16 fueled plates. Both HEU and LEU assemblies contain two unfueled outer plates to form an enclosed flow volume. The LEU assemblies would contain 225 g ^{235}U instead of 188 g ^{235}U in the current HEU assemblies.

Calculations shown in Ref.1 indicate that the epithermal flux at the bio-medical facility will be slightly larger in the LEU core. The lifetime of the LEU core is expected to be about the same as that of the HEU core. All safety margins with the LEU fuel are very similar to those with the current HEU fuel and are adequate to ensure the safety of the facility.

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