MASTER

CALCULATED PHYSICS AND PERFORMANCE PARAMETERS FOR THE ACPR UPGRADE*

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Reactor physics and core design calculations have been completed for the upgrade of the Annular Core Pulse Reactor (ACPR)[1] at Sandia Laboratories. The ACPR has been in operation since 1967 and is a U-Zr $H_{1.6}$ fueled swimming pool type reactor with a large dry central experiment cavity. The purpose of the upgrade of the ACPR is to provide improved pulse and steady-state capabilities for performing neutron simulation and reactor safety tests. The performance goals for the ACPR Upgrade were to achieve a factor of 2.6 times the pulse fluence available with the ACPR and a factor of 2 increase in the steady-state flux. In addition, the pulse width of the upgraded reactor was to be as short as practical to maintain the rapid transient simulation capability of the ACPR.

Three fuel types (UO_2-BeO, UC-ZrC-C, and U-$ZrH_{1.5}$) and several core configurations were examined as potential approaches to the upgrade. The core configurations included single and multi-region designs of 4, 5, and 6 fuel rows with several possible reflectors. Neutronic calculations performed to evaluate reactor parameters for these concepts utilized two-dimensional S_N and Monte Carlo analyses. Cross sections were based on ENDF/B data files and were processed with AMPX[2] code system.

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A summary of important reactor parameters for representative designs of the various concepts examined is given in Table I. Since the BeO-UO_2 single region core has the highest pulse performance and satisfies all the design goals, and since the BeO-UO_2 fuel development program was successful, this approach was selected for the ACPR Upgrade. Final design calculations have been completed for the UO_2-BeO core and fuel fabrication is underway at Lawrence Livermore Laboratory with criticality of the ACPR Upgrade scheduled for March 1978.

Predicted neutronic characteristics for the ACPR Upgrade based on final design calculations are compared with the original ACPR characteristics in Table II. Monte Carlo (MORSE)[3] and S_8,P_1 discrete ordinates (TWOTRAN)[4] calculations using both 9 and 18 energy groups agreed within 5% on pulse fluence calculations. Monte Carlo (Keno-II)[5] analysis was used to determine neutron generation times. The use of nickel reflecting elements at the core periphery reduced the neutron generation time and fission density peaking. A water filled reflector region results in a neutron generation time of 35 μsec as compared with 24 μsec with a nickel reflector. A major uncertainty in the characterization of the BeO-UO_2 core was the magnitude and nature of the prompt temperature coefficient of reactivity. Calculations revealed that 60% of the temperature coefficient is due to Doppler broadening of ^{238}U resonances, the remainder being primarily due to the spectral changes corresponding to prompt heating of the beryllium moderating matrix. Kinetic behavior was examined using point kinetics and space time[6] analysis. Sensitivities of the predicted characteristics to cell and spectral weighting schemes were examined and found to be small in comparison with modeling differences.

The calculated ACPR Upgrade characteristics indicate that the BeO-UO_2 core design will exceed performance goals and have favorable kinetic characteristics. Pulse operation will be characterized by lower reactivity insertion rates and higher pulse tail energies due to the Doppler dominated temperature coefficient of reactivity.

TABLE I

Comparison of Reactor Concepts

	$U\text{-}ZrH_{1.5}$	UC-ZrC-C/ $U\text{-}ZrH_{1.5}$	UO_2-BeO $U\text{-}ZrH_{1.5}$	UO_2-BeO
Pulse Performance Improvement Factor*	1.6	2.1	2.2	2.6/3.0
Max Temp. (^{0}C)	1100	2000	1200	1200/1400
Temp. Coeff. (27-627^{0}C)(¢/^{0}C)	≃ -1.7	-0.75	-0.83	-0.45
Neutron Gen. Time (μsec)	≃ 45	39	40	24

*Pulse Performance Improvement Factor =

$$\frac{\text{Cavity Fluence in ACPR Upgrade)}}{\text{Cavity Fluence in ACPR)}}$$

TABLE II

Comparison of ACPR and ACPR Upgrade

	ACPR Upgrade	ACPR
General		
Number of Elements	200	156
Number of Control Rods	11	9
Fuel Height (cm)	52.2	38.1
Excess Reactivity ($)	8.0	8.5
Pulse Fluence $\left(n/\mathrm{cm}^2\right)$		
900^{0}C	4.2×10^{15}	2.2×10^{15}
1200^{0}C	5.6×10^{15}	--
1400^{0}C	6.5×10^{15}	--
Steady-State Flux $\left(\frac{n}{\mathrm{cm}^2\ \mathrm{sec}}\right)$	3.8×10^{13} (2MW)	1.2×10^{13} (600kW)
Kinetics Parameters		
α(¢/^{0}C) 27-627^{0}C	-0.45	-1.25
ℓ(μsec)	24	33
Minimum Period (ms)	2.1	1.3
Peak Power (Mw)	26000	14000
Energy Release (Mw sec)	300	108
Neutron Spectrum		
(Fraction $>$10 KeV)	0.58	0.52

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