CONF-951006--27

THE ADVANCED NEUTRON SOURCE THREE-ELEMENT-CORE FUEL GRADING*

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For presentation at the *American Nuclear Society 1995 Winter Meeting*, October 29-November 2, 1995, San Francisco, California.

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Introduction

The proposed Advanced Neutron Source (ANS) neutron research facility's purpose is to provide unprecedented experimental capabilities in the areas of neutron scattering, materials research, and isotope production. The primary goals of the ANS project are to obtain neutron flux levels which are 5 to 10 times larger than any current existing facility and to provide isotope irradiation facilities which are at least as good as the High Flux Isotope Reactor (HFIR) at the Oak Ridge National Laboratory (ORNL).

The ANS pre-conceptual design[1] consists of a two-element 330 MW_f nuclear reactor fueled with highly-enriched uranium and is cooled, moderated, and reflected with heavy water. Recently, the ANS design has been changed to a three-element configuration in order to permit a reduction of the enrichment, if required, while maintaining or improving the thermal-hydraulic margins.[2] Figure 1 shows a diagram of the three-element ANS reactor core in *r-z* geometry. The core consists of three annular fuel elements composed of involute-shaped fuel plates. Each fuel plate has a thickness of 1.27 mm and consists of a fuel meat region of U_3Si_2-Al (50% enriched in one case that was proposed) and an aluminum filler region between aluminum cladding. The individual plates are separated by a 1.27 mm coolant channel. The three element core has a fuel loading of 31 kg of ^{235}U which is sufficient for a 17-day fuel cycle.

The goal in obtaining a new fuel grading is to maximize important temperature margins. The limits imposed are: (1) Limit the temperature drop over the cladding oxide layer to less than 119 °C to avoid oxide spallation. (2) Limit the fuel centerline temperature to less than 400 °C to avoid fuel damage. (3) Limit the cladding wall temperature to less than the coolant incipient-boiling temperature to avoid coolant boiling. Other thermal hydraulic conditions, such as critical heat flux, are also considered.

Methodology

The approach to determining an optimized fuel grading for the ANS is very similar to that for optimizing fuel cycles in LWR's. For this study a direct fuel-cycle optimization approach, which proved successful in the development of two-element fuel gradings[3], has been adopted. This is an iterative approach in which the first step is to perform a fuel cycle calculation for the latest fuel grading to obtain the power distribution. Next, a weighted cycle-averaged power distribution is computed to be used as the optimizing function. The ^{235}U loading in a given zone is adjusted based upon the ratio of the desired zone power and computed cycle-averaged zone power. These steps are repeated until the fuel grading is converged.

The fuel cycle calculations were performed using a four-group, finite-difference, diffusion-theory model using the VENTURE code system[4]. The continuous fuel grading is represented as 800 zones in each element allowing for fine spatial resolution in the fuel grading.

After a converged fuel grading is obtained the local power densities are used as input to the ANS steady-state core thermal-hydraulics code[5] for calculation of the temperature margins. The thermal-hydraulic methodology uses a statistical approach to incorporate uncertainties in the power distribution, geometry, correlations, and other key parameters.[6]

Results

The resulting peak-to-average power density for the three-element fuel grading is 1.7, which occurs in the middle element at the beginning of cycle (BOC). Calculations of the maximum thermal power were performed were performed and are given in Table 1 for the two-element core and three-element core. As this table indicates, the gradings are incipient-boiling limited with substantial increases in margins for the three-element core. The fuel grading results in a maximum thermal power, with all uncertainties accounted for, of 398 MW, which is well above the nominal operating thermal power of 303 MW, with the most limiting condition occurring at BOC in the middle element.

Acknowledgments

The thermal-hydraulics calculations were performed by W. R. Nelson, D. G. Morris, and G. L Yoder, Oak Ridge National Laboratory.

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Figure 1: An r-z diagram of the ANS three-element core configuration

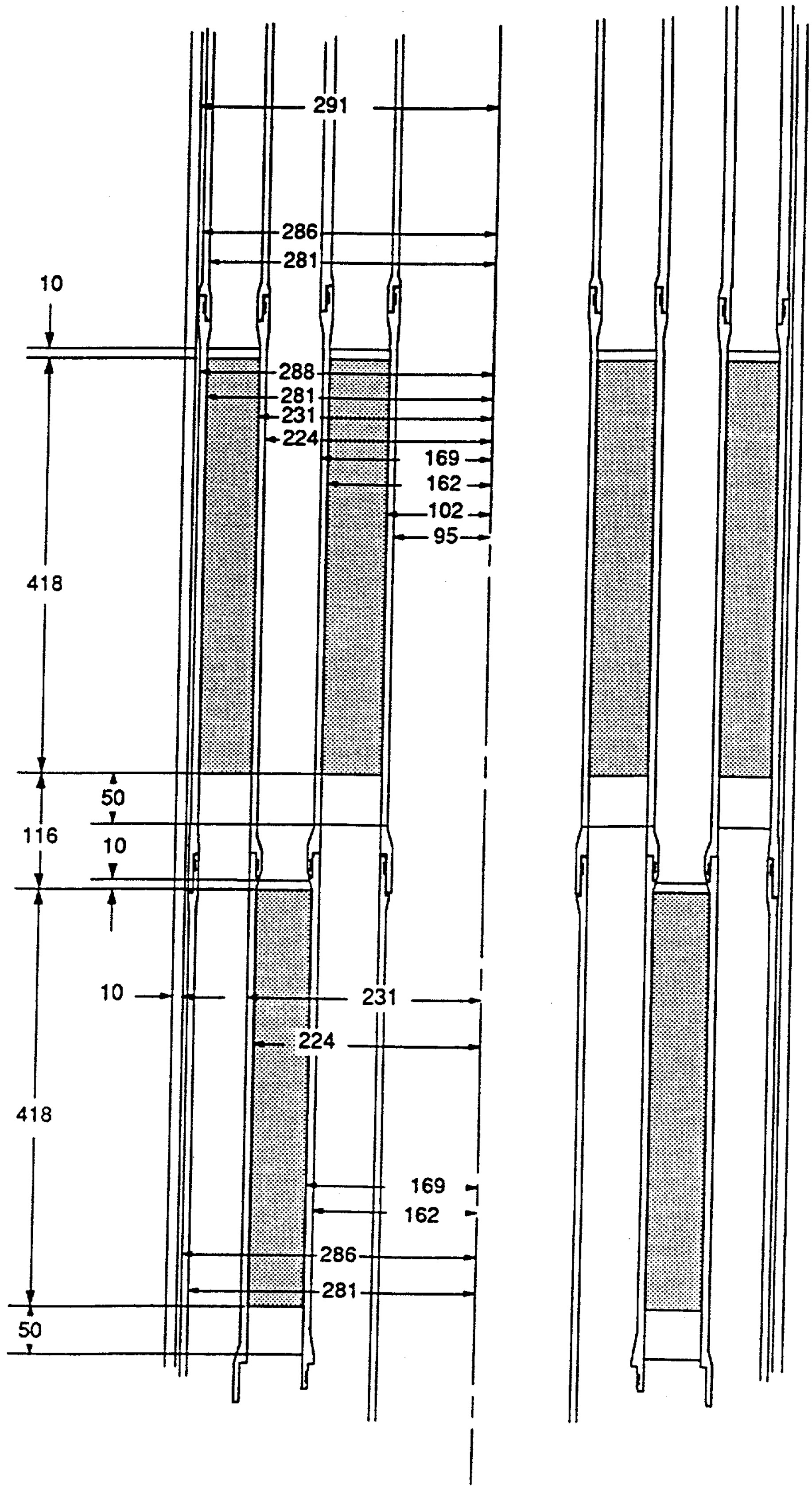
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Table 1: Limiting thermal power levels (MW) for the ANS Three-Element Core

	Maximum Thermal Power (MW)		
	Incipient Boiling	Oxide Temp. Drop	Centerline Temp.
Two-Element Core (ref. 5)	346	388	402
Three-Element Core	398	567	566