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HOT CHANNEL FACTORS AND POWER
DISTRIBUTIONS FOR THE APPR-1

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by

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For The Atomic Energy Commission

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INTRODUCTION

The hot channel factors and power distribution for the APPR-1 has been reviewed in light of the most recent reactor analysis and metallurgical information. An estimate of the heat release (per unit area) in the absorber section is included so that surface temperature of the absorber section can be checked.

The information herein can form part of the Thermal Analysis required in Phase III.

It is planned to determine some information on the effect of rod programming vs. shim bank operation of the control rods in the Zero Power Tests of the APPR-1 core. It is possible that programming will reduce the overall peak to average power.

FACTORS AFFECTING HEAT REMOVAL FROM APPR-1

1. Hot Channel Factors

1.1 Plenum Chamber Effects

An air flow test of a full scale mockup of the APPR-1 vessel is under construction. Until completion of this test the hot channel factors based on the STR air flow test are considered the best available. These are (1):

$$F_{AT} = 1.064$$

$$F_{\theta} = 1.051$$

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1.2 Tolerance on Plate Spacing

The tolerance on plate spacing is now $\pm 10\%$ ⁽²⁾ with no exceptions. Recent measurements on brazed elements indicates an average tolerance of $\pm 7\%$ and a local tolerance of $\pm 10\%$ should be conservative.

The factors for -7% average tolerance are taken from Fig. 4 of (1)

$$F_{AT} = 1.11 \quad F_{\theta} = 1.015$$

The factors for a local tolerance of $\pm 10\%$ are:

$$F_{AT} = 1 \quad F_{\theta} = 1.10$$

1.3 Tolerance of Uranium Content in Core of Fuel Plates

In (1) an average derivation of 0.76% and a maximum deviation of 1.1% was used as tolerances on uranium content based on measurements in test plates. In the specifications for the APPR elements ⁽²⁾ the homogeneity of the UO_2 has been set at $\pm 2\%$ while that of the B_4C as $\pm 20\%$.

Both tolerances affect the self shielding within the meat of the fuel plate. The worst combination is then -20% on B_4C (and B-10) and $\pm 2\%$ on UO_2 (and U-235). The effect of these local tolerances on the relative flux on the surface of the fuel plates is negligible. Calculations indicate that the self-shielding of a nominal and an out of tolerance plate differ less than 0.1% . The hot channel factor due to the local deviation of $\pm 2\%$ on UO_2 and -20% on B_4C is:

$$F_{\theta} = 1.02$$

The effect of this local tolerance on F_{AT} is neglected.

It will be assumed that the average tolerance on UO_2 is $\pm 1\%$ and on B_4C $\pm 10\%$. Then

$$F_{\theta} = F_{AT} = 1.01$$

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1.4 Tolerance on Core Thickness

The estimate of an average tolerance of ± 0.001 inch and a local tolerance of ± 0.0015 inches on core thickness are still adequate so the hot channel factors due to the average tolerance of ± 0.001 inch are (1):

$$F_{\Delta T} = 1.05$$

$$F_{\theta} = 1.05$$

The factors for a local tolerance of ± 0.0015 inch are

$$F_{\theta} = 1.075$$

$$F_{\Delta T} = 1.0$$

Tolerance of Clad Thickness

The factors derived in (1) are still adequate based on an average eccentricity of 0.001 inch.

$$F_{\Delta T} = 1.0138$$

$$F_{\theta} = 1.0138$$

The local eccentricity is taken as 0.002 inches.

$$F_{\theta} = 1.0286$$

1.5 Water Gap Peaking

A factor overlooked in (1) is the effect of thermal flux peaking in the water gap that exists in the APPR-1 around the control rod fuel element. In the APPR-1 there is a distance of 0.3 inches between the outside fuel plate in a control rod fuel element and outside fuel plate in an adjacent fixed full element. In the critical experiment there existed a gap of 0.394 inches between outermost fuel plates in adjacent fuel elements due to the presence of the dead end plates. An intercell traverse with Dy foils was made in the experiment with 20.11 Kg U-235 and 255 gr

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of B. This traverse indicated that the outside fuel plate is in a thermal flux 1.17 times the average flux on the fuel plates. The thermal flux on the outermost fuel plate will be less than this value due to the reactor operating temperature and the reduced water gap over that in the critical experiment. The actual water gap peaking in the APPR-1 will be measured at 68⁰F in the zero power tests. A conservative estimate of the relative thermal flux on the outside control rod plate to the average flux on this fuel plate is 1.1/1.

It is worth noting that the MTR Technical Quarterly Report for the fourth quarter of 1955, IDO-16259 reported that the peak neutron fluxes were about 20% higher next to the shim rod faces. The MTR rod type is similar to the APPR. They also state that the linear flow rate may vary as much as 20% between different plates.

A summary of the hot channel factors is given in the table that follows:

TABLE OF HOT CHANNEL FACTORS

	F_{DT}	F_{ϕ}
Plenum Chamber Effects	1.064	1.051
Tolerance on Plate Spacing		
Average Tolerance ($\pm 7\%$)	1.110	1.015
Local Tolerance ($\pm 10\%$)	1	1.10
Tolerance on Uranium Content		
Average deviation ($\pm 1\%$)	1.010	1.010
Local deviation ($\pm 2\%$)	1	1.020
Tolerance on Core Thickness		
Average tolerance of ± 0.001 in	1.050	1.050
Local tolerance of ± 0.0015 in	1	1.075
Tolerance on Clad Thickness		
Average eccentricity 0.001 in	1.014	1.014
Local eccentricity 0.002 in	1	1.029
Water Gap Peaking	1.1	1.1

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TABLE OF HOT CHANNEL FACTORS

F_{DT}	(average tolerances)	1.348
F_{θ}	(average tolerances)	1.24
F_{θ}	(local tolerances)	1.224

Axial Peak to Average Power

The most distorted axial power distribution exists at midlife before X_{θ} builds up to its equilibrium value. The five rod shim bank is inserted into the core 11". An estimate of the axial power distribution for this shim bank insertion can be obtained from the axial power measurements made in the critical experiment. The maximum to average power from this experiment should be conservative for the APPR-1 at 5 MWYR and 450^oF because both non-uniform burnout and the 450^oF temperature will tend to flatten the axial power distribution.

The maximum to average axial power ratio obtained from direct use of the experimental data is 1.93 to 1. However, due to the fact that the measurements in the rod region were made with the catcher foils in the fuel plate closest to the absorber so that the maximum to average is overestimated. The preliminary window shade calculation for this experiment gives 1.8/1 and this value is believed to be the best value. Fig. 1 gives the window shade results for 50% insertion.

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Radial Peak to Average Power

The radial peak to average power is required for the case of partially inserted control rods. Radial power measurements made in the critical experiment for 50% inserted rods indicate that the radial distribution in the region below the rods is a J_0 with about the same shape that exists for the rods out case. It is assumed that the radial power distribution is a J_0 with reflector savings equal to 7.63 cm at 450°F. The radial peak to average power 1.58/l.

Heat Release in Absorber Section of Control Rod

Based on a heat release of 2.5Mev per absorption the heat generation in the control rod absorber section is 2.16×10^{14} Mev/sec cm².

- (1) Thermal Analysis of APPR at Mid-life. J. G. Gallagher CF-55-8-68.
- (2) Preliminary Format of Specifications for Manufacturing Fuel Assemblies and Absorber Sections for the APPR. R. J. Beaver. CF-56-1-14.

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AXIAL POWER DISTRIBUTION

CRITICAL EXPERIMENT FIVE ROD INSERTION

BOTTOM OF
ABSORBER

TOP OF FUEL

WINDOW SHADE
INSERTION

ABSORBER

TOP OF FUEL

CALCULATED

EXPERIMENTAL

TOP REFLECTOR

CORE

BOTTOM REFLECTOR

$\frac{P}{P_{AVG}}$

0 4 8 12 16 20 24
IN.

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