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OTHER		PROJECT Water Boiler Transient Studies for UCLRL	DATE June 20, 1960	
			PAGE 1 OF 12	

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SUBJECT: Some Information Concerning the KEWB "B" With Regard to UCRL Instrument Calibration.

CONTENTS:

I	STATEMENT OF PROBLEM	PAGE 1
II	SUMMARY OF RESULTS AND RECOMMENDATIONS	PAGE 1
III	METHOD USED, DESCRIPTION OF EQUIPMENT, SAMPLE CALCULATIONS . . .	PAGE 1-4
IV	REFERENCES AND APPENDICES	PAGE 5

I STATEMENT OF PROBLEM

Recent use of the KEWB-B reactor as a calibration source for pulse detection instruments has created a need for the following three items:

1. Radial and axial distributions of fissions.
2. Number of fission seen by the detection instruments.
3. Materials seen by the detection instruments.

II. DESCRIPTION OF THE EXPERIMENTAL SET-UP.

The calibrations were achieved with the help of six transient runs. In each run, the instruments were exposed to the core through a 4 x 4 in. channel cut-out of the graphite reflector and centered around the auxiliary glory hole. A perspective view of the KEWB-B core installation is shown in Figure 1; the 4 x 4 in. channel is not shown, but the plug of the auxiliary glory hole is indicated. The loading during the first transient consisted of 1702 gm. of U²³⁵, 126 gm of U²³⁸ and a solution volume of 17.8 liters. After each run, a small amount of water is lost in the form of hydrogen-oxygen gases, the result being a slight decrease of the fuel solution volume. For the purposes of this study the volume change is negligible.

III. RADIAL AND AXIAL FISSION DISTRIBUTIONS

The radial and axial fission distributions were determined using two group diffusion theory. Such problems are best handled on the AIM-5 code⁽¹⁾ which solves one-dimensional multigroup diffusion theory problems. The core composition used to perform the calculations is reproduced in Table I. It was arrived at by treating everything inside the core, that is fuel solution, control and poison rod thimbles, cooling coils, cooling water and poison rod hole, as a homogenized solution. Further, this core composition corresponds

12-2

TECHNICAL DATA RECORD

Water Boiler Transient

DATE June 20, 1960

PROGRAM KEWB

PROJECT Studies for UCLRL

PAGE 2 OF 12

to a core loading as described above. The calculations were carried out in the following order.

1. Calculate with the aid of the Muft IV code⁽²⁾ fast cross-sections for the core, core vessel and reflector regions.
2. Calculate with the aid of the Sofocate code⁽³⁾ thermal cross-sections for the core. Use the option of averaging over a Wigner-Wilkins spectrum.
3. Calculate thermal cross-sections for core vessel and reflector regions. Use microscopic cross-sections from the Barn book⁽⁴⁾ averaged over a Maxwellian spectrum.
4. Perform with the aid of the AIM-5 code a radial flux search in cylindrical geometry and for a configuration as shown in Figure 2. Use a transverse buckling of 0.00711 cm^{-2} . This buckling is derived from

$$B_a^2 = \left(\frac{\pi}{H + \mathcal{J}} \right)^2 \quad (1)$$

where

H = height of core, 27.24 cm. The bottom of the core is actually elliptical. To arrive at this value of H, the core volume, that is fuel solution volume, cooling coils volume, etc., a total of $20,500 \text{ cm}^3$, was divided by πR^2 , where R = 15.5 cm, the inside radius of KEWB-B vessel.

$\mathcal{J}$ = Reflector savings due to the reflector below the core, 10 cm.

From the results of this search, determine group dependent radial bucklings.

5. Perform with the aid of the AIM-5 code an axial flux search in slab geometry and for a configuration as shown in Figure 3. Use the group dependent radial bucklings of step 4 as transverse bucklings. From this search, determine group dependent axial bucklings.
6. Same as step 4 except that the group dependent axial bucklings of step 5 are used as transverse bucklings.
7. Same as step 5 except that the group dependent radial bucklings of step 6 are used as transverse bucklings.

The source distributions, i.e., fast fissions plus thermal fissions, obtained from steps 6 and 7 and normalized to a power of 1 watt are shown in Figures 4 and 5. Both of these flux searches yielded a k_{eff} value of 1.025. The experimental k_{eff} was 1.05. In the KEWB-B, the value of k_{eff} is quite sensitive to the fast transversal buckling. Thus a 10 to 20% change in transversal buckling causes a change of 1.5% in k_{eff} . The shape of the source distribution is insensitive to the value of k_{eff} . A change

TECHNICAL DATA RECORD

PROGRAM KEWB

PROJECT Water Boiler Transient Studies for UCLRL

TDR NO. 5420

DATE June 20, 1960

PAGE 3 OF 12

of 3.5% in k_{eff} will cause a change varying from .5% at the center of the core to 5% at the edge of the core in the fission distribution. On the basis of these considerations, it is believed that the results of Figures 4 and 5 are accurate to within $\pm 5\%$.

A source of errors that should not be neglected is the assumption of treating everything inside the core vessel as a homogenized solution. However, the effect of poison hole, cooling coils, etc., is one of perturbation, that is the flux shape or source distribution is primarily affected locally. To properly account for these perturbations, a three dimensional multigroup diffusion code would be necessary.

For reference purpose the fast and thermal cross-sections for all regions are reproduced in Table II.

IV. NUMBER OF FISSIONS SEEN BY DETECTION INSTRUMENT

The number of fissions seen by the detection instruments was obtained using the relation

$$N = \frac{V_{fs}}{V_{fo}} \frac{\bar{S}_{as}}{\bar{S}_a} C v \quad (2)$$

where

N = Number of fissions seen by the detection instruments
fiss/cc.sec

V_{fs} = Fuel volume seen by detection instrument, 1215' cm³.
This fuel volume is corrected for the cooling coils, control rod thimbles and glory hole.

V_o = Total fuel volume, 17800 cm³

$\bar{S}_{as}$ = The average axial fission distribution over a 4 x 4 in. sector centered around the auxiliary glory, 2.62×10^6 fission/watt.sec.cm³

This number is obtained from Figure 5.

$\bar{S}_a$ = The average axial fission distribution 2.85×10^6 fiss/cm³sec watt obtained from Figure 5.

C = A constant, 3.43×10^{10} fissions/watt.sec. The reason for selecting such a value for C will be described later.

v = Non-void fraction, 0.96. This number is arrived at by assuming a total void of 700 cc in the fuel volume of 17,800 cm³.

The evaluation of equation (2) gave for N a value of $.21 \times 10^{10}$ fissions/sec. Watt.

TECHNICAL DATA RECORD

Water Boiler Transient

DATE June 20, 1960

PROGRAM KEWB

PROJECT Studies for UCLRL

PAGE 4 OF 12

The value of 3.43 fissions/watt sec. for the constant C was chosen for the following reasons. In the KEWB-B, the reactor power calibration technique is based on calorimetry. That is, the heat extracted from the core while the reactor is operated at a few kilowatts is the measure of the actual power being dissipated. This power does not correspond directly to the total energy released, since all radiative energy is not deposited in the core. Therefore, it is necessary to obtain a correlation between reactor power and the absolute fission rate. The energy release per fission is 204 Mev and is distributed as follows:

- 168 Mev fission fragment kinetic energy
- 4.9 Mev fast neutrons
- 7.5 Mev prompt gamma ray
- 5.9 Mev fission product gamma ray
- 8.0 Mev fission product beta-ray
- 10.5 Mev neutrons

Of this energy, the following distribution is assumed to remain in the core while the rest leaks into the surrounding and is undetected.

- 168 Mev fission fragment kinetic energy
- 3.2 Mev fast neutron (approximately 35% of all fast neutrons leak out of the core)
- 6.0 Mev fission product beta's. It is assumed that half of all beta rays are emitted very shortly after fission occurrence and are absorbed in the core. Of the delayed beta's, only half of their energy is seen shortly after fission and therefore detected in the calorimetric procedure.
- 6.0 Mev gamma rays. Half of all gammas that are released shortly after fission are assumed to be absorbed in the core.

The total energy seen per fission is then, 183 Mev, which leads to a number of 3.43×10^{10} fissions/watt sec. The possible error in C is about $\pm 3\%$. This corresponds to ± 5 Mev in the energy seen per fission. In view of the 5% error S, the error in N is therefore about $\pm 8\%$.

V. MATERIALS SEEN BY THE DETECTION INSTRUMENTS

The materials in sight through a 4 x 4 in. duct centered around the auxiliary glory hole were found by examining the lay-out drawings. The following items can be seen:

1. Half of each of the four control rod thimbles. Each control rod thimble has an outer diameter of $11/8$ in.
2. Two inlet coolant tubes for a height of 4 in. The outer diameter of an inlet coolant tube is $7/8$ in. During operation these tubes are filled with water.

TECHNICAL DATA RECORD

Water Boiler Transient

DATE June 20, 1960

PROGRAM KEWB

PROJECT Studies for UCLRL

PAGE 5 OF

3. 68 in. of coolant coils. The outer diameter of the coolant coils is 1/4 in. During operation, the coolant coils are filled with water.
4. The upper part of the central expose tube for the poison rod. Nothing is seen of the poison rod.

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12-6

TECHNICAL DATA RECORD

PROGRAM KEWB

Water Boiler Transient
PROJECT Studies for UCLRL

TDR NO. 5420

DATE June 20, 1960

PAGE 6 OF 12

TABLE I.

Core composition of a homogenized KEWB-B containing 17.8 liters of fuel solution with 1702 gm of U^{235} and 126 gm of U^{238}

Element	Atomic density (atoms/cc) $\times 10^{-24}$
H	.05856
O	.03063
Fe	.002895
S	.0002245
U^{235}	.0002090
U^{238}	.00001556

TECHNICAL DATA RECORD

PROGRAM KEWB

PROJECT Water Boiler Transient
Studies for UCLRL

TDR NO. 5420

DATE June 20, 1960

PAGE 7 OF 12

TABLE II.

Nuclear Cross-section for Core, Pressure Vessel and Reflector.

	Core	Pressure vessel	Radial Reflector	Axial reflect or below core
Σ_{a1}	.003825 cm ⁻¹	.01985	.0001204	.00019933
Σ_{r1}	.038133 cm ⁻¹	-	.003411	.0033973
D_1	1.378408 cm ⁻¹	1.100	1.100	1.100
$\nu\Sigma_{f1}$	.004558 cm ⁻¹	-	-	-
Σ_{a2}	.12402 cm ⁻¹	.23136	.00062502	.0015489
D_2	.2060 cm ⁻¹	.31504	.8268	.82502
$\nu\Sigma_{f2}$	.2181 cm ⁻¹	-	-	-

12-8

Figure 1. Perspective View of the KDWB "B" Core Installation

TDR 5420
June 20, 1960
Page 8 of 12

13-7

Figure 2. Radial Configuration Used in Calculations

Air, 35.64 cm

—Core, H = 27.24 cm

—Core vessel, stainless steel, 0.635 cm

—Bottom reflector, graphite, 60.0 cm

12-11

FIGURE 4: RADIAL FISSION DISTRIBUTION IN KEWB-13

REACTOR POWER 1 WATT
CORE LOADING 1702 GM U^{235}
FUEL SOLUTION VOLUME
17,800 cm^3
CORE $k_{eff} = 1.025$

FISSION DISTRIBUTION
(FISSIONS/ CM^2 ·SEC)

10 X 10 TO THE CM. 359-14
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE 5. AXIAL FISSION DISTRIBUTION IN KEWB-B (ALONG Z axis)

12-13