united nations educational, scientific and cultural organization
international atomic energy agency

the **abdus salam** international centre for theoretical physics

ICTP 40th Anniversary

SMR.1555 - 3

Workshop on
Nuclear Reaction Data and Nuclear Reactors:
Physics, Design and Safety

16 February - 12 March 2004

WIMS Exercises

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Workshops for WIMSD

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2 March 2004

HOMOGENEOUS CALCULATIONS

No spatial problems

Use full library groups

Solve neutron balance equations

In any energy group, for a critical system

Source of neutrons = Removal rate.

Source = Fission neutrons + Inscatter

Removal= Absorption + Outscatter + Leakage

For a 2-group calculation without upscatter or leakage

Group 1: $$\frac{1}{k_\infty}(\upsilon\Sigma_{f_1}\phi_1 + \upsilon\Sigma_{f_2}\phi_2) = \Sigma_{a_1}\phi_1 + \Sigma_{12}\phi_1$$

Group 2: $$\Sigma_{12}\phi_1 = \Sigma_{a_2}\phi_2$$

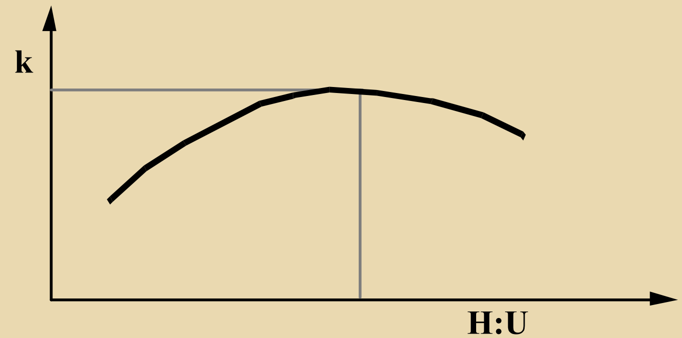
INFINITE HOMOGENEOUS

Infinite medium of one material: k-infinity

Typical variable parameters are: fissile concentration (H:Pu)
enrichment
degree of poisoning

Leakage can be introduced (buckling):   k-effective.

Very quick and cheap.



Examples: Pu(NO3)4 storage; UO2(NO3)2 evaporator.

Warning: Parameters that give the maximum k-infinity may not be those that give the maximum k-effective

WORKSHOP 1

k-effective for an Oak Ridge Sphere

Use DSN method

Solution composition:

Hydrogen	0.066394
Oxygen	0.033592
Nitrogen	1.11e-4
U234	4.090e-7
U235	3.6185e-5
U236	2.2e-7
U238	1.985e-6

Calculate buckling for sphere of radius 61.01cm with extrapolation of 7cm

READDATA

Input is in the form of:

- CODEWORD (upper or lower case) followed by numerical data items.

Only the first 4 letters of a codeword are relevant.

Data items may be real or integer or containing E for exponent, but must contain no blanks(eg. 1.0e-2).

Data items for one codeword may occupy several lines (without $ signs) but must not extend beyond column 72.

Repeated items may be input as:

13@1 0 1 * (instead of 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1)

3 (1 2 3) * (instead of 1 2 3 1 2 3 1 2 3)

An asterisk(*) indicates that all the following information on the current line is a comment

WORKSHOP 1

$$\text{k-effective} = \frac{\text{k-infinity}}{1 + M^2 Bg^2} \qquad (1)$$

$$M^2 = \frac{\text{k-infinity} - 1}{B_c^2} \qquad (2)$$

When k-effective = 1 $\quad B_c^2 = B_g^2 \quad$ (3)

WORKSHOP 1

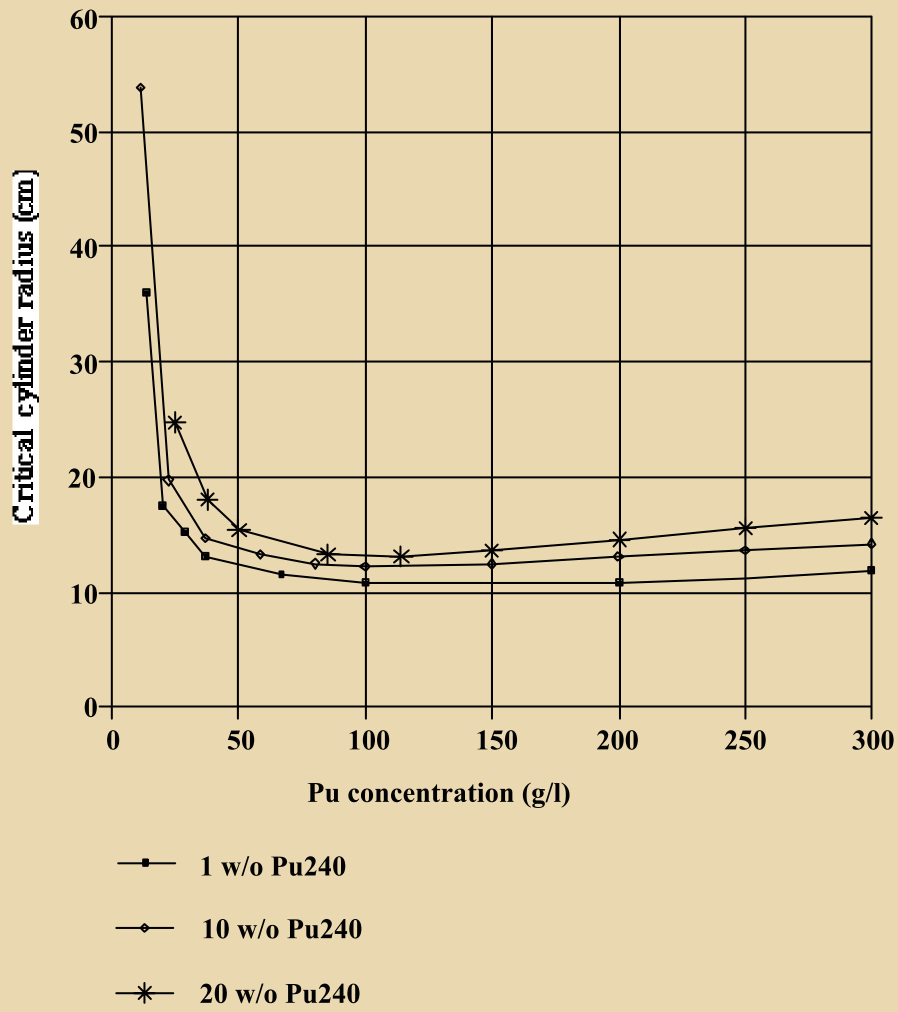
Taking the output from CHAIN 14 to obtain k-infinity from the case without Buckling and Bc^2 from the case with Buckling and using equations 1,2 and 3, find:

(a) The dimensions of a sphere whose contents are just critical at various Pu concentrations.

(b) The dimensions of a sphere whose contents have k-effective = 0.95, at various Pu concentrations.

Assume □ = 7 cm

WORKSHOP 1
CRITICAL CYLINDER RADII

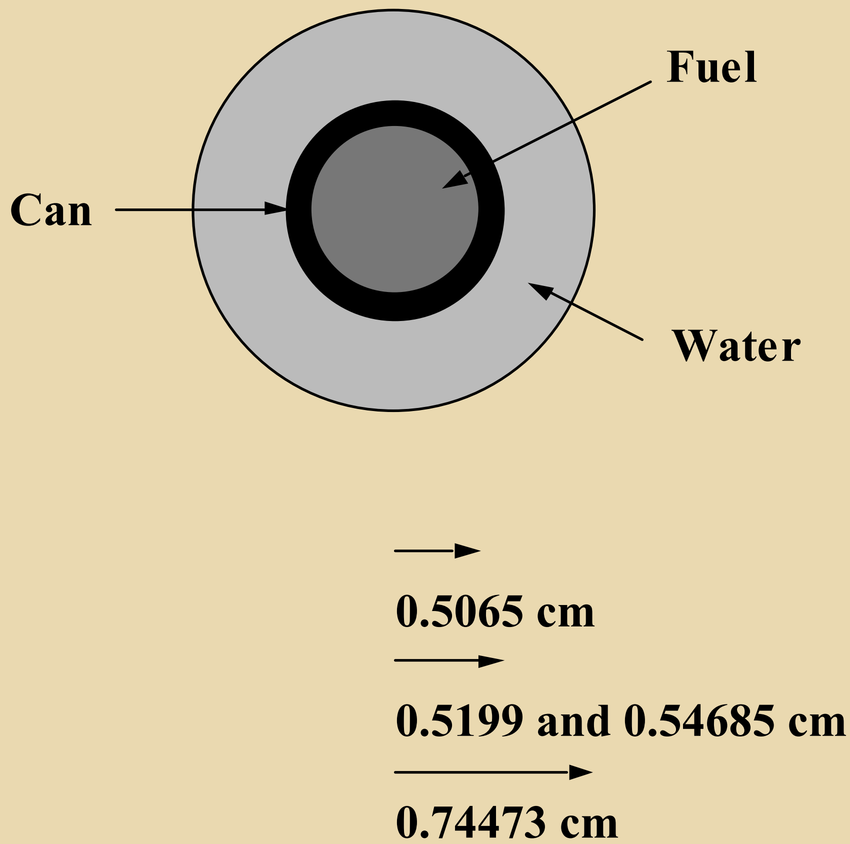


WORKSHOP 2

k-effective for a regular PWR benchmark lattice

1. U235 enrichment 3.0 w/o
2. Square pin pitch 1.32 cm
3. Assume: fuel density 10.4 g/cc
   fuel radius 0.5065 cm
   aluminium wrapper radius 0.5199 cm
   clad radius 0.54685 cm
   clad material 7.8 g/cc (Fe 58% Ni 12% Cr 18%)
4. Bucklings: radial 0.00415, axial 0.00215

PIN CELL CALCULATION



WORKSHOP 2

Required input data

Prelude:	pincell
	dsn
	nmesh/nregion/nmaterial
Main:	material
	annulus
	mesh
Edit::	buckling

WORKSHOP 2

$$B_c^2 = \frac{2.405^2}{(R+\lambda)^2} + \frac{\pi^2}{(H+2\lambda)^2}$$

$$N = \frac{R^2}{R_p^2}$$

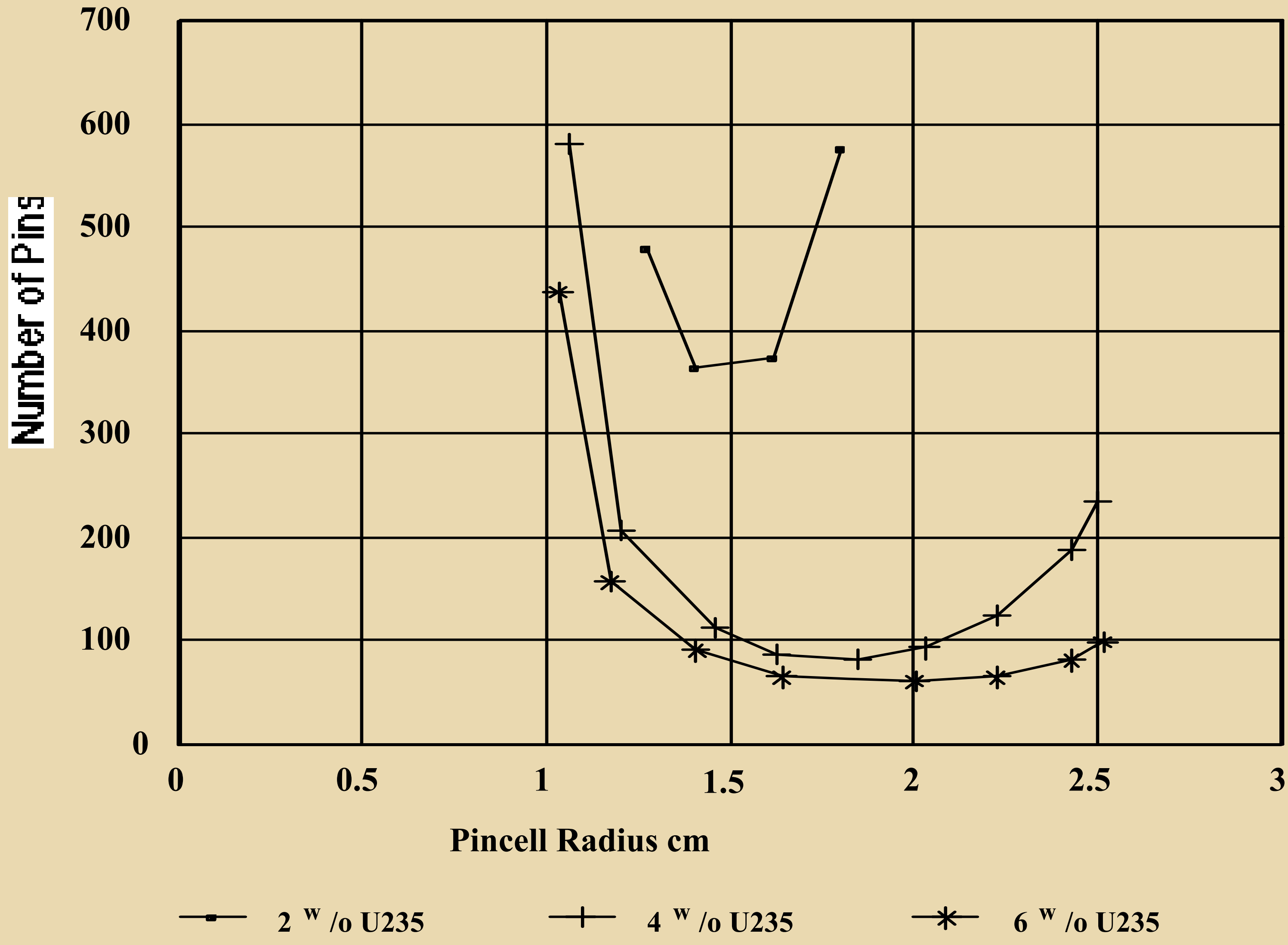
where N is the number of pins

Rp is the pin cell radius

λ= 6.5 cm.

1) For each of the pin cell radii considered, use Bc2 from the output to obtain the radial dimension of a cylindrical array of pins which is just critical.
2) How many pins will fit into the cylindrical array?

WORKSHOP 2



700
600
500
400
300
200
100
0
Number of Pins
0
0.5
1
1.5
2
2.5
3
Pincell Radius cm
2 w /o U235
4 w /o U235
6 w /o U235

LEAKAGE OPTIONS in CHAIN 14

Homogeneous solutions based on:

- Diagonal Transport Corrected Flux Solution
- B1 Flux Solution

Diffusion Coefficients based on:

- Benoist 3-region model
- Transport cross sections
- Ariadne method

WORKSHOP 3

LEAKAGE and REACTION RATES

Repeat workshop 2 pincell:

- Using PERSEUS
- adding all combinations of LEAKAGE CALCULATIONS
- adding 2-group reaction edits for U235 and U238

WORKSHOP 3

LEAKAGE EDITS

BEEONE to request diagonal transport and B1 solutions

DIFFUSION to request all diffusion coefficient options

REACTION RATES

LEAKAGE to select spectrum

PARTITION to select structure

REACTION to select nuclides

Repeat workshop 2 pincell:

WORKSHOP 4

Repeat Workshop 3 with CONDENSEDGROUP STRUCTURE

INPUT

MICROSCOPICS

RESONANCE TREATMENTS

SPECTROX

CONDENSE

PERSEUS

EDITS

WORKSHOP 4

Input Data

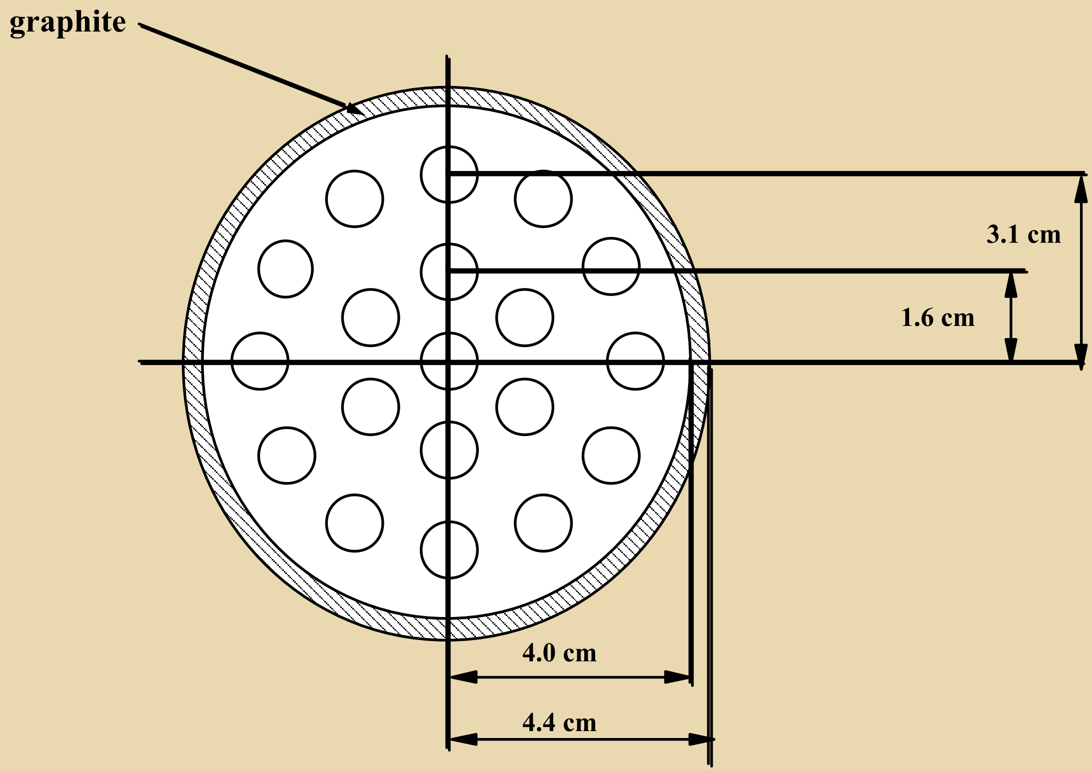
To Condense 'main transport' group structure to give energy bounds at 821 and 9 KeV, and at 4.0 0.625 and 0.14 eV.

PRELUDE data:	NGROUP	
MAIN data:	FEWGROUPS	(define the 6 groups)
EDIT data:	THERMAL	

Output

Compare 69 group k-effective values from WORKSHOP 3 and WORKSHOP 4

RBMK FUEL ELEMENT



Tie rod:	radius	0.75 cm
Fuel pellet :	radius	0.5915cm
Clad:	radius	0.6815 cm
Pitch	Square Lattice	26.56 cm

WORKSHOP 5

k-infinity for an infinite array of RBMK assemblies

1. Model an RBMK assembly using ring-smearing and DSN
2. Fuel density 10.0g/cc and 2 w/o enrichment, temperature 1000k
3. Clad Zr, density 6.5 g/cc, temperature 600k
4. Coolant H20, density 0.5 g/cc, temperature 550k
5. Moderator carbon, density 1.8 g/cc, temperature 500k
6. Centre ‘tie rod’ and pressure tube also Zr
7. Condensed main transport group structure (~ 6 groups)

WORKSHOP 5

Required Input

PRELUDE Data:	CLUSTER geometry
	NREGION to define annuli with rods
MAIN Data:	RODSUB data to define fuel rods
	ARRAY data to position rods in cluster

WORKSHOP 6

DSN CLUSTER with BURNUP

Required Input

Prelude Data:	NMATERIAL to define number of burnable materials
Main Data:	POWER to define rating and steps
Edit Data:	ALPHA Option

Exit one short step to get equilibrium Xe, and a few longer steps to get k at 4000MWd/te

WORKSHOP 7

Required Input:

Prelude Data:	NRODS
Main Data:	Note the MESH data
	Note the ANNULUS radii
	PLOT to get a 'picture'
Edit Data:	As for Workshop 5

Compare k values from Workshop 5 and 7

{Optional extras: (a) try SQUARE boundary
(b) place 'empty tubes at corners}

SUMMARY OF WORKSHOPS

1. Homogeneous calculations
2. DSN Pincell in 69 groups
3. PERSEUS Pincell with leakage in 69 groups
4. As 3 with condensation to 6 groups
5. RBMK assembly - DSN ring-smearing

6 As 5 with depletion

7. As 5 with PIJ explicit geometry