THE NIGERIAN RESEARCH REACTOR-1 : DESIGN, SAFETY, AND OPTIMIZATION

Yusuf A. Ahmed

Reactor Engineering Section,
Centre for Energy Research and Training,
Ahmadu Bello University, Zaria.

Ahmadu Bello University
Zaria - Nigeria

OUTLINE

- TIMELINE
- Basic REACTOR PHYSICS
- DESIGN CONCEPTS & Modifications
- SAFETY & Physical Security
- OPTIMIZATION & Calibrations

MODULE I

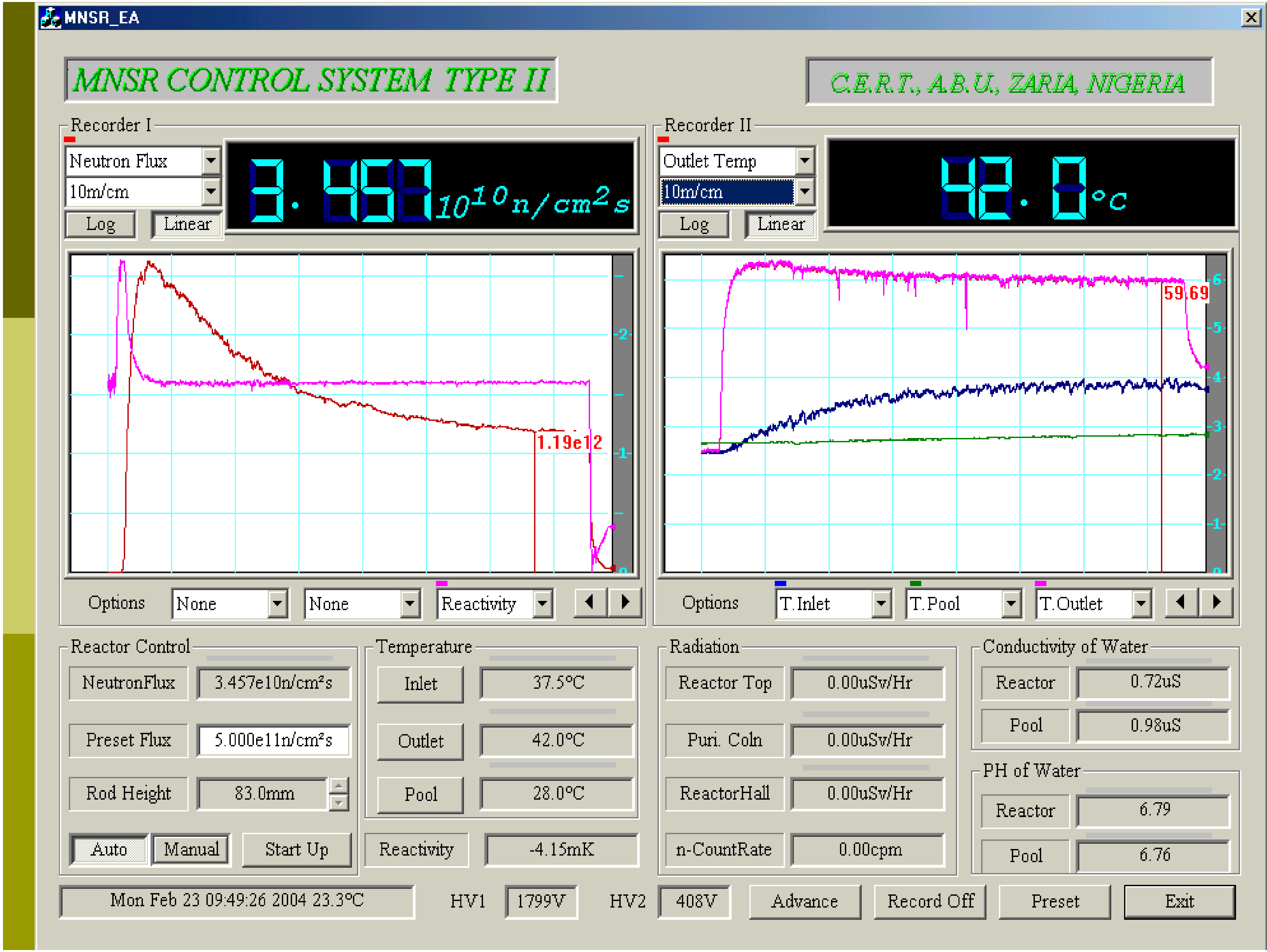
TIMELINE

TIMELINE-MNSR

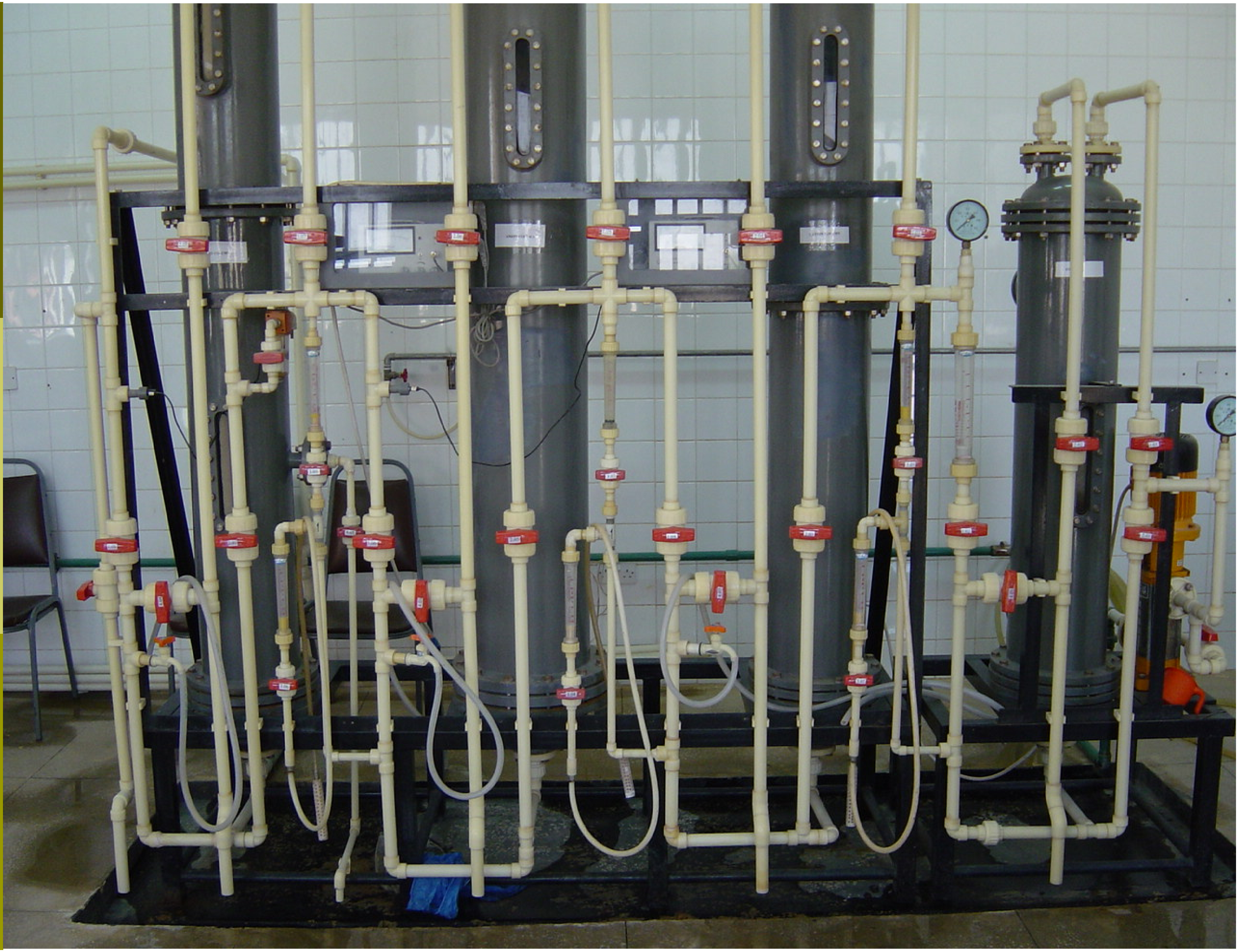
- MNSR with a thermal power of 30 kW is a low-power, tank-in-pool- thermal reactor
  - Similar to the Canadian SLOWPOKE
- 1st prototype started in 1980, critical in1984
- 8 commercial MNSRs in the world:
  - 3 in China; 1 each in Ghana, Iran, Pakistan, Syria and lately Nigeria
- 1 in China has been de-commissioned in 2007

TIMELINE-Nigerian Reactor

- Construction began in 1997 commissioned in 2004
  - No.8 commercial MNSR in the world
  - Criticality Feb. 03, 2004
  - Licensed June 01, 2004
- Applications:
  - Neutron Activation Analysis
  - Reactor Training
  - May be Radioisotope Production
- 6 irradiation sites connected for NAA
  - Suitable flux for NAA is $1 \times 10^{10} – 1 \times 10^{12}\ n/cm^2.s$
- Flux stabilizes 15 min after start-up
  - Radial and axial flux variation around core is ±3%
  - Flux variation inside irradition vial is ±1%
  - Max. Temp., inner site is 55 °C, thus suitable for liquid & biological samples


MNSR_EA
MNSR CONTROL SYSTEM TYPE II
C.E.R.T., A.B.U., ZARIA, NIGERIA
Recorder I
Neutron Flux
10m/cm
Log
Linear
3.457 10¹⁰n/cm²s
1.19e12
Options
None
None
Reactivity
Recorder II
Outlet Temp
10m/cm
Log
Linear
42.0 °C
59.69
Options
T.Inlet
T.Pool
T.Outlet
Reactor Control
NeutronFlux
3.457e10n/cm²s
Preset Flux
5.000e11n/cm²s
Rod Height
83.0mm
Auto
Manual
Start Up
Temperature
Inlet
37.5°C
Outlet
42.0°C
Pool
28.0°C
Reactivity
-4.15mK
Radiation
Reactor Top
0.00uSv/Hr
Puri. Coln
0.00uSv/Hr
ReactorHall
0.00uSv/Hr
n-CountRate
0.00cpm
Conductivity of Water
Reactor
0.72uS
Pool
0.98uS
PH of Water
Reactor
6.79
Pool
6.76
Mon Feb 23 09:49:26 2004 23.3°C
HV1
1799V
HV2
408V
Advance
Record Off
Preset
Exit


EG&G ORTEC



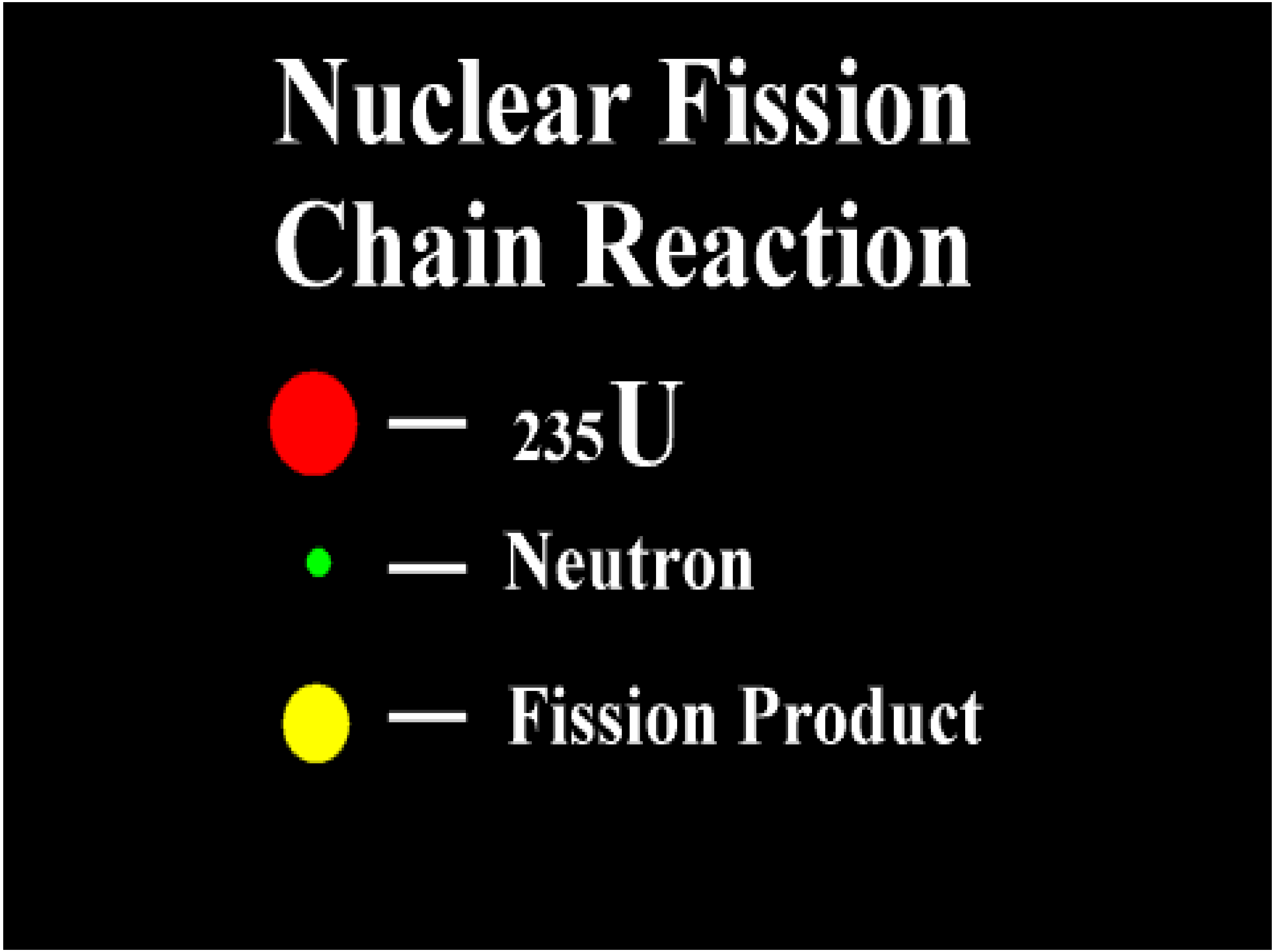
MODULE II

REACTOR PHYSICS

(Basic)

-We are here to learn advanced!!!


Fission
235U


Nuclear Fission
Chain Reaction
235U
Neutron
Fission Product

REACTOR PHYSICS-Multiplication System

- Condition for self-sustaining chain reaction is that rate of production of n's must be equal/greater than rate of loss

$$k = \frac{prod\ .rate}{absorp\ .rate + leakage}$$

i.e. Effective Mult. Factor

- k is an eigen value for a finite reactor system and is a measure of the ciriticality condition
- k = 1, reactor is said to be critical
- k < 1, reactor is said to sub-critical
- k > 1, reactor is said to super critical
- Reactors are designed with k > 1

REACTOR PHYSICS-Neutron Diffusion

- Neutron distribution from a plane source in infinite system is given as:

$$\frac{d^2\phi}{dx} - \frac{\Sigma_a}{D}\phi = 0$$

Where,

$$\phi(x) = Ae^{-\sqrt{\frac{\Sigma_a}{D}}X} + Ce^{\sqrt{\frac{\Sigma_a}{D}}X}$$

$$L = \sqrt{\frac{D}{\Sigma_a}}$$

- L is the diffusion length and is related to the geometry and material composition of the reactor system as follows

$$B_M^2 = \frac{k_\infty - 1}{L^2}$$

$$B_G^2 = \frac{k_\infty - 1}{L^2}$$

REACTOR PHYSICS-Neutron Diffusion

- Diffusion Lenght (L) is essentially a measure of how far the neutrons will diffuse from a source before they are finally absorobed
  - it is very important in the design of reactor core
  - If L is small, the dimension of the core can be designed to be compact
  - as in low-power reactors like MNSR and SLOWPOKE
- With regards to geometry and material composition, the criticality conditions is: $B_M^2 = B_G^2$
- Thus in hypothetical design of a reactor, B_G can be fixed, while the appropriate value of B_M can be determined from calculations

REACTOR PHYSICS-The Four-Factor Formula

- From a simple reactor kinetics, it can be shown that:

$$T = \frac{l}{k - 1}$$

Where , T is reactor period and l is the neutron life time,

- k, is made slightly greater than 1 to make the reactor super critical
- In the design of a reactor, k is affected by the coolant, structural material etc. This relationship is given by the four factor formula i.e.

$$k_{\infty} = \eta.\varepsilon.p.f$$

Where, η is the factor rep no. of fission neutrons produced

  - ε is the fast neutron factor (i.e. Capture neutrons from ^{238}U
  - p is probalility of escape of capture in the resonance of ^{238}U
  - f is thermalization utilization factor

REACTOR PHYSICS-The Six-Factor Formula

- For a finite system, the equation is modified to six-factor formula

$$k_{\infty} = \eta.\varepsilon.p.f.P_f.P_t$$

Where, P_f is fast non-leakage probability

P_t is thermal non-leakage probability

- Six-factor formula provides insight into the various mechanisms involved in nuclear fission chain reactions
  - Example, once fuel has be chosen, then ε & η are fixed,
  - f & p can varied by the ratio of fuel density to moderator density as in the case of prototype MNSR and Commercial MNSR

REACTOR PHYSICS-Reactivity & Reactor Kinetics

- Reactivity, ρ, is a measure of departure of a reactor system from citicality

$$\rho = \frac{k_{eff} - 1}{k_{eff}}$$

- Where, k_{eff} is the effective multiplication factor
  - If $\rho = 0$, reactor is ciritical
  - If $\rho > 0$, reactor is super critical
  - If $\rho < 0$, reactor is sub critical

- Reactor Physicists/Nuclear Engineers design the reactor with in-bulit reactivity known as core excess reactivity, ρ_{ex}, for it to operate
  - ρ_{ex} is the margin by which the reactor system is greater than unity

- MNSRs are designed ρ_{ex} = 3.5 – 4.0 mk; approx 0.5\$; 350 – 400 pcm

MODULE III

DESIGN

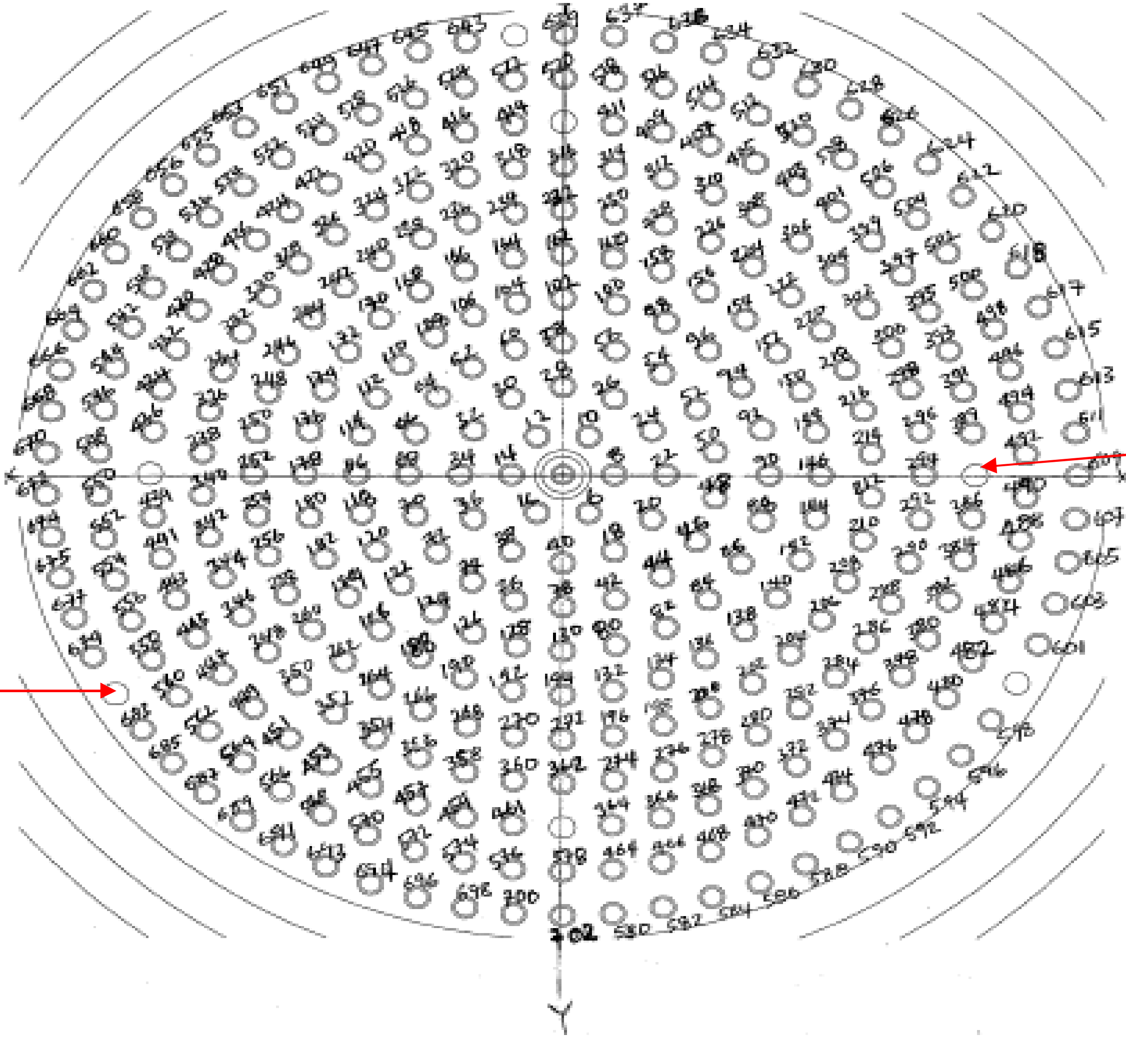
Design of MNSR-HEU core

- Low critical mass (about 1 Kg of ^{235}U)
- Compact core 23 x 23 square cylinder
- Under moderated core $H/^{235}U = 197$
- Negative temp. coeff of reactivity
- High ratio of neutron flux in irradiation channels
- Codes used for core calculations and modelling:
  - HAMMER 1977
  - EXTERMINATOR-II
  - RELAP V
  - MCNP5
  - WIMS & CITATION
  - PARET

Modification Attempts (MCNP CODE)

- Geometry of NIRR-1 HEU core was created in a 3-D, Cartesian coordinate system.
- An MCNP input deck was constructed using detailed from NIRR-1 Safety Analysis Report
- Core centre was taken as the origin (0, 0, 0) in the x- and y-plane and the center of the fuel pin in the z-plane

Core	Fuel Pins
347 Fuel Pins	Fuel Meat OD: 4.3 mm
3 Dummy Al Pins	Clad OD: 0.6 mm
4 Al tie rods	Clad Thick: 0.6 mm
1085g U-235	Fuel Height: 230 mm
90% Enr. U	U-235 per Pin: 2.88 g

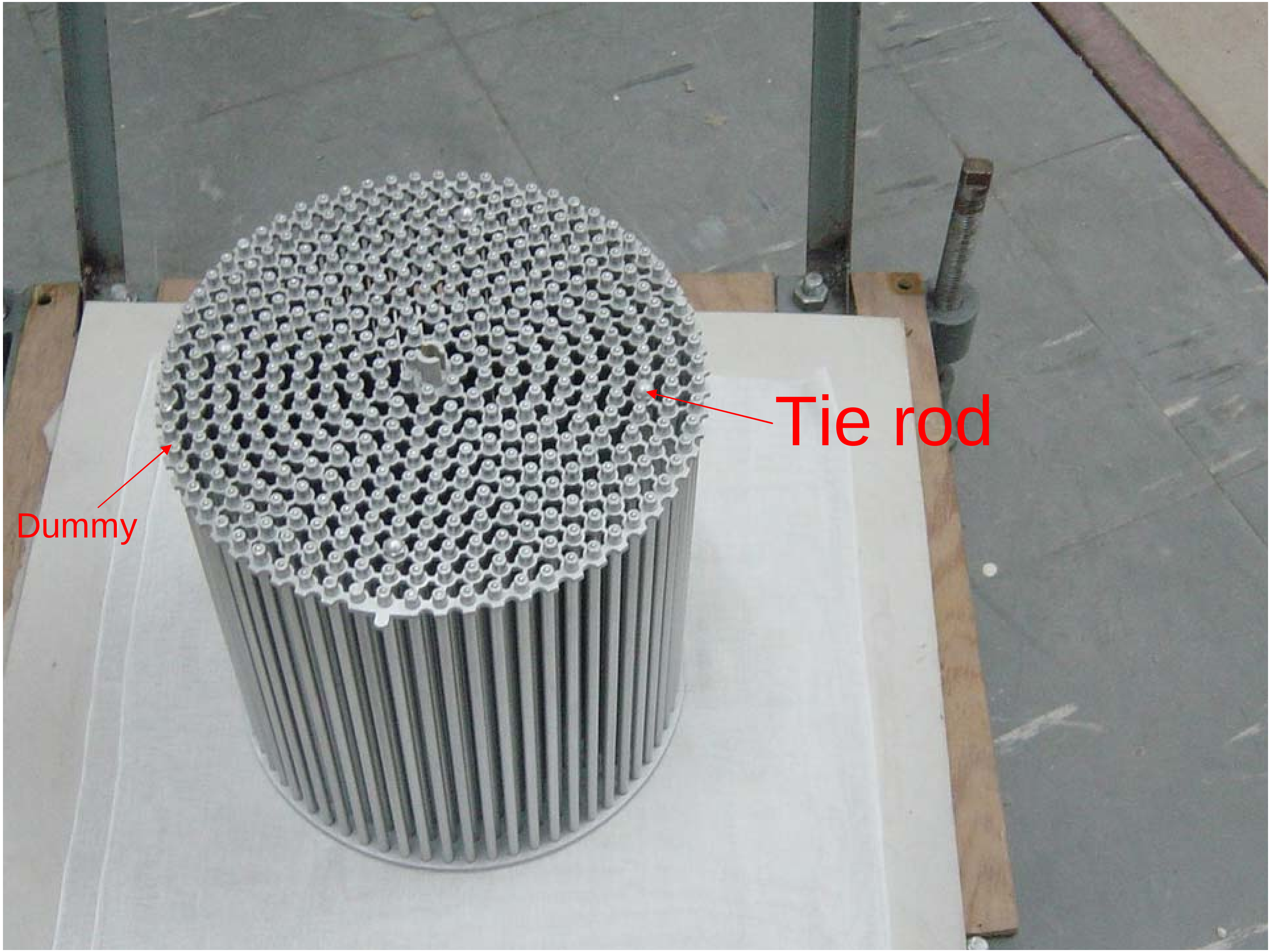


Tie rod

(4 No.s)

Dummy

(3 No.s)


Tie rod
Dummy

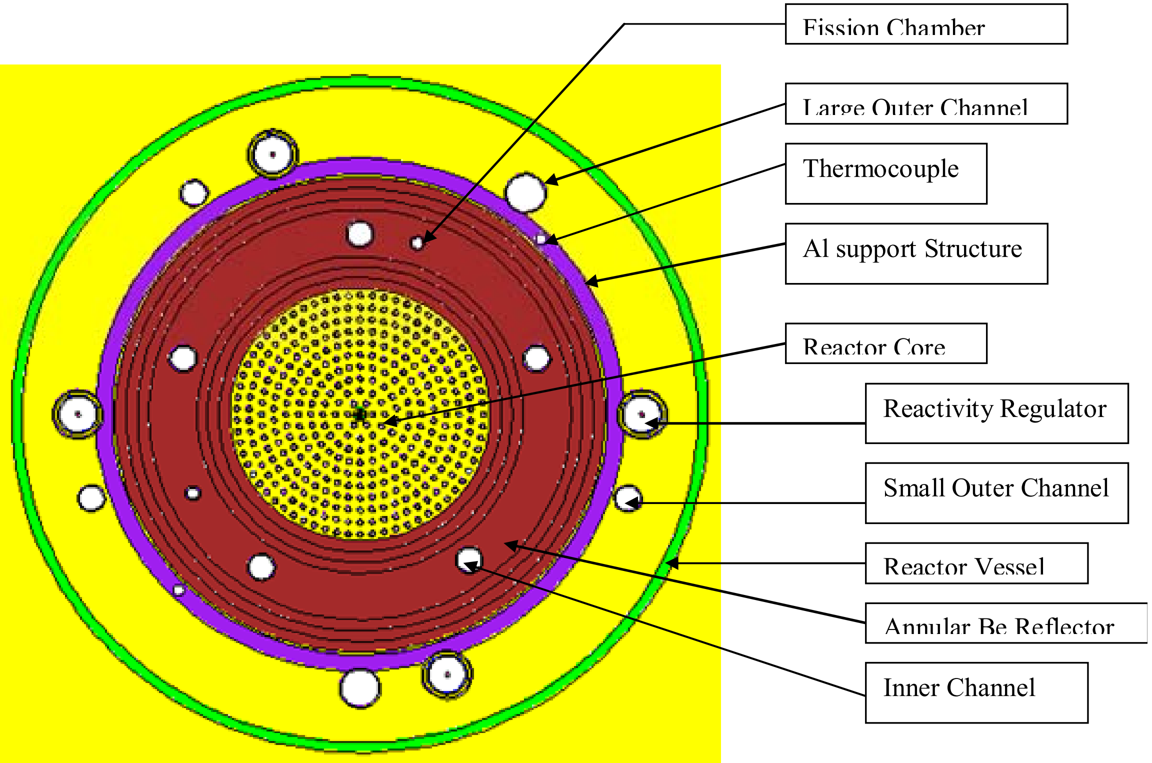
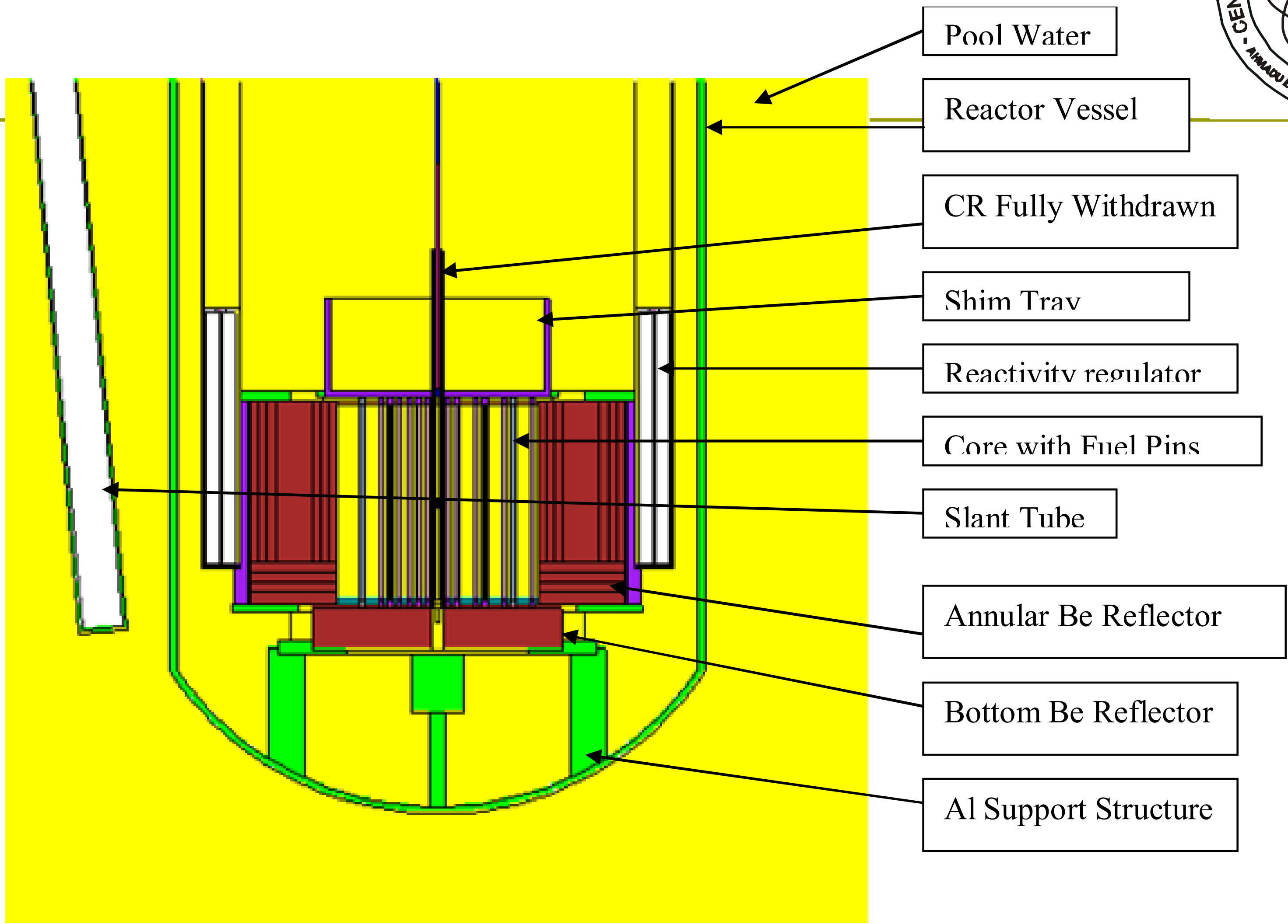
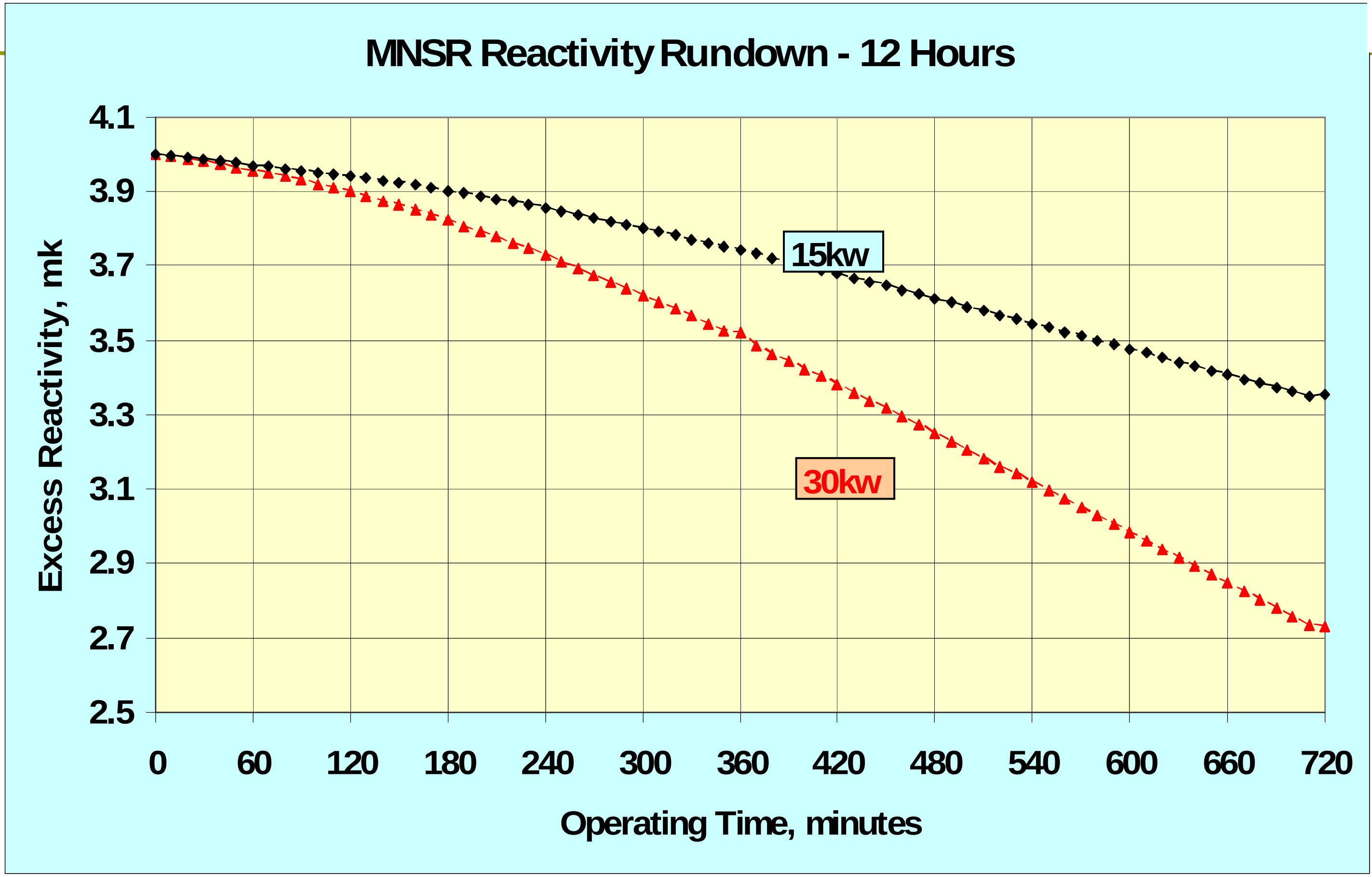
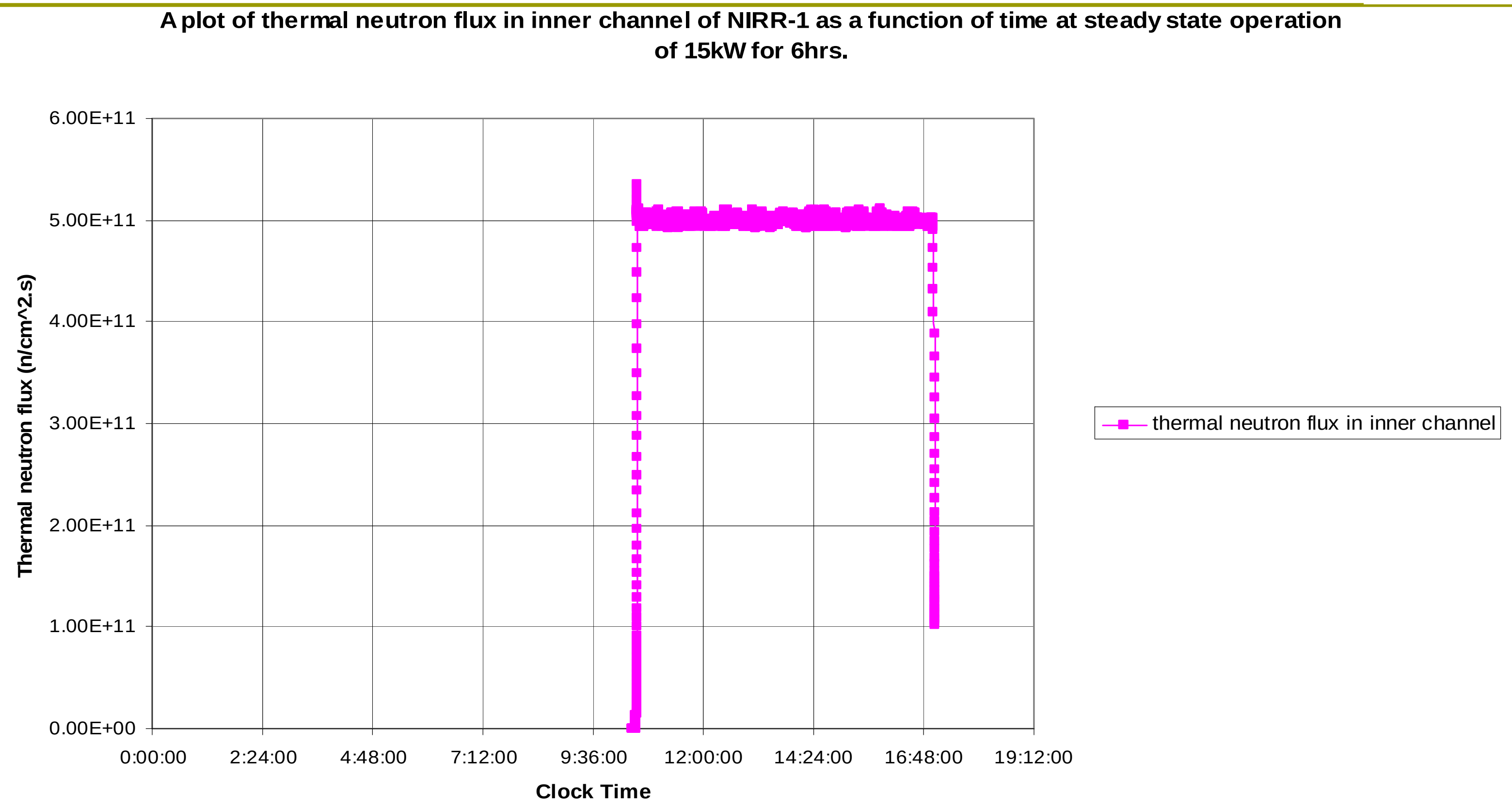


Fig. 1 A geometric diagram of NIRR-1 in the x-y plane from MCNP


Pool Water
Reactor Vessel
CR Fully Withdrawn
Shim Tray
Reactivity regulator
Core with Fuel Pins
Slant Tube
Annular Be Reflector
Bottom Be Reflector
Al Support Structure


MNSR Reactivity Rundown - 12 Hours
4.1
3.9
3.7
3.5
3.3
3.1
2.9
2.7
2.5
Excess Reactivity, mk
0
60
120
180
240
300
360
420
480
540
600
660
720
Operating Time, minutes
15kw
30kw

Modification Attempts-FLUX STABILITY Test



Modification Attempts-SPECTRUM PARAMETERS

parameters	inner		outer	
	A1	B2	A2	B4
ϕ_{th} x10^{11} n/cm^2.s	4.96	4.89	2.40	2.45
ϕ_e x10^{10} n/cm^2.s	2.81	2.55	0.49	0.49
ϕ_f x10^{11} n/cm^2.s	0.96	1.0	0.16	0.17
α	-0.047	-0.52	0.024	0.029
f	18.4	19.2	49.7	48.3
ϕ_{th}/ϕ_f (f_f)	5.2	5.0	15.0	15.5
ϕ_f/ϕ_e (f_e)	3.54	3.84	3.33	3.12
$r(\alpha)\sqrt{T_n/T_0}$	0.0471	0.0459	0.0180	0.0183
T_n, (°C)	52.3	60.6	40.4	44.5

MODULE IV

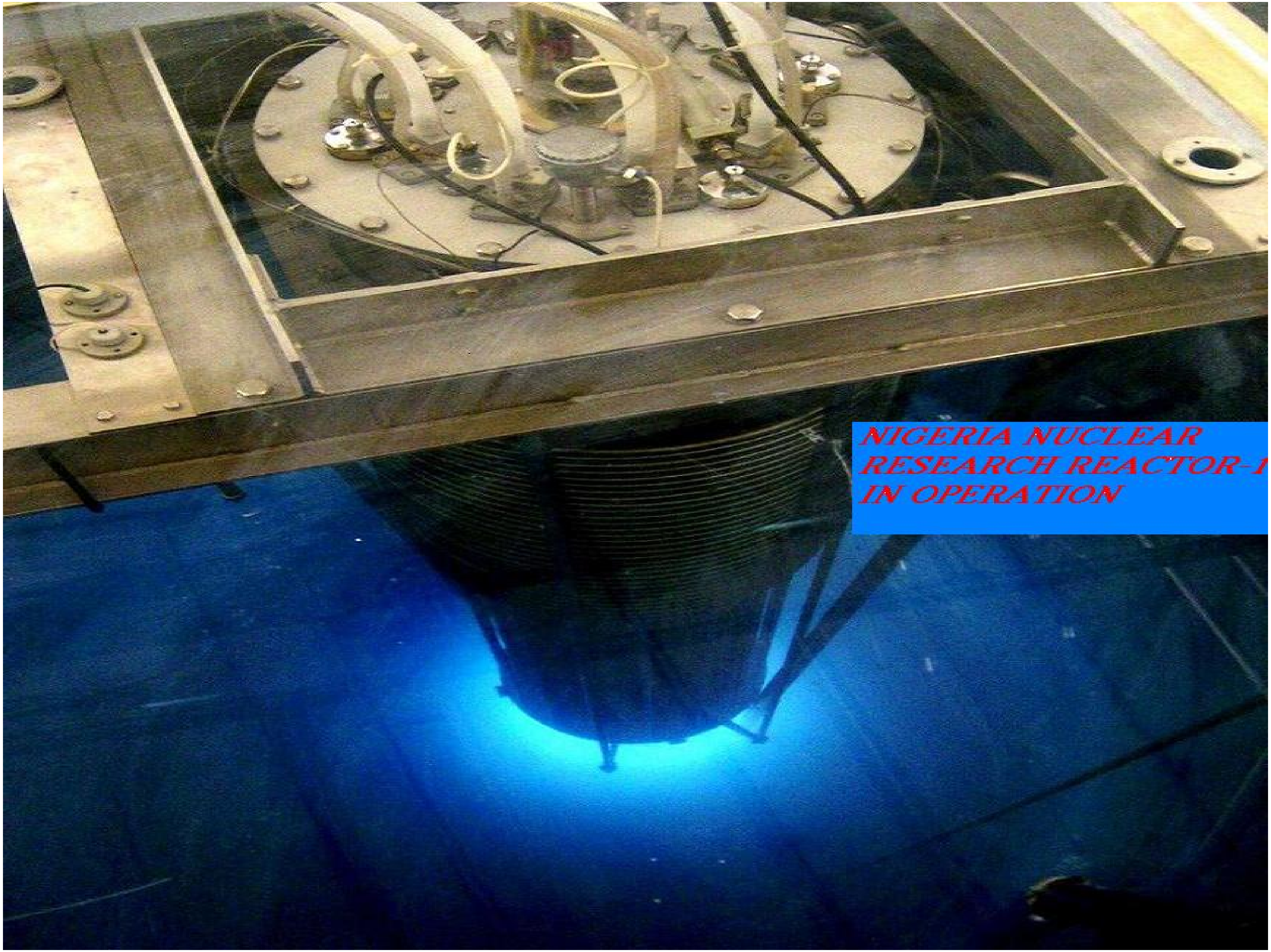
SAFETY

Safety Aspects

- Safe Shutdown:

$\rho_{rod} = 7$ mk; $\rho_{ex} = 3.77$ mk therefore $\rho_{margin} = 3.23$ mk > 2.5 mk

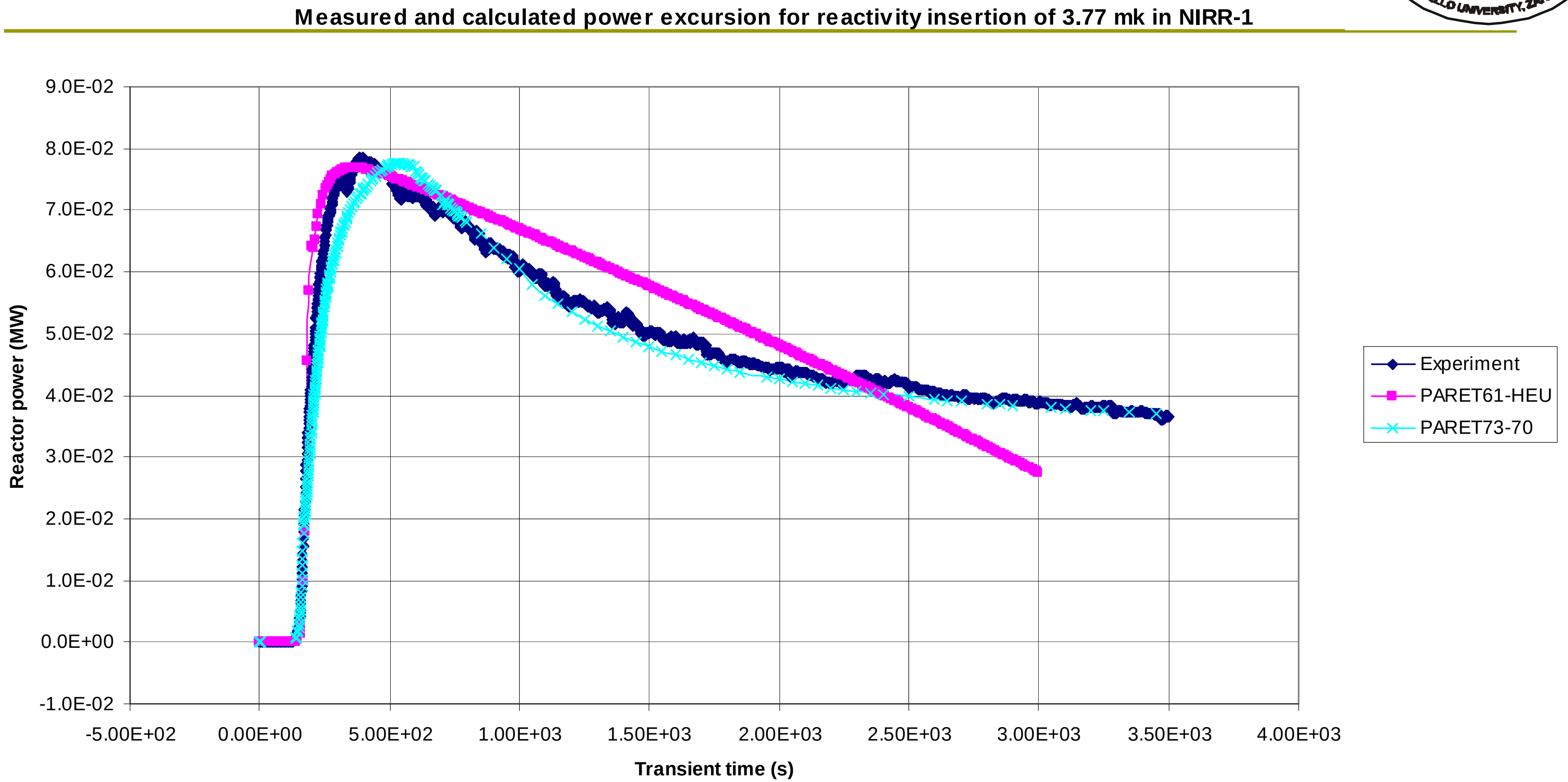
- Emergency shutdown via Cd rabbits and strings
- Residual heat removal via natural circulation and large heat sink
- Low value of $\rho_{ex} = 1/2\beta_{eff}$;
- Defense-in-depth concept (Design)
  - Several barriers to prevent release of radioactivity passive features i.e. natural convection
  - Redundancy
  - Fail safe via in-sufficient circulation
  - Easy access to reactor top-CERT innovation


NIGERIA NUCLEAR
RESEARCH REACTOR-
IN OPERATION

Safety Culture and Accident Scenarios

- Organization and managerial characteristics and attitudes
  - Good working culture has been established
  - Adherence to procedures for operation
  - Adherence to routine preventive maintenance
  - Training programmes
- Most severe is inadvertent release of total ρ_{ex} = 3.77 mk
  - Measured and simulated to be safe
- Fuel rod damage (i.e. DBA), safe for prototype
  - Need to calculate 'source term' for NIRR-1
- Maximum Hypothetical Accident (i.e. BDBA)
  - Collapse of building/ earth quake

Measure and Calculated power excursion for reactivity insertion of 3.77mk



Safeguards and Physical Security

- IAEA Safeguards Inspectors perform criticality tests annually-Core is a sealed type
- The 3 spare fuel pins are well secured and are declared during routine inspection by the IAEA Safeguards Inspectors
- There is a perimeter fence around CERT to ensure physical security
- Surveillance cameras are installed and guards are stationed 24 hours daily
- Comparison of measured and calculated critical depth of insertion as way of ensuring critical loading of the reactor-CERT INNOVATION

MODULE V

OPTIMIZATION

Optimization [Annals of Nuclear Energy 30 (2003) 81-92]

Automating some analysis and design calculations of miniature neutron source reactors at CERT (I)

G.I. Balogun*
Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria

Received 2 January 2002; accepted 8 April 2002 Annals of Nuclear Energy 30 (2003) 81–92

Abstract
Installation of Nigeria's Miniature Neutron Source Reactor (MNSR) has been completed and the facility is awaiting commissioning. The operator organization, Centre for Energy Research and Training (CERT), is therefore embarking on an ambitious project of automating crucial reactor design/analysis calculations with a view to simplifying them for the average reactor engineer or scientist. In this work, we show how the lattice code WIMS and core analysis code CITATION, have been combined in an innovative, interactive Windows environment, to automatically carry out each of the following calculations on MNSRs: Super- or sub-criticality test, control rod worth, core excess reactivity and shutdown margin, locating control rod's critical depth of insertion, control rod calibration, beryllium shims calibration, verification of some safety criteria, modifying core dimensions interactively, modifying beryllium reflectors dimensions interactively and calculating various temperature coefficients of reactivity. Only one CITATION base input data need to be prepared from group constants generated by WIMS and any of these calculations are carried out automatically, thereby eliminating the tedium and errors that usually attend manual data manipulation or regeneration. Consequently, calculations that used to take days may now be more reliably done within minutes.

Efforts in optimization

Annals of Nuclear Energy

The Behavior of Reactor Power and Flux with Changes in Core-Coolant Temperature for a Miniature Neutron Source Reactor

***Y. A. Ahmed, G. I. Balogun, S.A. Jonah, I.I. Funtua**

Reactor Engineering Section, Centre for Energy Research and Training,
Ahmadu Bello University, Zaria, Nigeria

*Correspondence Author. E-mail: yaahmed1@gmail.com

ABSTRACT

The paper establishes the behavior of reactor power and flux parameters with changes in core inlet temperature (T_{in}) and temperature difference (ΔT) of the Nigeria Research Reactor-1 (NIRR-1), which is a miniature neutron source reactor. Our result shows that there is a strong dependence of the reactor power on coolant temperature. Except at isolated points, the semi-empirical relationship between these parameters was found to be accurate to within 1.1%. The relationship was therefore used to predict the power level of NIRR-1 from its neutron flux parameters to which it has been found to be directly proportional. The variation of T_{in} and ΔT with the reactor power and flux was investigated and the results obtained are hereby discussed.

Efforts in optimization

Comparative study of Prototype and Commercial low power Miniature Neutron Source Reactors

*Y.A., Ahmed[1,2], M. Johri[2,3], T. Bezboruah[2,4], H. Gabdo[5], I.O.B. Ewa[1], I.M. Umar[1], I.I. Funtua[1]

[1]*Associates Office, Enrico Fermi Building, The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste 34014, ITALY.*

[2]*Centre for Energy Research and Training, Ahmadu Bello University, PMB 1014, Zaria, NIGERIA*

[3]*Department of Physics and Electronics, DAV College, CSJM University, Kanpur-208001, UP, INDIA*

[4]*Department of Electronics Science, Gauhati University, Guwahati-781014, Assam, INDIA*

[5]*Physics Department, Federal College of Education, Yola, NIGERIA.*

*Correspondence Author: Email: yaahmed1@gmail.com

Tel.: +234 80 36913646; Fax: +234 69 550737

PACS: 28.50.-k; 28.50.Dr; 28.41.Ak

ABSTRACT

Relative to its prototype in China, the commercial Miniature Neutron Source Reactor (MNSR) is designed with hydrogen to uranium-235 ratio reduced from 240 to 197 in its fuel lattice. This is done to enhance the reactor’s life span, improve safety, and ensure a relatively higher negative temperature coefficient of reactivity. To study flux behavior of the commercial MNSR, the neutron flux parameters in the inner and outer irradiation channels of Ghana Research Reactor-1 (a commercial low power MNSR) are measured. The result obtained here and the ones reported in literature (when compared) shows that the prototype in China has higher flux parameters than its commercial type. This reveals that the latter has better thermalization than the former, which is in agreement with the 1:1 zero-power audit experimental results for the MNSR.

Efforts in optimization

Optimization of Compton Suppression Spectrometer for Application in Neutron Activation Analysis

Y.A. Ahmed[1,2*], S. Landsberger[2], P. Gray[2], J.D. Baristed, D.J. O'Kelly[2], I.O.B. Ewa[1], I.M. Umar[1]
[1]Centre for Energy Research and Training, Ahmadu Bello University, Zaria, NIGERIA
[2]Nuclear Engineering Teaching Lab., University of Texas at Austin, Texas 78712, USA
*Correspondence Author, Email: yaahmed1@gmail.com

Abstract

The present study determines the Compton Suppression Factors (SF) and Compton Reduction Factors (RF) of the University of Texas at Austin's Compton suppression spectrometer as parameters characterizing the system performance. The factors were determined using ^{137}Cs and ^{60}Co point sources. The system performance was evaluated as a function of energy and geometry. The (P/C), A(P/C), (P/T), C_{pl}, and C_e were determined for each of the parameters. The natural background reduction factors in the anticoincidence mode compared to the normal were measured and the effect of that on the detection limit of biological samples was evaluated.

To test for the applicability of the spectrometer and the method developed to biological samples, twenty four elements (Ba, Sr, I, Br, Cu, V, Mg, Na, Cl, Mn, Ca, Sn, In, K, Mo, Cd, Zn, As, Sb, Ni, Rb, Cs, Fe, and Co) commonly found in food, milk, tea and tobacco items were determined from seven National Institute for Standards and Technology (NIST) certified reference materials (Rice flour, Oyster tissue, Non-fat powdered milk, Peach leaves, Tomato leaves, Apple leaves, and Citrus leaves). Our results shows good agreement with the NIST certified values, indicating that the method developed in the present study is suitable for simultaneous determination of these elements in biological samples without undue interference problems. Following this success, further research is now ongoing for the determination of macro and micro nutrients and toxic elements in the Nigerian food and tobacco samples using this spectrometer.

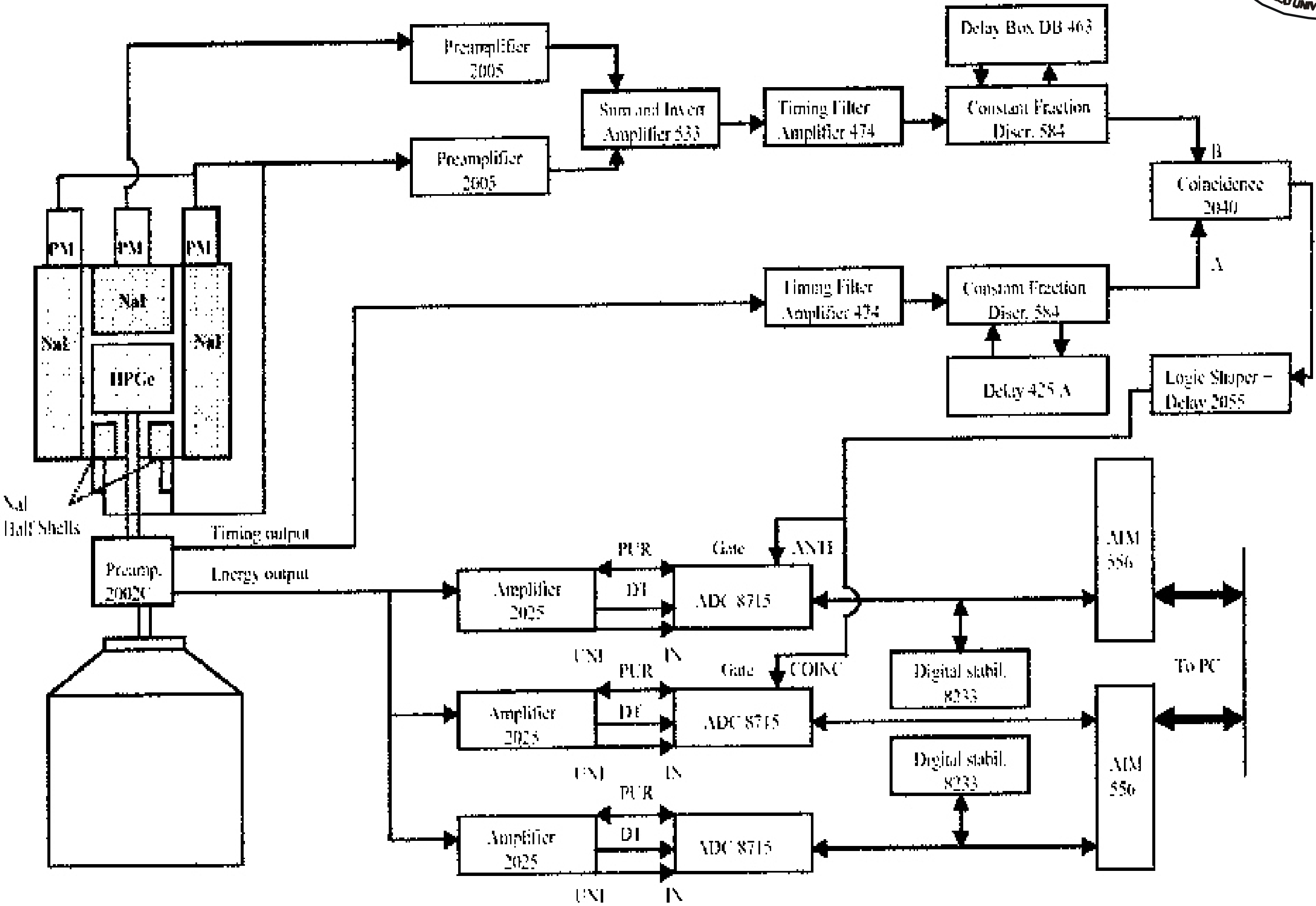
Activation Problems

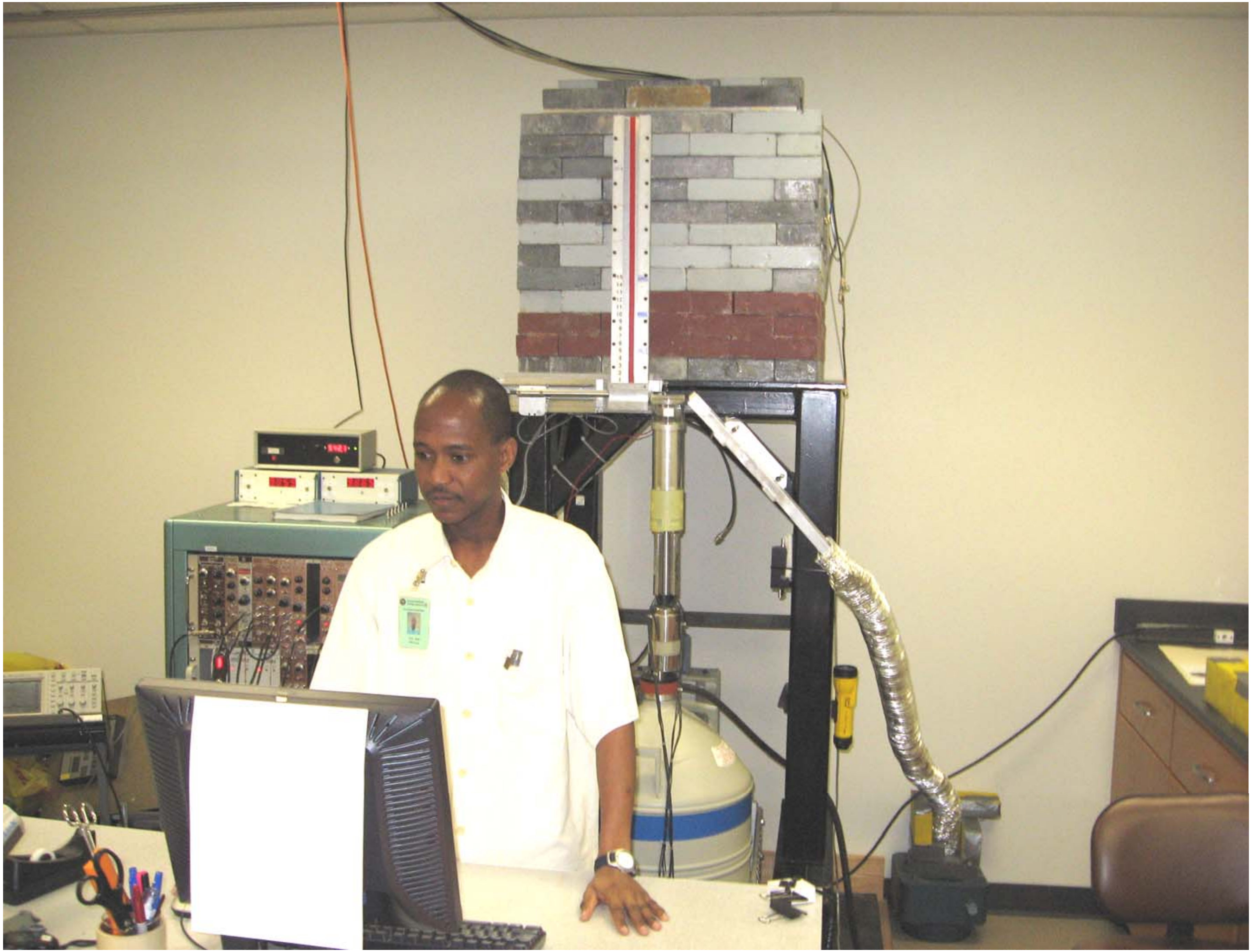
- Interference from Compton plateau of high-energy γ-rays
  - Hampers identification of nuclides with lower energy
  - Increases number of counts in background
  - Unreliable peak integration in lower energy region
  - Leads to poor detection limits due to:
    - Poor background reduction
    - Sum and Escape peaks
- Better detection limits can only be achieved if:
  - Irradiation conditions are optimized
  - Detector parameters are well measured
  - Counting geometry is evaluated
  - Advantage Factors are considered
  - Matrix effects are avoided

How do we go about it?

- Compton suppression spectrometry GIVES BETTER DETECTION:
  - Solve interference problem of Compton plateaus
  - Introduce ten folds reduction in the background of measurement
  - Yield superior photo peak resolution especially in lower energy
  - Gives good photo peak efficiency in full-energy peaks
- Important things to achieve:
  - Elimination of overlapping peaks
    - Suppression of coincident γ-rays
  - Reduction of background
    - for strongly coincident gamma rays
  - Removal of peak interferences
    - help peak fitting routines

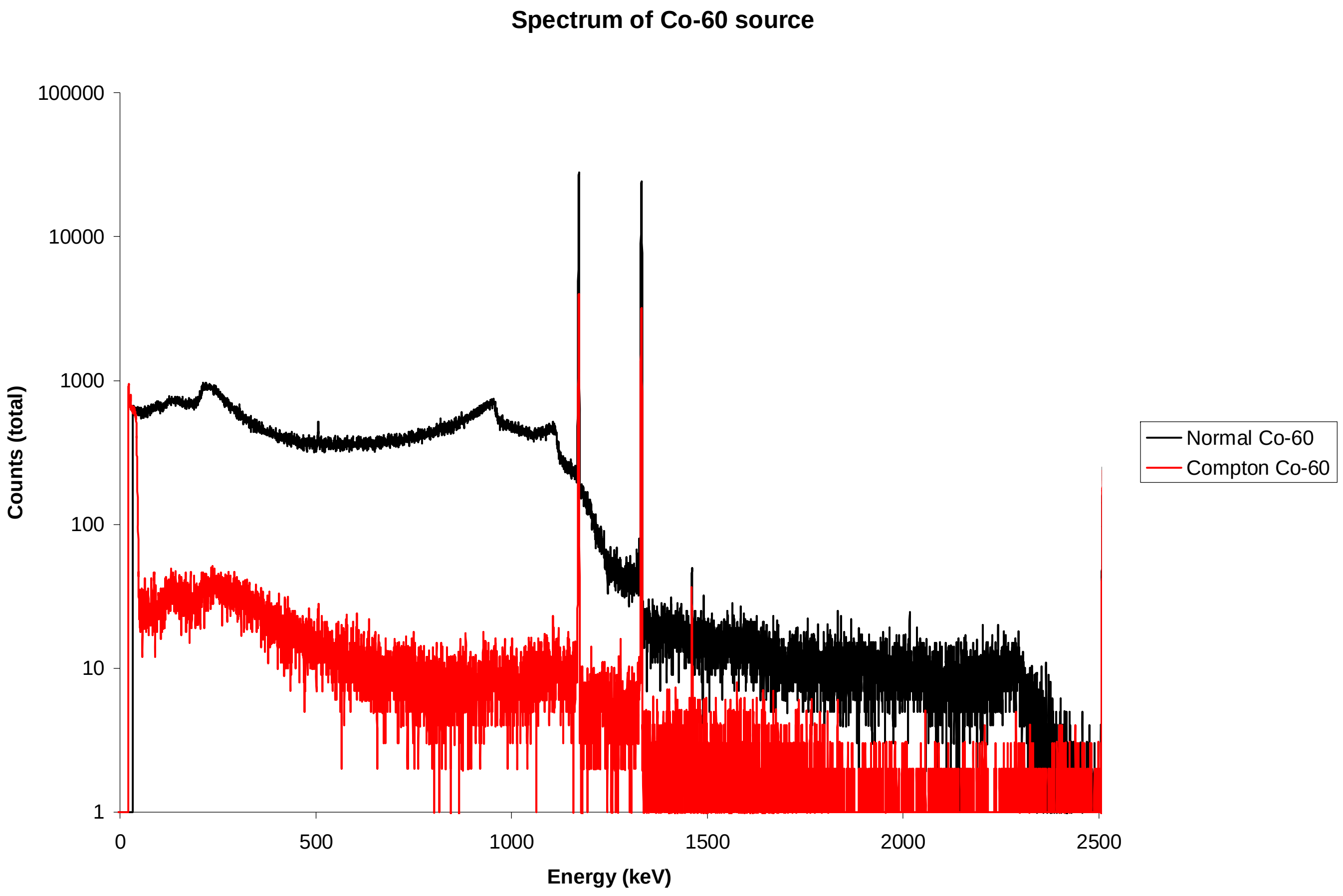
Compton Suppression Spectrometry System





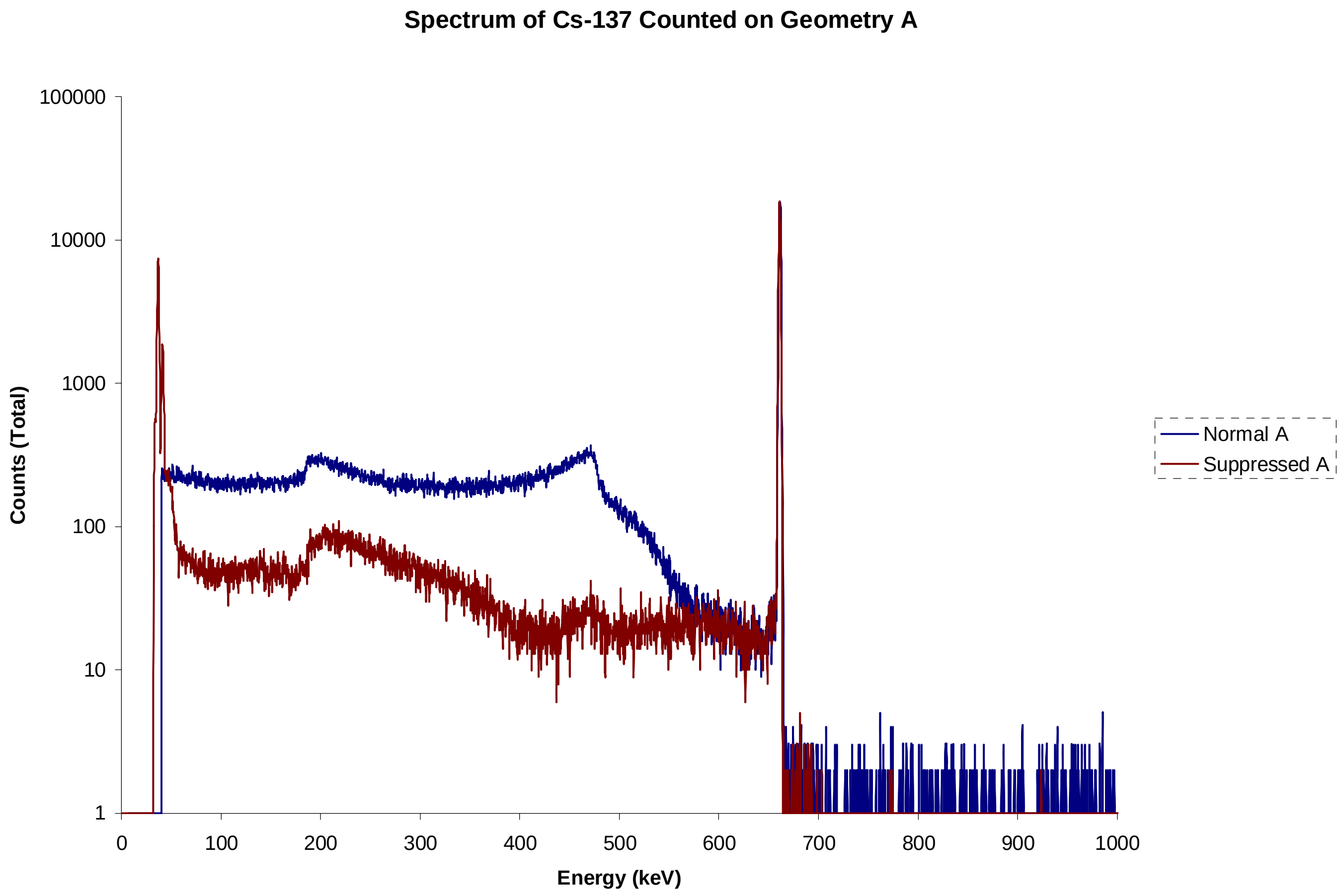
SUPPRESSED COMPTON SPECTRA (thermal)

Red=suppressed Black=normal peak



SUPPRESSED COMPTON SPECTRA (epithermal)

Brown=suppressed Blue=normal peak



RESULTS (I)
CS Performance parameters

Parameter	*Landsberger 94, 96*	*Masse 96*	*Wahl 96*	*Lin 97*	*Parus 2003*	*This work 2006*
^{137}Cs						
SF_b (191-210)	2.9	5.2	4.0	4.2	4.3	3.95
SF_{Pl} (350-370)	4.6	10.0	8.0	8.7	7.7	5.44
SF_e (471-470)	7.9	12.6	12.0	10.2	11.9	11.3
P/C_e (471-470)	800	670	804	---	859	644.17
^{60}Co						
RF (50-60)	---	---	---	18.0	25.1	20.78
RF (100)	---	23.0	---	18.8	25.5	23.97
RF (200-210)	---	19	---	15.6	25.2	24.45
RF (600)	---	31.0	30.0	22.8	31.4	31.70
RF (950-960)	44.0	45.0	32.0	30.0	56.1	77.70
RF (1110)	29.0	32.0	28.0	17.6	40.1	53.07
1173 Peak Red.	6.2	---	7-8	4.2	5.2	6.94
1333 Peak Red.	6.7	---	7-8	4.5	5.7	7.59

RESULTS (II)
Geometry

Geom.	Height (cm)	Normal P/C	Suppressed P/C	Suppression Factor
A	1.43	89.1	393.9	4.420875
B	2.86	73.6	382.3	5.194293
C	4.92	80.93	310.9	3.841591
D	8.89	61.32	250.81	4.090183

RESULTS (III) Detection Limits

Nuclide	This work	Detection Limit	Certificate (NIST)
Mg-27	0.26 ± 0.008	0.015	0.27 ± 0.008
Na-24	29.0 ± 4.000	13	24.4 ± 1.2
Al-28	291.8 ± 3.400	2.2	286 ± 9.0
Mn-56	48.1 ± 1.000	1.0	54.0 ± 3.0
Cl-38	575 ± 10.000	9.0	579.0 ± 23.0
Ca-49	1.4 ± 0.021	0.75	1.5 ± 0.015

Did we achieve Optimization?

- YES….in addition to lowering background and reducing detection limits:
  - Elimination of severely interfering peaks
    - 279 keV of Se-75 from 279 keV of Hg
    - 1115 keV of Zn-65 improved due to suppression of overlapping 1120keV of Sc-46 which is in coincidence with 889keV peak
    - 1112 keV of Eu-152 also suppressed due to its coincidence with other peaks
  - Reduction of peak overlaps
    - Helps software better resolve multipletes
    - Background continuum is less complex in shape
    - Peak fitting routines simplified

And what again?

- Removal of interfering nuclides in the epithermal region
  - Reduction of high Compton background
  - Reduced cross-section in ePNT for Na, Cl, Al
    - Reduction of background from 1642, 2167keV of Cl-38
      - 1368, 2754kev of Na-24.
    - Reduction of double escape 620keV from 1642keV of Cl-38
      - since it is in coincidence with 2167keV peak
  - Easier determination of Br,I,Zn,Sb,Sn,As etc (high resonance cross-section)

Publications on optimization

Nucl Instr Meth Phy Res

Performance of Compton Suppression Method in the Analysis of Food and Beverages

***Y.A. Ahmed[1], S. Landsberger[2], D.J. O'Kelly[2], J.D. Braisted[2], I.O.B. Ewa[1], I.M. Umar[1], I.I. Funtua[1]**

[1]Centre for Energy Research and Training, Ahmadu Bello University, Zaria, NIGERIA

[2]Nuclear Engineering Teaching Lab., University of Texas at Austin, Texas 78712, USA

*Correspondence Author, Email: yaahmed1@gmail.com

Abstract

Applicability and performance of Compton suppression method in the analysis of food and beverages was re-established in this study. Using ^{137}Cs and ^{60}Co point sources Compton Suppression Factors (SF), Compton Reduction Factors (RF), Peak-to-Compton ratio (P/C), Compton Plateau (C_{pl}), and Compton Edge (C_e) were determined for each of the two sources. The natural background reduction factors in the anticoincidence mode compared to the normal mode were evaluated. The reported R.F values of the various Compton spectrometers for ^{60}Co source at energy 50-210 keV (backscattering region), 600 keV (Compton edge corresponding to 1173.2 keV gamma-ray) and 1110 keV (Compton edge corresponding to 1332.5 keV gamma-ray) were compared with that of the present work. Similarly the S.F values of the spectrometers for ^{137}Cs source were compared at the backscattered energy region ($S.F._b$ = 191-210 keV), Compton Plateau ($S.F._{pl}$ = 350-370 keV), and Compton Edge ($S.F._e$ = 471-470 keV) and all were found to follow a similar trend. We also compared peak reduction ratios for the two cobalt energies (1173.2 and 1332.5) with the ones reported in literature and the two results agree well. Applicability of the method to food and beverages was put to test for twenty one major, minor, and trace elements (Ba, Sr, I, Br, Cu, V, Mg, Na, Cl, Mn, Ca, Sn, K, Cd, Zn, As, Sb, Ni, Cs, Fe, and Co) commonly found in food, milk, tea and tobacco. The elements were assayed using five National Institute for Standards and Technology (NIST) certified reference materials (Non-fat powdered milk, Apple leaves, Tomato leaves, and Citrus leaves). The results obtained shows good agreement with NIST certified values, indicating that the method is suitable for simultaneous determination of micro-nutrients, macro-nutrients, and heavy elements in food and beverages without undue interference problems.

Publications on optimization JRNC

Determination of Nutrients and Heavy Metals in Nigerian Food and Beverages by Compton Suppression Method and Epithermal NAA

Y.A. Ahmed[1*], S. Landsberger[2], D.J. O'Kelly[2], J. Braisted[2], I.O.B. Ewa[1], I.I. Funtua[1], I.M. Umar[1]

[1]Centre for Energy Research and Training, Ahmadu Bello University, Zaria, NIGERIA
[2]Nuclear Engineering Teaching Lab., University of Texas at Austin, Texas 78758, USA
*Correspondence Author, Email: yaahmed1@gmail.com

Abstract

Compton suppression method and epithermal neutron activation analysis were used concurrently to determine the concentration of nutrients and heavy metals in Nigerian food and beverages. The use of the Compton suppression method has reduced interferences from Compton scattered photons thereby allowing easy evaluation of Na, Cl, *Ca, Cu, Mn, Mg, Co, Cr, Rb, Fe, and Se*. The application of epithermal NAA has cut off fission neutrons interference enabling the determination of *Cd, As, Ba, Sr, Br*, *I,* and *V.* The work was performed at the University of Texas TRIGA Reactor by short, medium, and long irradiation protocols, using thermal flux of 1.4 x 10^{12} n.cm^{-2}s^{-1} and epithermal flux of 1.4 x 10^{11} n.cm^{-2}s^{-1}. Accuracy of the method was tested by analyzing four Standard Reference Materials (Non-fat powdered milk, Apple leaves, Citrus leaves, and Peach leaves) obtained from National Institute for Standards and Technology. The results show that sorghum, millet, and maize have high values of *Zn, Mn, Fe*, low values of *Cd, As*, and *Se*. Powdered milks, rice, beans, and soybeans were found to have moderate amounts of all the elements. Tobacco recorded high content of *Cd, Mn*, and *As,* whereas tea, tsobo, bowbow leaves, and okro seed have more *As* values than others. However, biscuits, macaroni, spaghetti, and noodles show lower concentrations of all the elements. The distribution of these nutrients and heavy elements in the food and beverages analyzed shows the need to fortify biscuits and pastas with micro and macro nutrients and reduce the use of tobacco, tea, tsobo, bowbow leaves, and Okro to avoid intake of heavy elements.

Acknowledgment

- Professor S. Landsberger, The University of Texas at Austin, USA
- International Atomic Energy Agency Vienna, Austria (Fellowship)
- Nigeria Atomic Energy Commission, Abuja
- Centre for Energy Research and Training, Zaria
- Ahmadu Bello University, Zaria
- Professor S.A. Jonah, (R.M. NIRR-1) Zaria

THANK YOU