ACR PHYSICS TESTS IN ZED-2

By Mike Zeller, Experimental Section Head,
Reactor & Radiation Physics Branch,
Chalk River Laboratories,

US NRC Work Shop Meeting on ACR at Chalk River,
December 4-5, 2002

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Presentation Outline

- Preliminary comments about the ZED-2 experimental program in support of ACR
- List experiments to be performed plus physics phenomena addressed by activity
- As each experiment is listed a brief description of the basic procedure plus analysis will be included

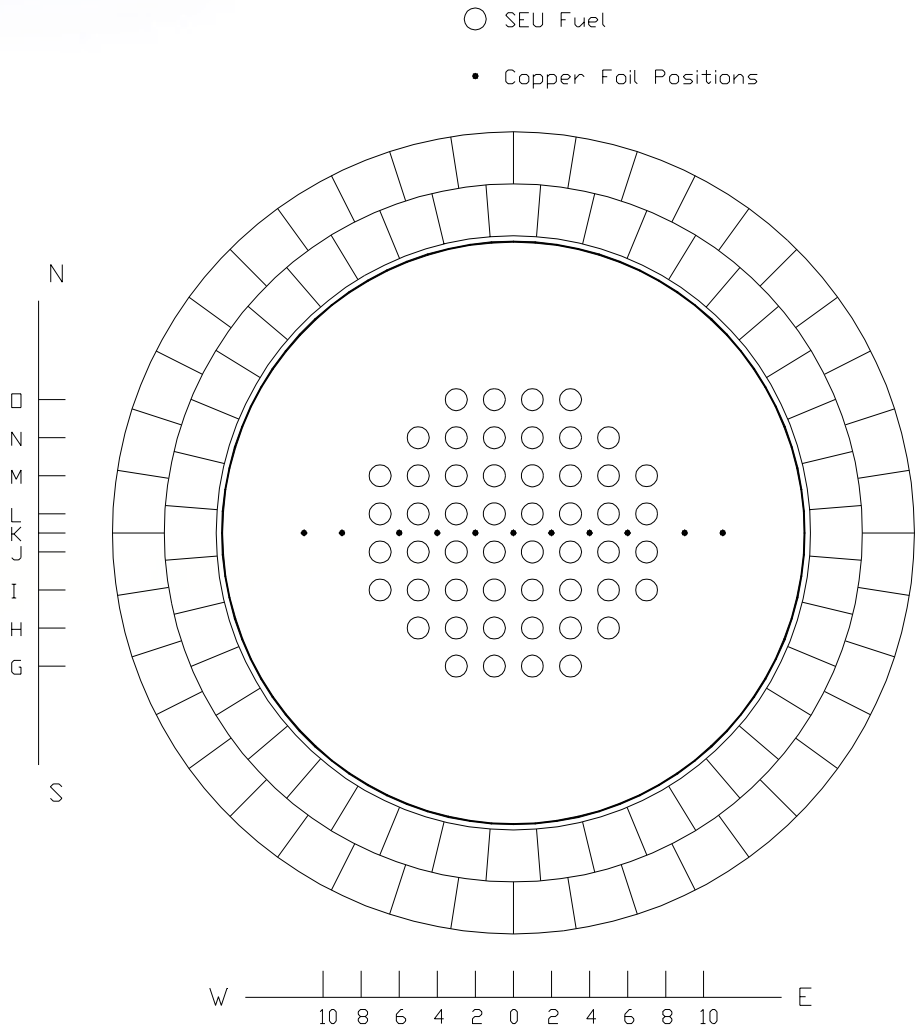
Preliminary Comments

- ZED-2 (Zero Energy Deuterium reactor)
- Maximum power is 200 Watts (nominal)
- This corresponds to an average neutron flux of about 10^9 neutrons cm^{-2} s^{-1}
- Standard fuel charge for the ACR program is 300 CANFLEX bundles containing SEU
- Data obtained are to validate physics codes and associated nuclear data libraries used for design and licensing ACR

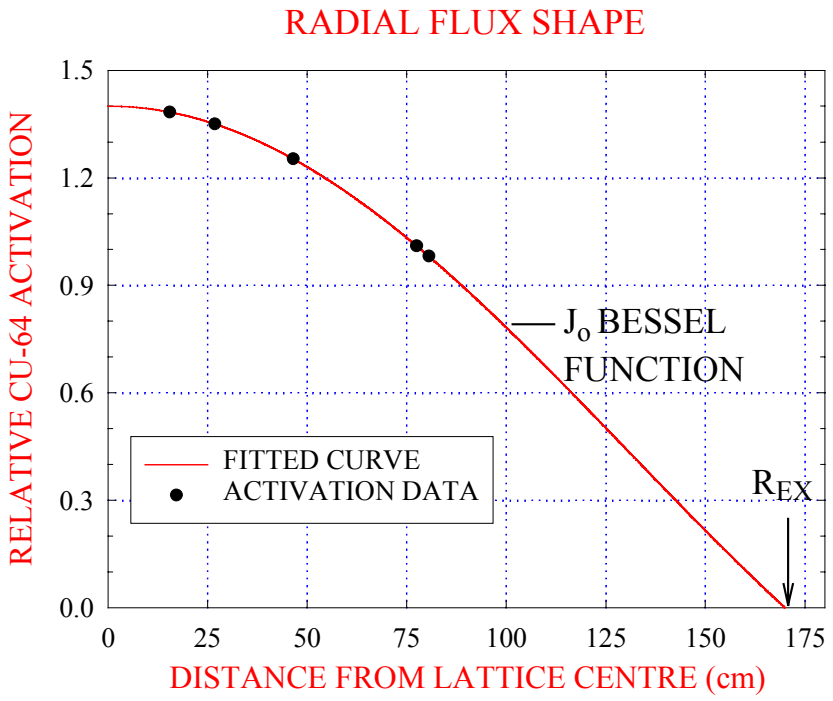
Flux Map Experiments

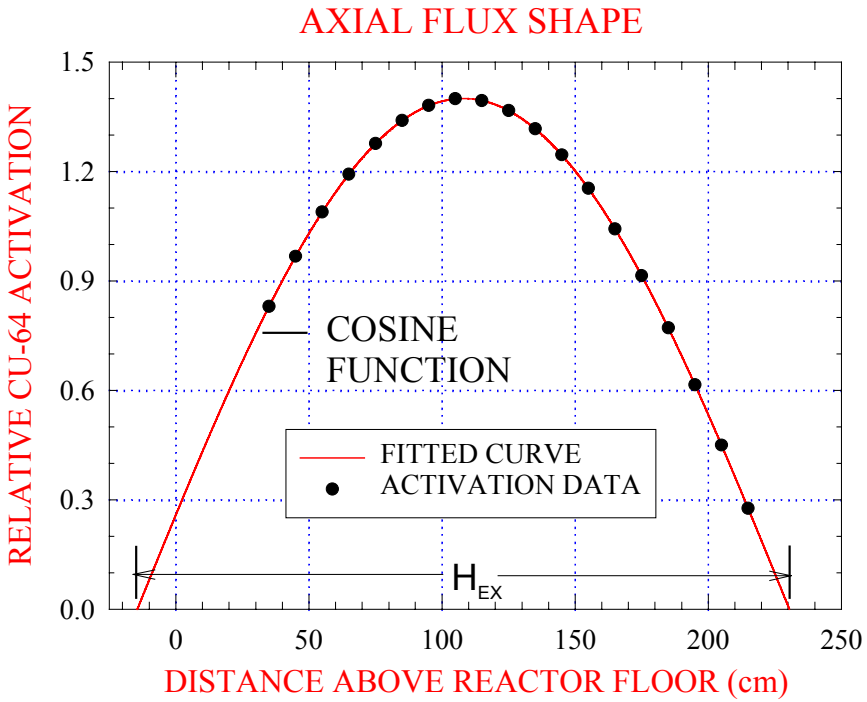
- These experiments provide validation data related to lattice reactivity and coolant void reactivity (CVR)
- Physics Phenomena (PH0 PH1)
- Measurements are performed by positioning activation foils across a lattice of SEU
- The reactor is operated to activate the foils and the foils are counted to determine the global flux distribution across the lattice
- Measurements to be performed at various lattice spacings and at two coolant conditions—H_2O and air

Flux-Map Set Up



ANALYSIS



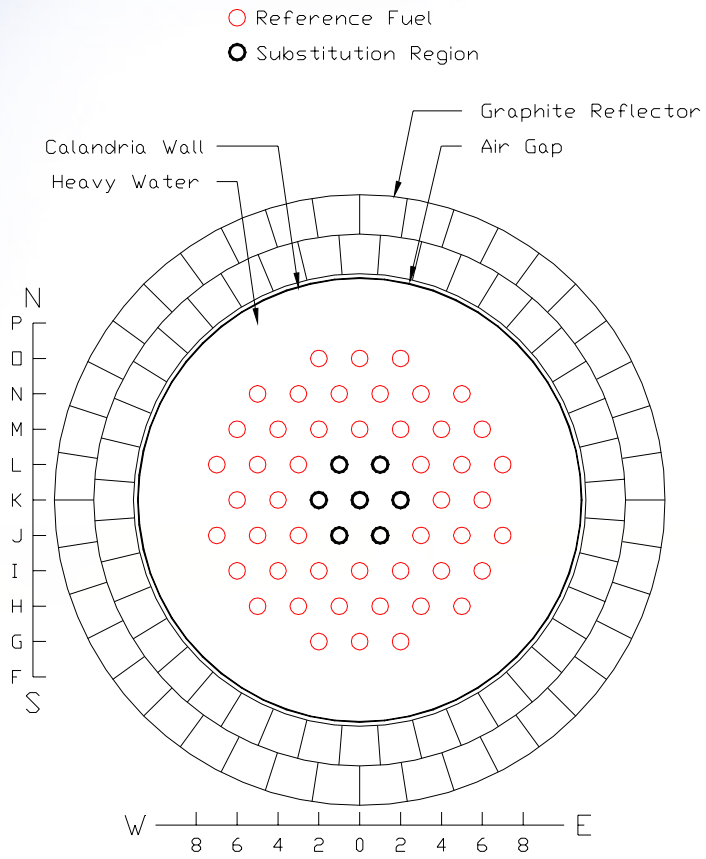


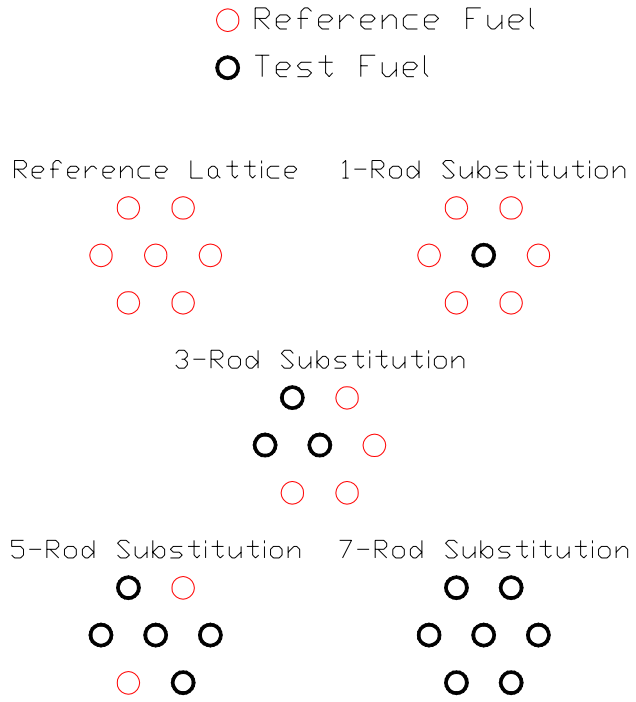
$$\text{Buckling} = (2.405/R_{EX})^2 + (\pi/H_{EX})^2$$

SUBSTITUTION EXPERIMENTS

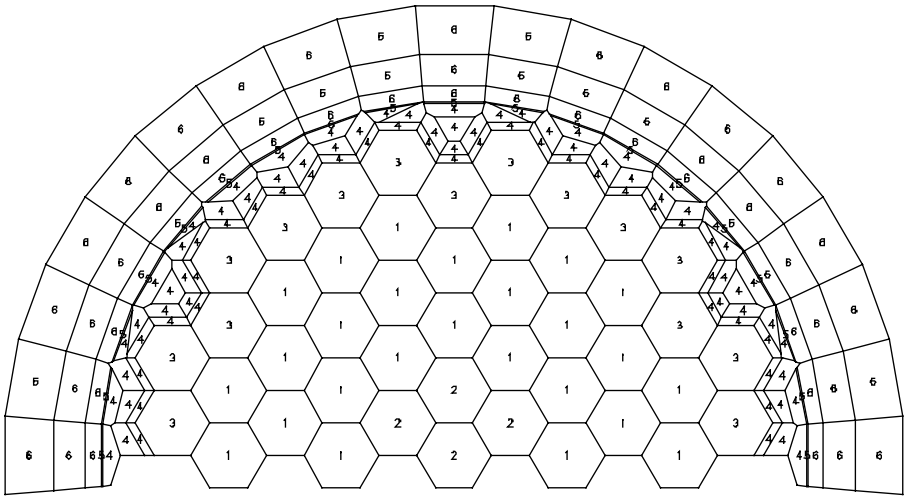
- These experiments provide validation data related to lattice reactivity and CVR for simulated irradiated fuel
- Physics Phenomena (PH0 PH1 PH8)
- The simulated irradiated fuel will be a mixed-oxide (MOX) containing Pu and depleted U
- Measurements are performed by systematically replacing reference fuel with test fuel while observing the resulting change in moderator critical height
- Measurements will be performed using two test fuels, SEU and MOX (representing fresh fuel and irradiated fuel) with the test fuel at two coolant conditions

SUBSTITUTION SET UP





ANALYSIS



Legend

Region 1 – Reference Channels

Region 2 – Test Fuel Channels

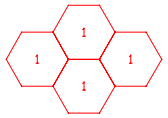
Region 3 – Heavy Water Reflector

Region 4 – Heavy Water Reflector

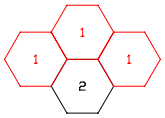
Region 5 – Calandria Wall

Region 6 – Graphite Reflector

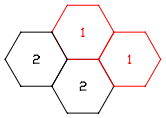
Reference Lattice



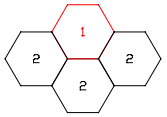
1-Rod Substitution



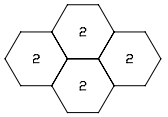
3-Rod Substitution



5-Rod Substitution



7-Rod Substitution

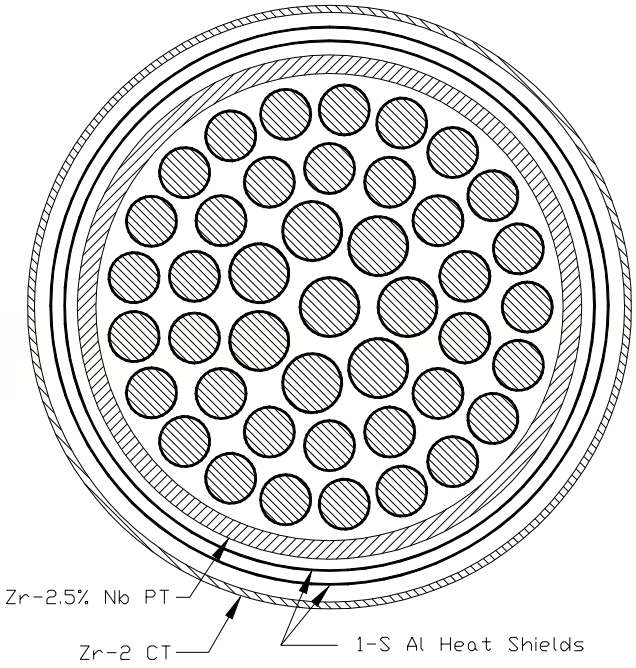


FUEL/COOLANT TEMPERATURE COEFF.

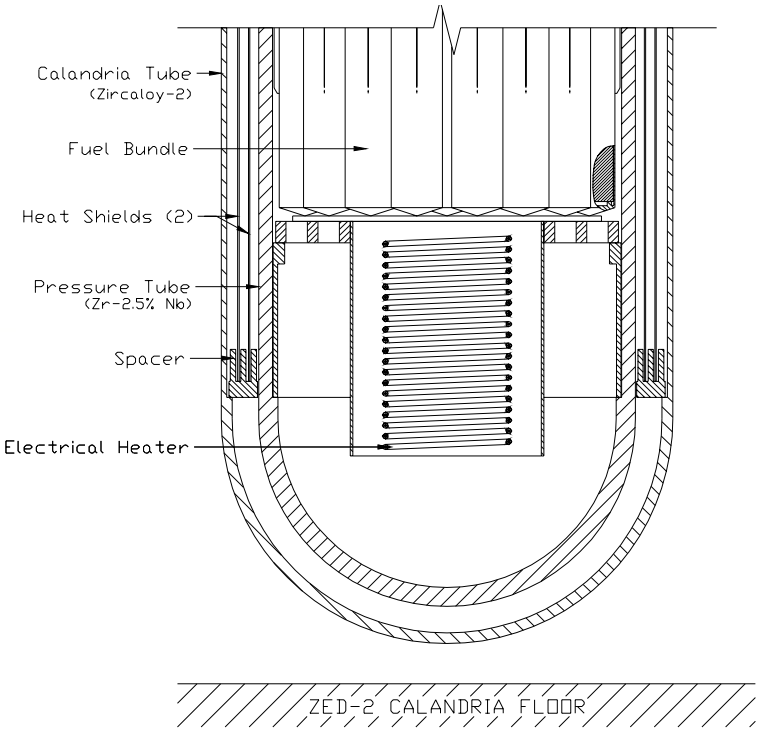
- These experiments provide validation data for fuel-temperature coefficient and the effect on CVR vs channel temperature
- Physics Phenomena (PH0 PH1 PH2 PH7 PH8)
- Measurements are performed in a 7-rod substitution lattice with the test fuel contained in specially modified channels
- Measurements to be performed using both SEU and MOX (fresh fuel and irradiated fuel) and at two coolant conditions

H.T. EXPERIMENTAL SET-UP

PLAN VIEW



BOTTOM SECTION



PROCEDURE AND ANALYSIS

- Channel contents are heated from room temperature to 300°C (572°F)
- As pre-selected temperatures are achieved the reactor is stabilized and the critical height and core conditions are recorded
- For the water-coolant tests a He cover gas is used to suppress boiling
- High pressure CO_2 gas (~500 psi) is used as the convective medium for the fuel-temperature coefficient tests
- A substitution-type analysis is performed using the moderator critical-height data obtained as the channel contents are heated to derive bucklings for the various temperatures and coolant conditions

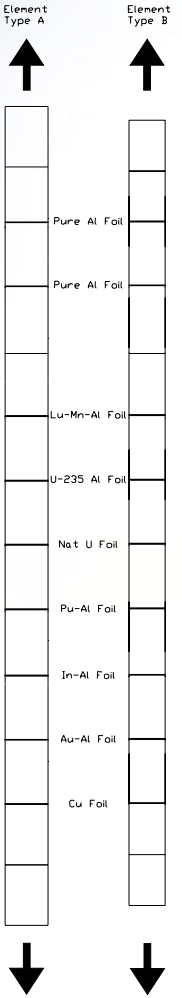
MODERATOR TEMPERATURE COEFFICIENT

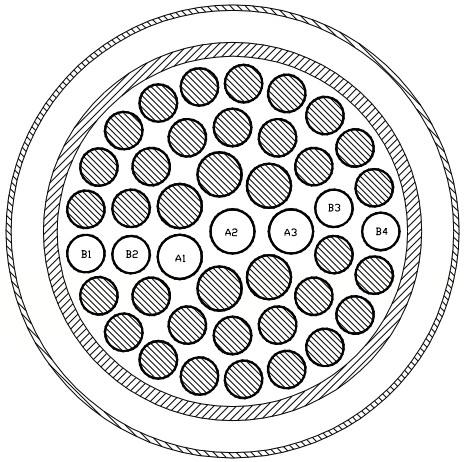
- These experiments provide validation data for the effects on lattice reactivity and (CVR) with moderator temperature
- Physics Phenomena (PH0 PH1 PH3 PH4)
- Flux-map experiments will be performed using SEU lattices at moderator temperatures between room temperature and ~40^{o}C (104^{o}F)

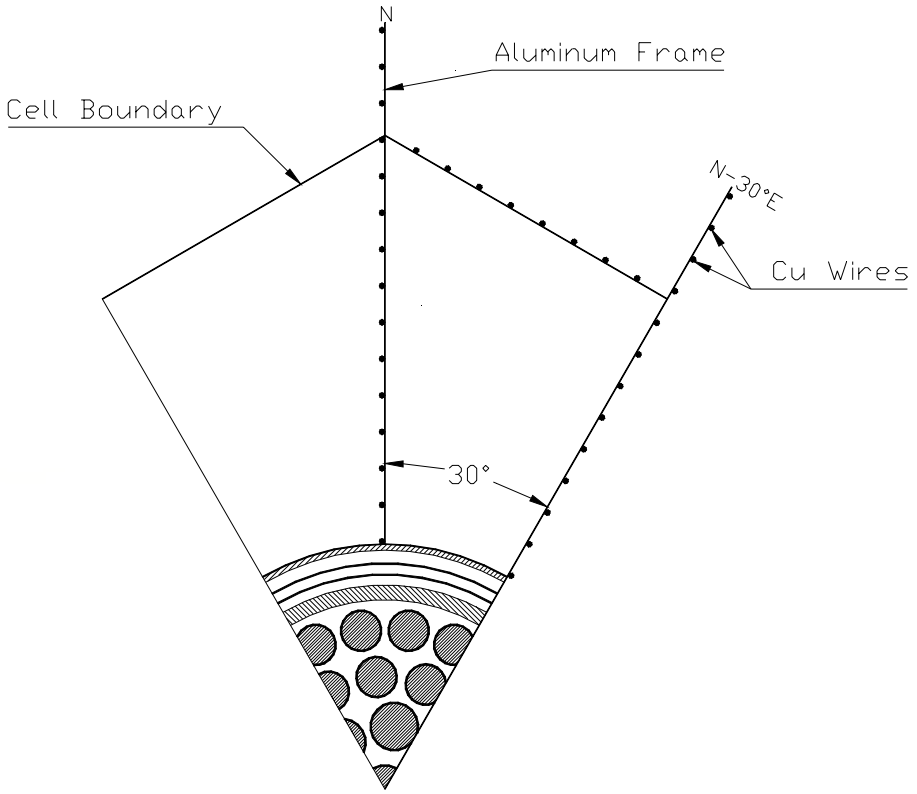
FINE-STRUCTURE REACTION RATES

- These experiments will provide information about detailed neutron distributions in space and energy plus end-flux peaking effects
- Physics Phenomena (PH0 PH1 PH2 PH7 PH14)
- Activation foils are placed between the fuel pellets of a special demountable bundle
- The bundle is positioned in the center location of a seven-rod lattice and the reactor is operated to activate the foils
- Measurements will be done using SEU (fresh fuel) and MOX (simulated irradiated fuel) and at two coolant conditions

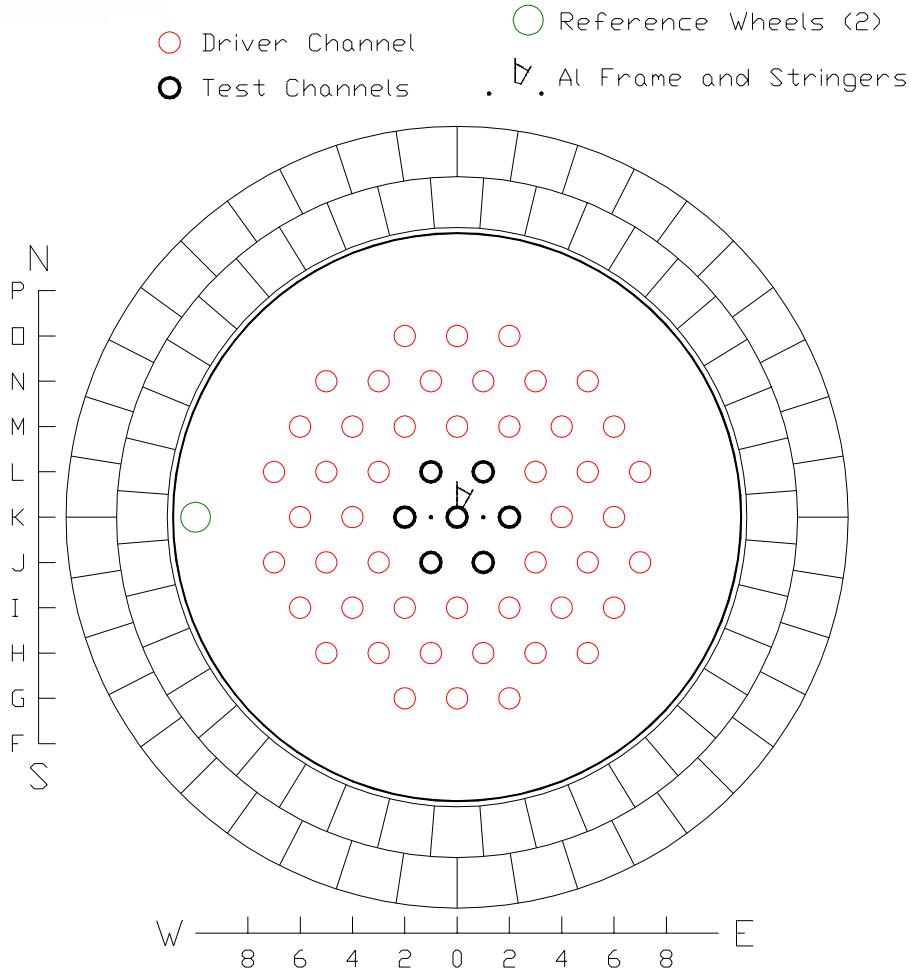
FINE STRUCTURE SET UP



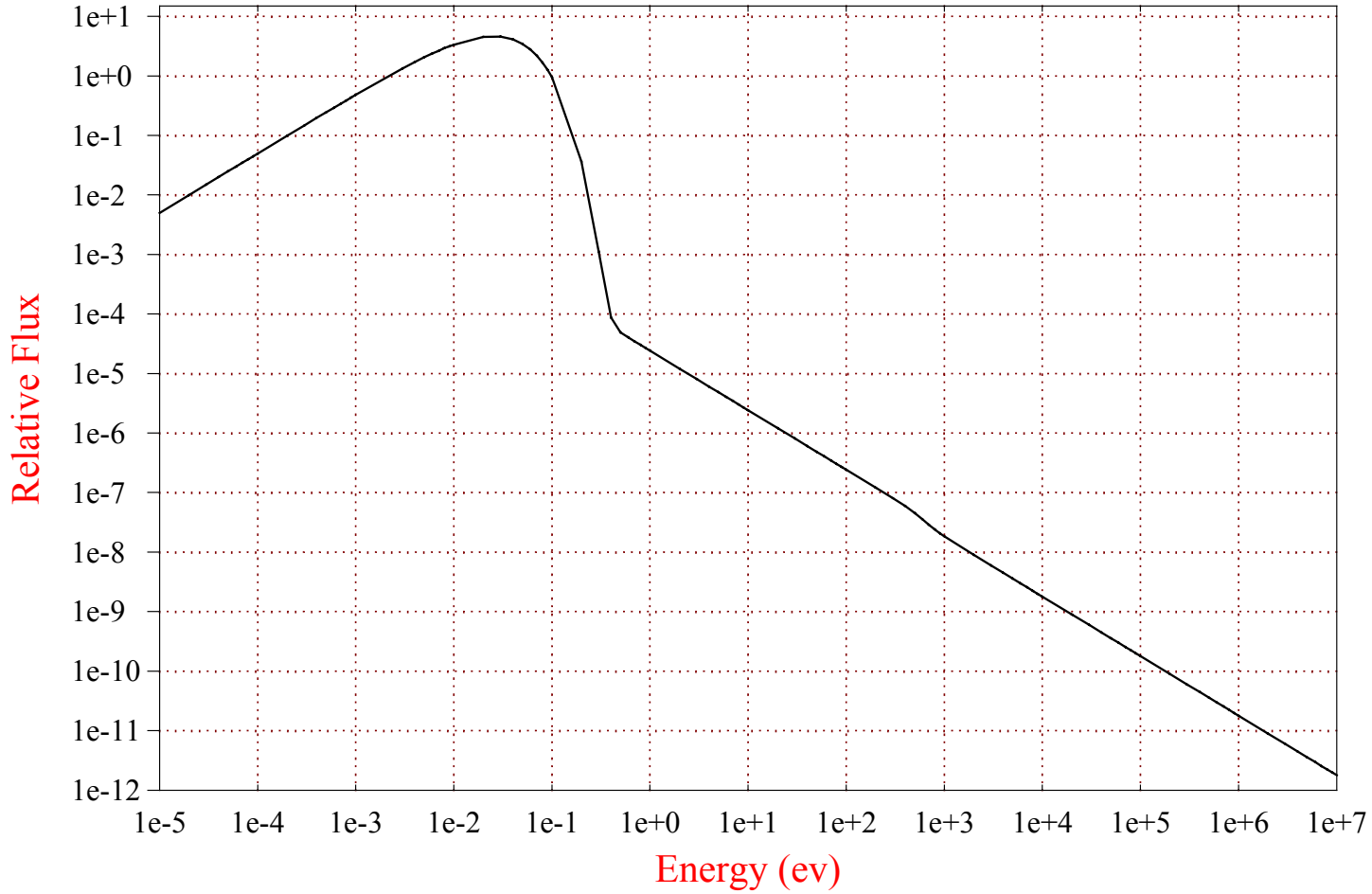




FINE STRUCTURE LATTICE



REFERENCE WHEEL SPECTRUM



ANALYSIS

- U-235, Cu-63, and Mn-55 are approximately 1/V absorbers having only small resonance integrals
- Au-197 and In-115 have large resonances in the epithermal region at 4.916 eV &1.457 eV, respectively
- Pu-239, Lu-176 have large thermal resonances at 0.296 eV & 0.141 eV, respectively
- Reaction-rate ratios (normalized to the reference-wheel spectrum) are sensitive indicators of the energy spectra across the test cell (i.e. Pu-239/U-235 fission, Lu-176/Mn-55 capture, In-115/Cu-63 capture etc.)
- Activation data will be compared directly to lattice cell predictions

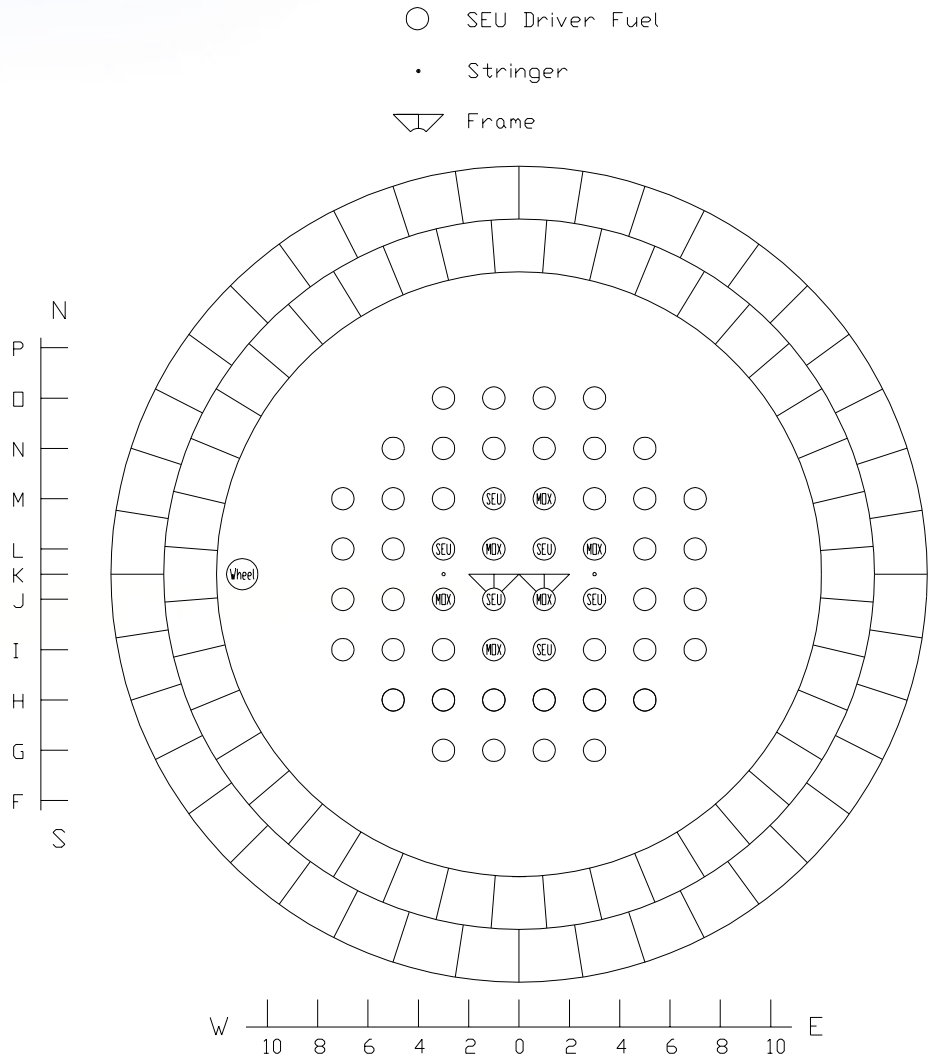
MODERATOR POISON EXPERIMENTS

- These experiments are to provide validation data for the lattice reactivity and void reactivity effect of poisoning the moderator
- Physics phenomena (PH0 PH1 PH3 PH4)
- Flux map experiments will be performed using a SEU lattice with and without poison (e.g. Gd, B) added to the moderator and reflector
- The flux maps will be performed at two moderator temperatures and two coolant conditions

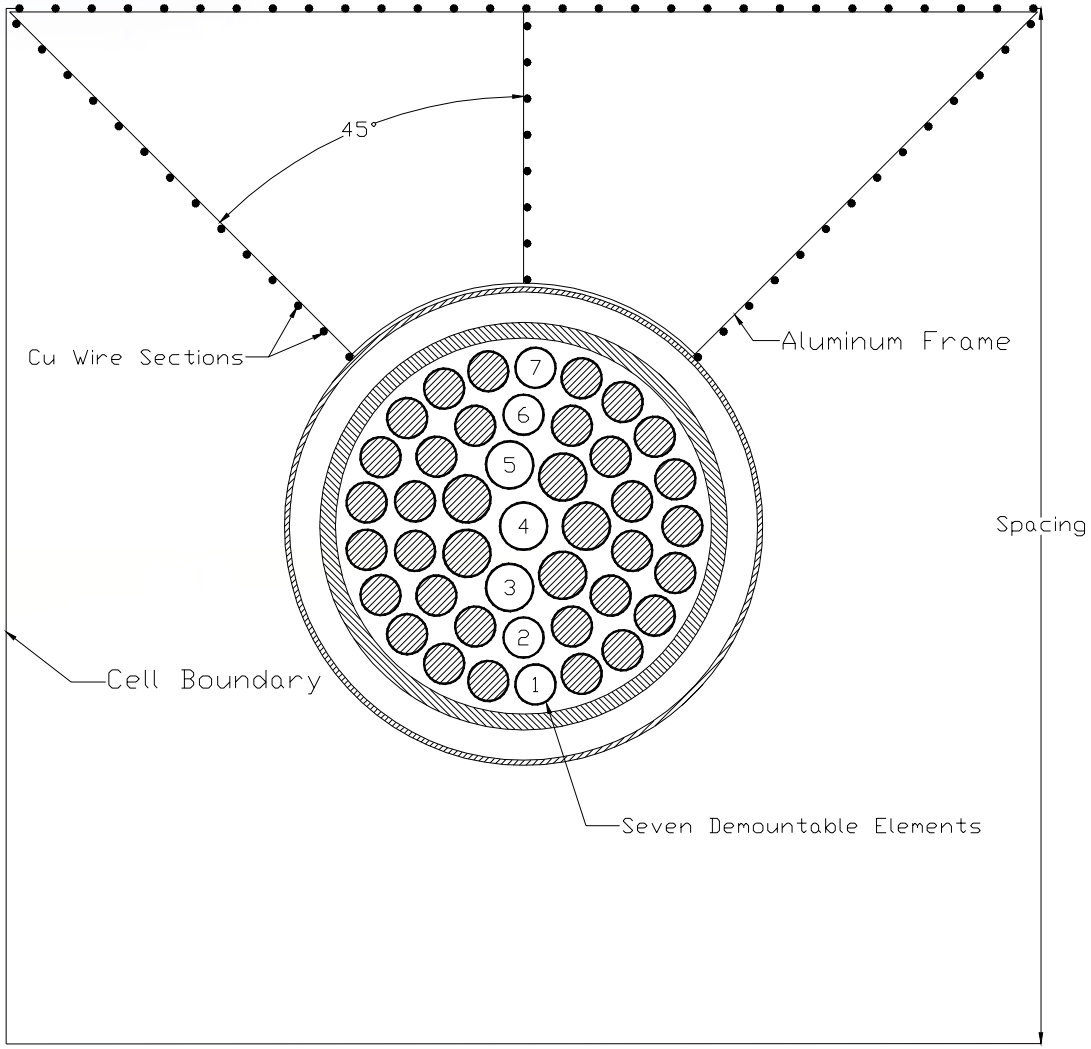
CHECKERBOARD LATTICE MEASUREMENTS

- These measurements are to provide validation data for detailed radial cell-to-cell leakage in an ACR-type lattice representing bi-directional fueling
- Physics phenomena (PH0, PH8, PH14)
- Checkerboard region in the lattice will contain alternating SEU (fresh fuel) and MOX (irradiated fuel) channels
- Measurements will use various coolant conditions in the checkerboard region (e.g. all channels cooled, SEU cooled MOX voided, SEU voided MOX cooled, etc.)

CHECKERBOARD LATTICE



TEST CELLS


45°
Cu Wire Sections
Aluminum Frame
7
6
5
4
3
2
1
Spacing
Cell Boundary
Seven Demountable Elements

ANALYSIS

- Activation data will be compared directly to lattice-cell calculations and diffusion calculations to demonstrate the ability of the codes to predict detailed cell-to-cell neutron distributions

CONTROL DEVICE MEASUREMENTS

- These measurements are to demonstrate the ability of our physics toolset codes to calculate reactivity-device cell parameters
- Physics phenomena (PH0 PH11)
- The device will be inserted into the test region of the checkerboard lattice and fine-structure plus flux-map measurements will be performed
- The device will be inserted into a uniform lattice of SEU to derive the reactivity worth using period measurements

ROD DROP EXPERIMENT

- This test is to determine the component of the delayed neutron fraction due to photo neutrons
- Physics phenomena (PH12)
- An SEU lattice will be set up in ZED-2 and after operating for a pre-determined period an absorber rod will be inserted into the lattice
- The resulting negative transient will be analyzed to determine the contribution of delayed photo neutrons to Beta through the reaction D(γ,n) Eγ ~ 2.225 MeV

ANALYSIS

Requirements for the analysis are:

- Neutron yield per fission of ^{235}U
- An effective delayed fraction and relative group yields and half-lives for ^{235}U direct delayed neutrons
- Neutron yield per fission of ^{238}U
- Relative numbers of fissions of ^{235}U and ^{238}U in the lattice
- An effective delayed fraction and relative group yields and half-lives for ^{238}U direct delayed neutrons
- Relative group yields and half-lives for delayed photo-neutrons
- Relative yields of delayed photo-neutrons for ^{235}U and ^{238}U
- The effective yield of delayed photo-neutrons for ^{235}U and ^{238}U (allowed to vary in the analysis)

SUMMARY

- ZED-2 tests are to provide validation data for the physics codes and associated nuclear data libraries used in the design and licensing of ACR
- The presentation has listed the experiments planned to address various physics phenomena identified in the Physics Code Qualification Plan for ACR
- Experimental techniques to be employed are flux maps, substitution experiments, fine-structure experiments and kinetics experiments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