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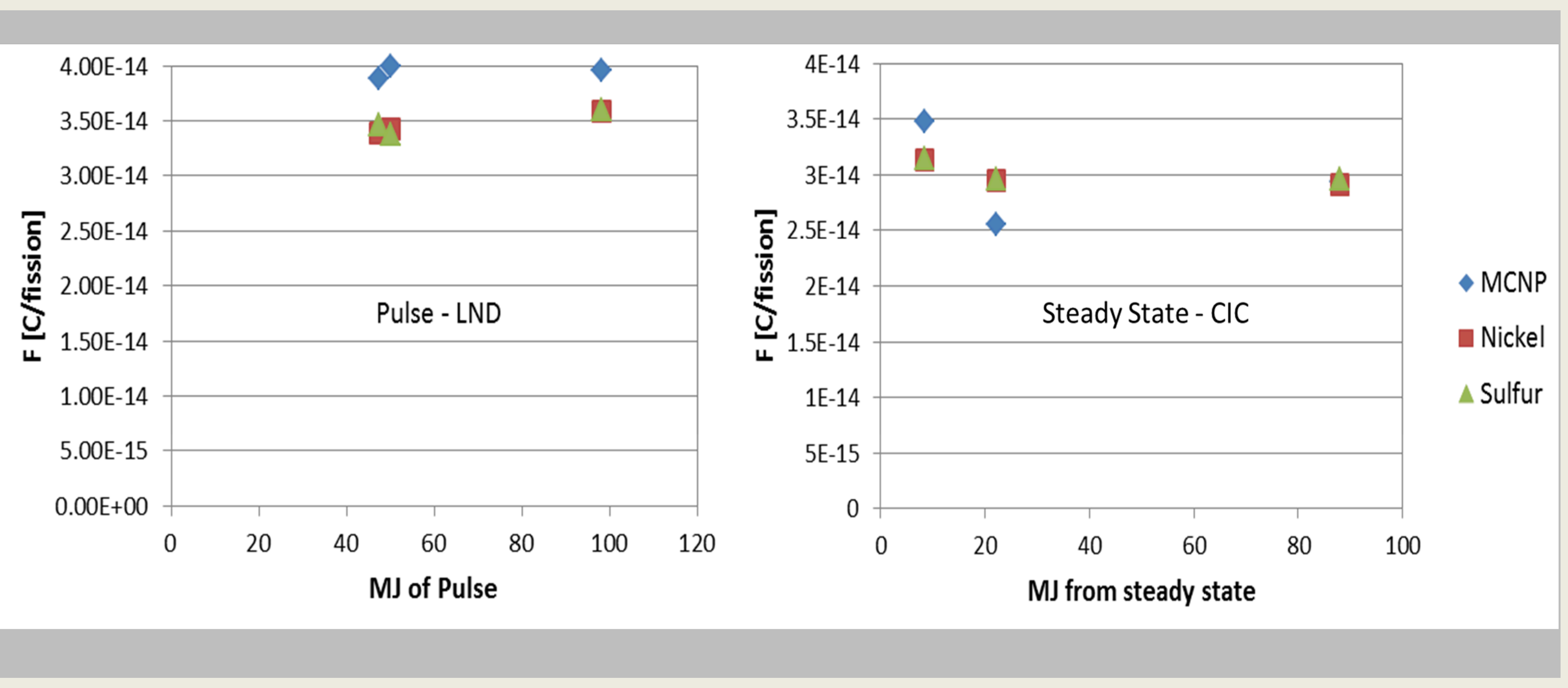

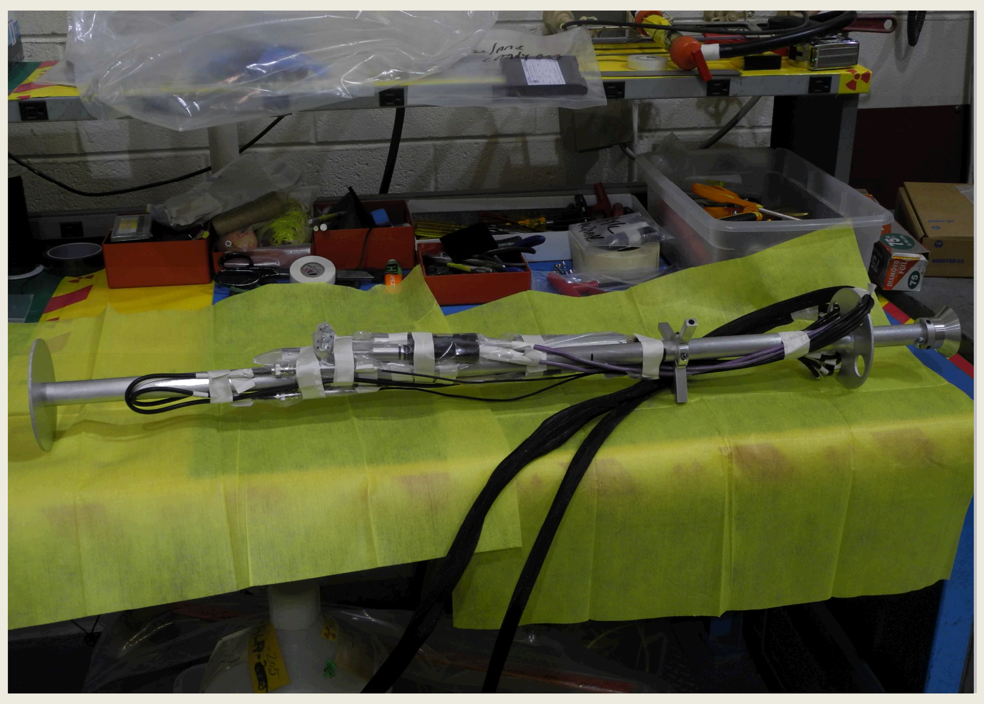

Run Number	Type	Energy [MJ]	Time [s]
1	Pulse	36	0.696
2	Pulse	47.3	0.663
3	Pulse	50	0.450
4	Pulse	98	0.455
5	Steady-state	8.5	466
6	Steady-state	22.2	582
7	Steady-state	88.1	557

MCNP Fissions/MJ Constant:	$3.04*10^{6}$ [Fissions/MJ]
A_{FC}/A_{LND} Ratio:	0.0977
G_{FC}/G_{LND} Ratio:	0.844
$\overline{\Sigma_f}$ for LB36 Environment	0.0679 [cm^{-1}]

Modeling, Calibration, and Verification of a Fission Chamber for ACRR Experimenters

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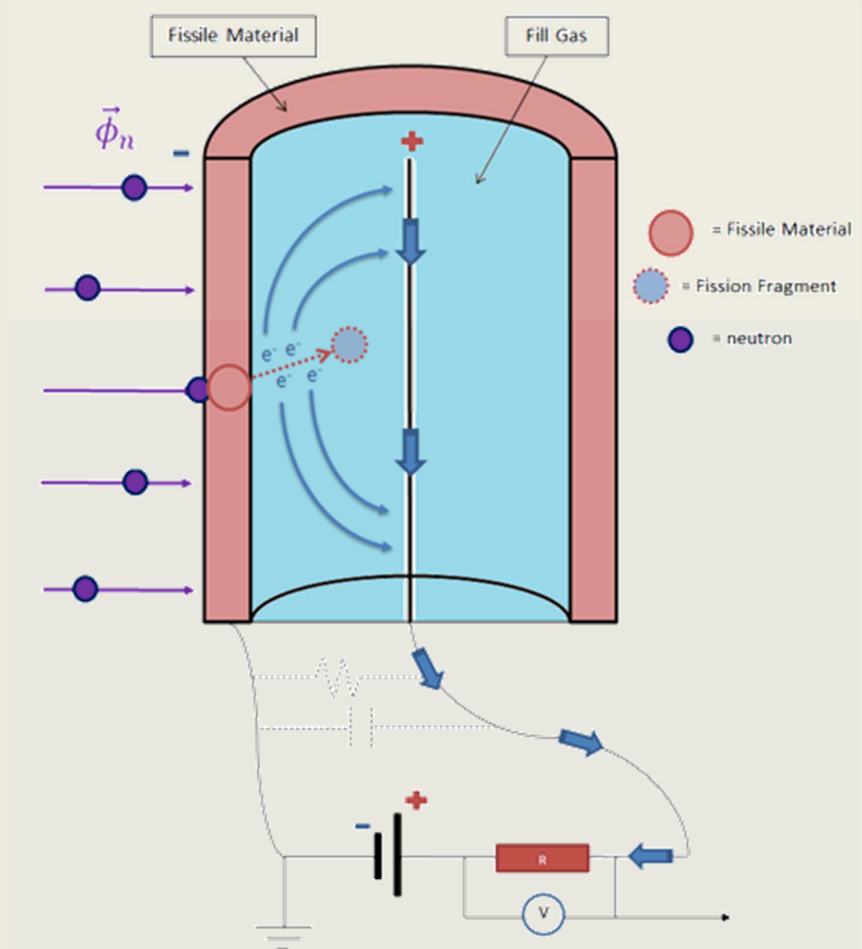
Purpose of Study

When performing research at a reactor facility, experimenters often need to determine the neutron fluence achieved during an operation. Facilities typically provide guidance in the form of neutron fluence per megajoule (MJ) or through passive dosimetry results. Active dosimetry may provide an estimate of neutron fluxes, but few active detectors are available that have been calibrated to measure neutron fluxes obtained inside the Annular Core Research Reactor (ACRR) central cavity environment. For past experiments at the ACRR, the neutron fluence was calculated by integrating the response of a fission chamber rate detection signal and then normalizing this integral to fluence determined from passive dosimetry. An alternative method of directly measuring neutron flux is desired; the new methodology described provides a complete neutron flux profile after a reactor pulse, utilizing fission chamber physics in combination with a compensating ion chamber to extract and convert a current signal to neutron flux as a function of time.



Fission Chamber Basics

A fission chamber works to detect neutrons as follows:

1) An incident neutron is absorbed with a fissile nucleus and causes fission.
2) The fissile nucleus splits into two fission fragments. Due to conservation of momentum, the fission fragments travel in opposite directions. One of the fission fragments will travel into the gas region of the detector.
3) The fission fragments have a high linear energy transfer, and will deposit most if not all of their energy in the fill gas by ionizing the gaseous atoms.
4) Due to the applied voltage, the free electrons are collected on the inner anode wire, producing a current that is the output by the fission chamber.

Methodology

In general, the amount of current generated by the fission chamber is proportional to the incident neutron flux. For a given neutron environment, the relationship between net neutron fission chamber current $I_n(t)$ and neutron flux is given by Equation (1):

$$I_n(t) = F \cdot A \cdot x \int \varphi_n(E,t) \cdot \Sigma_f(E) dE$$

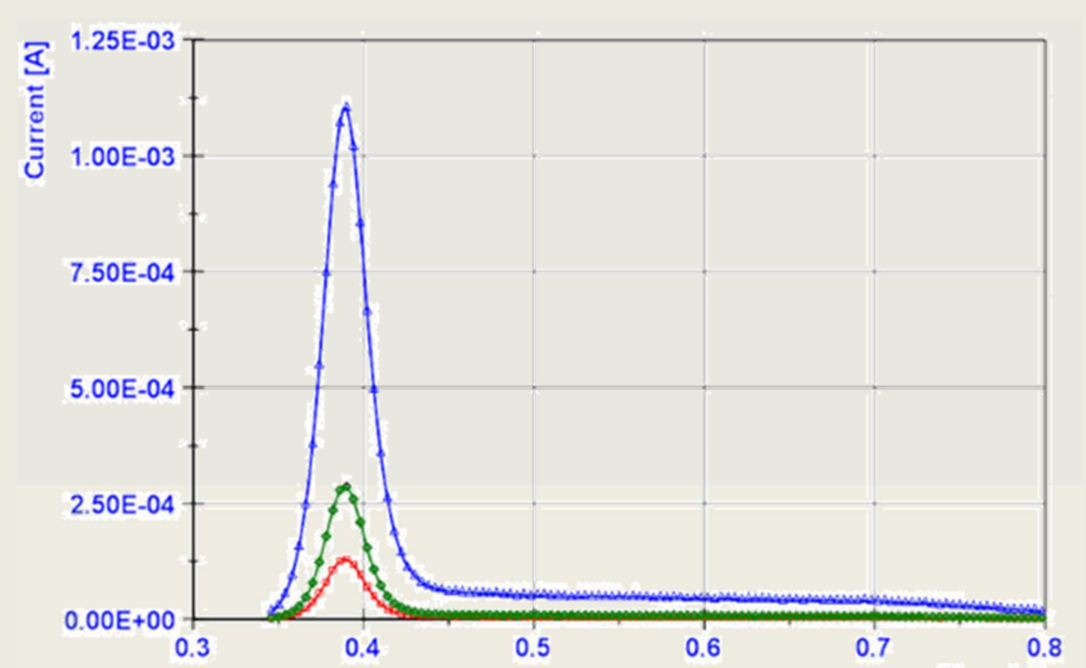
Where F is a chamber dependent constant (related to the Coulombs of charge produced per fission within the detector), A is the active detector area, x is the fissile material thickness, $\varphi_n(E,t)$ is the neutron flux as a function of neutron energy and time, and $\Sigma_f(E)$ is the fission cross section as a function of neutron energy. A useful relationship between the current and the neutron flux is obtained by integrating and rearranging:

$$\overline{\varphi_n}(t) = \frac{I_n(t)}{F \cdot A \cdot x \cdot \overline{\Sigma_f}}$$

F, A, and x are aspects of a given fission chamber and $\overline{\Sigma_f}$ is dependent upon the neutron environment.

Evaluation of Calibration Technique in ACRR LB36 Environment

A fission chamber/ion chamber pair was fielded in the LB36 epithermal environment at the core centerline. The experiment setup included a second LND-brand ion chamber, nickel dosimetry foils, and sulfur pellets. The setup was fielded during multiple reactor pulses and low power steady-state runs.



Sample detector data for run #3 (50 MJ Pulse)

The specific detector used in the experiment is a Photonis fission chamber / compensating ion chamber (CIC) pair, model numbers CFUF53/SA-U5 and CRGF10/SA. The fission chamber contains 39 µg of uranium oxide, with 92.1 w/o U^{235}, 6.6 w/o U^{238}, and 1.3 w/o U^{234}. Both chambers have similar dimensions with an active region of 3.987 cm^2, are filled with argon gas, and are operated at 150 volts. The value of F can be obtained experimentally by integrating the above equation with respect to time and rearranging.

$$F = \frac{Q}{\overline{\Phi_n} \cdot A \cdot x \cdot \overline{\Sigma_f}}$$

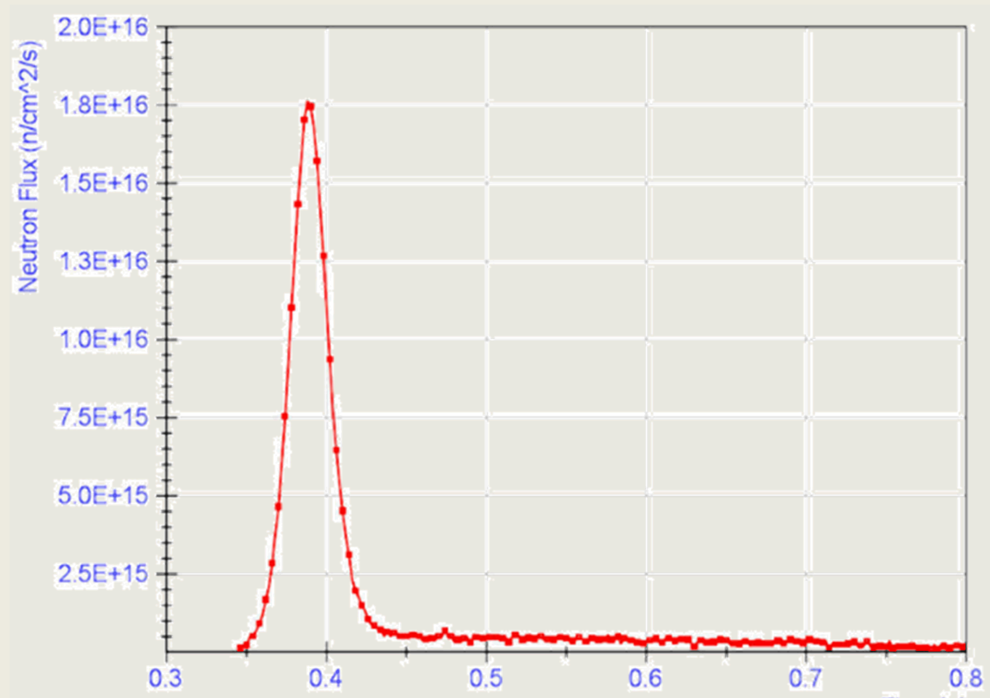
Results and Evaluation of Calibration Factor

The results from both the pulse and steady-state experimental data can be combined and averaged in order to determine the proper value for the conversion factor F. Averaging will be weighed slightly more towards the pulsed results from the CIC data based on consistent results and engineering judgement

$$F = 3.26 \cdot 10^{-14} \left[\frac{C}{fission}\right]$$

With the data points having a standard deviation of 4.62%. As for uncertainty, nickel foils possess about 4.3% and sulfur about 3.6%. There are uncertainties for the values G and A of 1.5% and 1.6% respectively, and MCNP uncertainty depends on uncertainty in the neutron spectrum being modelled.

With F known, researchers at ACRR can relate the detector current to a neutron flux profile. This operation can be performed for any well-characterized reactor environment for which $\overline{\Sigma_f}$ is known, and can be performed just a few minutes after data has been retrieved.



Neutron flux profile for run #3 (50 MJ Pulse)

Conclusions

The new experimental calibration technique was successfully tested and implemented for the Photonis fission chamber for use at Sandia National Laboratories' ACRR facility. The calibration technique has allowed for the experimental determination of the calibration factor F for the detector, representing the number of coulombs of charge produced per fission event for the chamber. Thus, experimenters at the ACRR facility can now gather data on the neutron flux profile of future pulsed or steady-state experiments, just a few minutes after data collection. In addition, the same calibration technique can be utilized for future fission chamber / compensating ion chamber pairs for use at the ACRR facility.

Future work in this area includes more extensive testing of the calibration technique at the ACRR facility, for more data points in various reactor environments. Additionally, more accurate MCNP models can always be implemented, and different dosimetry methods can be investigated.

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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