NE 5742 Nuclear Radiations and Their Measurements

Lab 6 Report

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I. Introduction

In this lab, the operation of a uranium-lined fission chamber was studied in pulse and current modes, by measuring the following from the OSURR Reactor: A plateau curve at two different reactor power levels in current mode, a plateau curve for the detector prior to reactor startup, in pulse mode, the pulse height from the detector in pulse mode, and a discriminator curve for the fission chamber when operated in pulse mode.

II. Theory

Fission chambers, sometimes called fission counters, are ionization chambers with inner surfaces coated with a fissile material (as noted above, this particular model used U-238). Detection of low-energy neutrons requires a converter material to capture the low-energy neutron, such as BF3 in previous detectors, with the resulting reaction emitting a charged particle which is detected by the instrument channel and signifies the neutron detection. While for the previously-used BF3 detector the ionizing particle emitted was the alpha particle released in the B-10/Neutron capture reaction, for fission counters the ionizing particles are fission fragments.

Under conditions of higher incident flux, individual pulse output can no longer be distinguished as the charge pulses overlap and merge to form a current signal instead. For such cases, the magnitude of the current signal is taken as an indication of incident flux. This regime of fission chamber operation is known as ‘current mode,’ and is typical when observing power reactors operating above 1% power.

III. Experimental Setup

The instrumentation used in this lab is shown in Table 1. Note that the preamp and DSA were used only for the pulse-mode operation, with the bias voltage supply and electrometer replacing the entire setup for current mode. Figure 1 shows a representative cross-section of the type of fission chamber used.

For pulse-mode operation, the procedure was as follows:
1.) Set up the fission chamber detector channel with the MCA as the data collection device.
2.) Obtain a plateau curve for the fission chamber when it is operated in pulse mode. Your instructor will provide you with the maximum voltage bias that the detector can handle.
3.) Determine the proper operating bias for the detector.
4.) Obtain a pulse height spectrum from the fission chamber on the MCA with the LLD set to zero. Comment on the features of this spectrum in your laboratory write-up.
5.) Obtain a discriminator curve for the fission chamber. A discriminator curve is a plot of the total counts in the spectrum versus LLD setting.

Table 1: Lab Instrumentation

Tennelec Model TC 175 Preamplifier
Canberra Model DSA 2000 Digital Spectrum Analyzer
Toshiba Satellite Laptop (with UCS-30 DAC software)
Reuter-Stokes RSN-10A Fission Chamber
Keithley Model 240A Bias Voltage Supply
Keithley Model 616 Electrometer

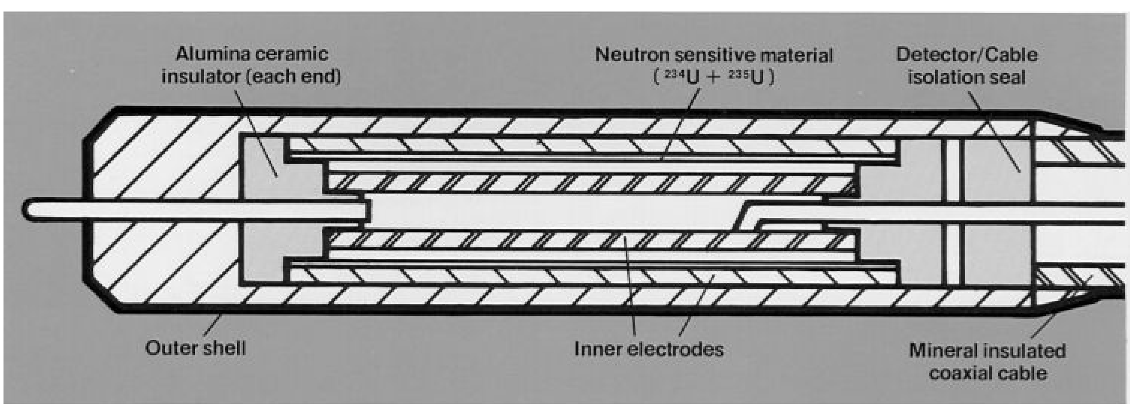

Figure 1: Fission Chamber Cross-section

The setup was as follows for the current mode experiment:
1.) Set up the fission chamber in current mode configuration.

2.) Obtain a plateau curve for the detector at two reactor power levels. In this case a plateau curve refers to a plot of current output from the detector versus detector operating bias.

The two power levels used in this experiment were 500W and 10 KW, so as to be appropriately separated.

IV.Results and Analysis

A figure of the plateau curve for the fission chamber in pulse mode can be seen below.

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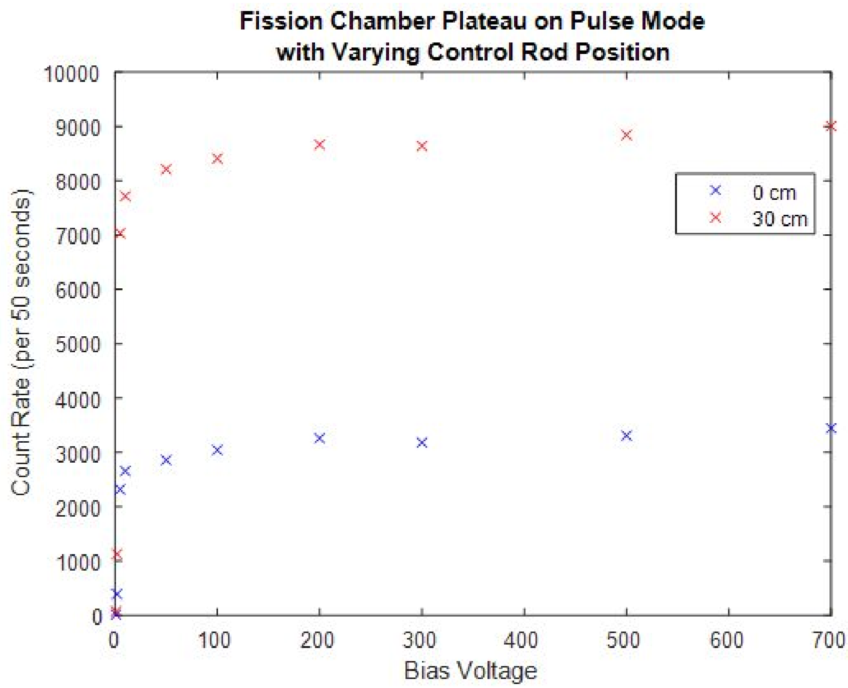

Figure 2: Plateau Curve of Fission Chamber on Pulse Mode

From this, it can be seen that the count rate plateaus at around 200 V of bias voltage for both positions of control rods. Taking an average between this voltage and the max used gives an operating bias voltage of 450 V for the detector. Pulse height spectrum was obtained at a bias voltage of 500 V and can be seen below.

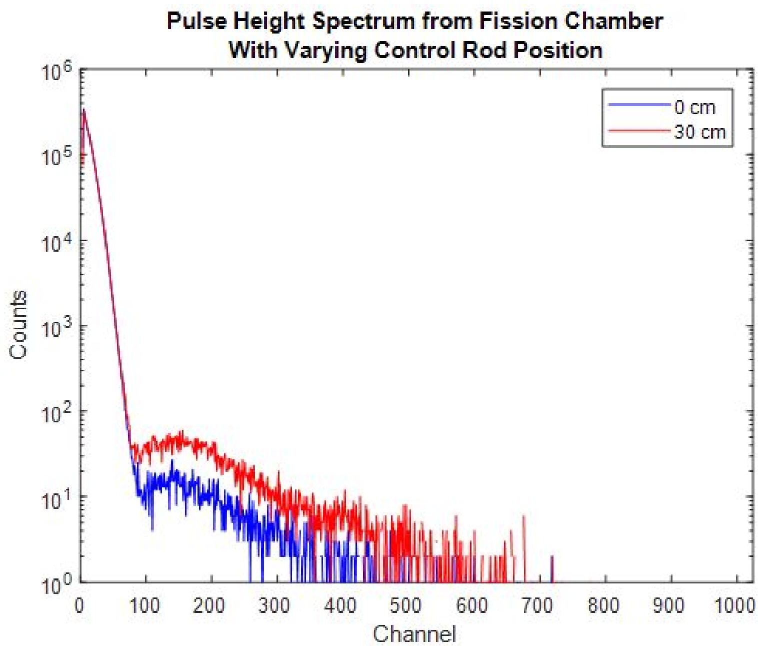

Figure 3: Pulse Height Spectrum of Fission Chamber

The pulse spectrum picks up alpha decay from the U-235 within the detector, generating many counts for low channels. Neutron peaks are seen to peak after the alpha peaks drop off around channel 80. A discriminator curve was created using this spectrum and is shown below.

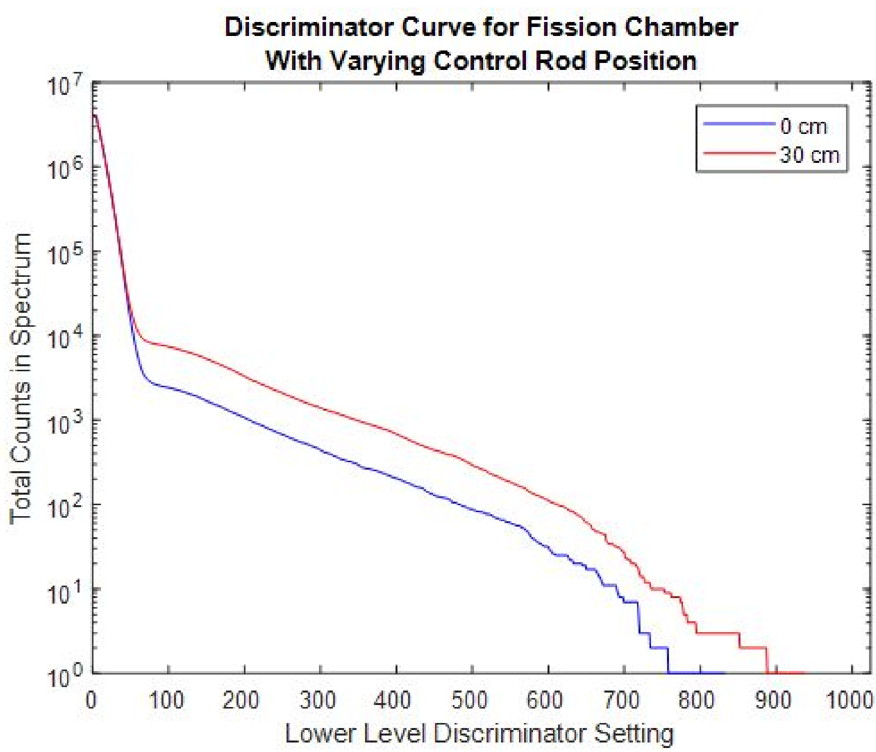

Figure 4: Discriminator Curve for Fission Chamber

This curve further verifies that the alpha counts drop off after channel 80. In order to measure only pulses due to neutrons in the fission chamber, the lower level discriminator should be set to channel 80.

Next, the detector was operated in current mode to get an average current from neutron interactions in the chamber, which can be used to determine neutron flux. Below is a figure showing the plateau curve for the fission chamber in current mode at two different reactor power levels.

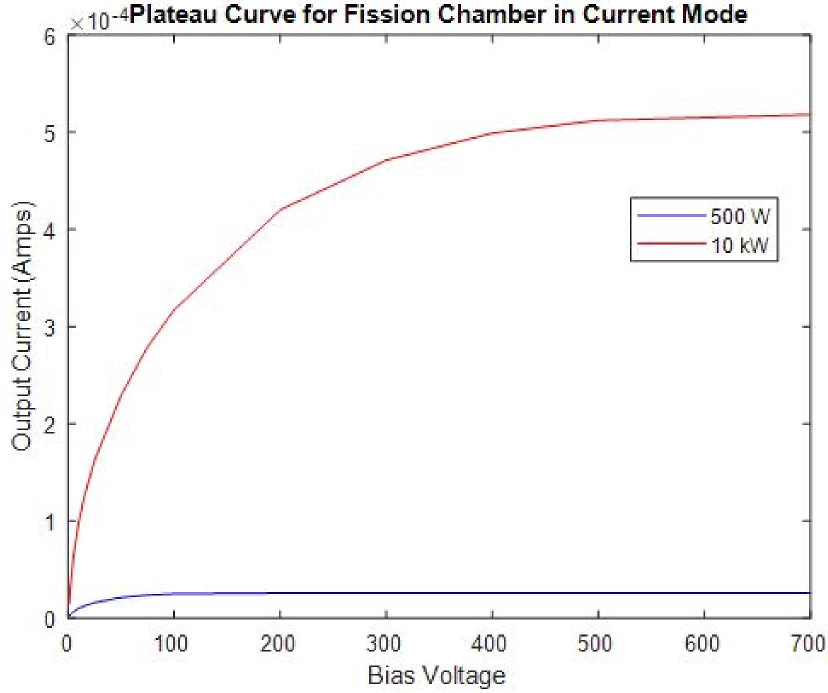

Figure 6: Plateau Curve of Fission Chamber in Current Mode.

As the reactor power level is increased, the “knee”, or total curve of the figure, takes much longer to plateau. The output powers are different by a factor of 20, which corresponds to the same change in output current once both curves have plateaued. A bias voltage that is on the plateau for as many different power levels of the reactor should be chosen, or for the power levels most used. In this case, a bias voltage of 700 V would be used to ensure scaled current outputs at all power levels in between 500 W and 10 kW to determine flux levels.

V.Conclusion

As with other neutron detectors, fission chambers are able to determine neutron count and flux rates but record nothing about incident neutron energy. Depending on fission chamber size, a wide variety of bias voltages can be used. For the chamber used in this experiment, operating voltage for pulse mode was found to be 450 V and for current mode to be 700 V. The quantum sink for these detectors is likely the mineral insulated cable used to connect the detector with the signal processing electronics, as they are a compromise between electrical properties and radiation hardness.

Appendix A
MATLAB Code

```
%% NE5742 Lab 6 %%
% Mark Luke %

load('NE5742_Lab6_1.mat')

channel = linspace(0, 1023, 1024);

bias = [1 2 5 10 50 100 200 300 500 700];
pulse0 = [18 394 2319 2660 2859 3045 3261 3183 3308 3445];
pulse30 = [79 1130 7031 7715 8212 8407 8664 8638 8840 9003];


%% Plateau Curve %%

plot(bias, pulse0, 'bx', bias, pulse30, 'rx')
title({'Fission Chamber Plateau on Pulse Mode','with Varying Control Rod Position'})
xlabel('Bias Voltage')
ylabel('Count Rate (per 50 seconds)')
legend('0 cm','30 cm')

biasvoltage = (200+700)/2; %bias voltage for detector

%% Pulse Height Spectrum

figure
semilogy(channel, V_500_0, 'b', channel, V_500_30, 'r')
xlim([0 1024])
title({'Pulse Height Spectrum from Fission Chamber','With Varying Control Rod Position'})
xlabel('Channel')
ylabel('Counts')
legend('0 cm','30 cm')
```

```
%% Discriminator Curve for Fission Chamber

for i = 1:length(V_500_0)

   LLD_0(i) = sum(V_500_0(i:1024));     %control rods 0 cm
   LLD_30(i) = sum(V_500_30(i:1024));   %control rods 30 cm

end

figure
semilogy(channel, LLD_0, 'b', channel, LLD_30, 'r')
xlim([0 1024])
title({'Discriminator Curve for Fission Chamber','With Varying Control Rod Position'})
xlabel('Lower Level Discriminator Setting')
ylabel('Total Counts in Spectrum')
legend('0 cm','30 cm')

%set LLD to 80 to get counts only from neutrons

%% Current Mode %%

bias = [1 2 5 10 15 25 50 75 100 200 300 400 500 700];
c1 = [1.95 3.41 6.50 9.88 12.33 15.93 21.2 23.7 24.9 25.8 26.0 26.0 26.0 26.1]*10^-6; %Amps
c2 = [0.143 0.300 0.628 0.980 1.236 1.623 2.29 2.79 3.17 4.20 4.71 4.99 5.12 5.18]*10^-4;
%Amps

plot(bias, c1, 'b', bias, c2, 'r')

title('Plateau Curve for Fission Chamber in Current Mode')
xlabel('Bias Voltage')
ylabel('Output Current (Amps)')
legend('500 W','10 kW')
```