Correlating reactor core power with radiation detector noise outside of primary shielding

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Introduction

Currently reactor power is monitored using a combination of in-core and out of core monitoring techniques such as ion chambers, fission chambers, and thermocouples. With the increased interest and research of constructing generation four reactors such as molten salt reactors, sodium-cooled fast reactors, high-temperature gas reactors, and others comes a problem of increasingly difficult environments to place these devices while still maximizing the lifetime of the detector without increasing cost of replacement or design of the core. Based on the future in-core and out-core environments, it should be know whether the core power can be measured outside of primary shielding where conditions are suitable to the majority of radiation detector types currently on the market.

One of the problems with placing a radiation detector outside of shielding is the low radiation field due to the shielding, one method to determine the power is to increase the radiation field by decreasing shielding or change the layering of shielding. Another method would be to associate the noise in the detector from the low count rate with the reactor core power. This can effectively be done with any type of radiation detector including gas chambers, scintillators, and semi-conductors. Currently gas-chambers are used due to their robust nature and simple electronics and data analysis. Alternatively, by placing detectors outside the primary shielding of the core, scintillators and semi-conductors can be used, which allows for the use of gamma-ray spectroscopy for fuel cycle analysis and planning. As well as many other types of analysis that can be useful for research, industry, and security purposes.

Objectives

The purpose of this experiment was to discover if useable data can be taken from a university research reactor operating under normal conditions and with various types of radiation detectors placed around the primary core-shielding. If useable data is found the follow-up is to decide what methods the data can be used to correlate reactor power.

- Perform data acquisition at a Mark II TRIGA Reactor and observe changes in the detector based on reactor power changes.
- If noticeable changes are seen determine what data analysis methods can be used to correlate power with noise.

Methods

All data used for this poster was acquired at the Texas A&M University TRIGA Reactor, we would like to thank Dr. Pavel Psvetkov for organizing this with the reactor group at Texas A&M.

To perform the experiment multiple types of gas chambers and scintillators were placed around the reactor at different locations outside the primary shielding. The detectors used encompassed both gamma-ray detectors and neutron detectors to cover both the gamma-ray and neutron fields produced from the reactor. This can be seen in figure 1. The detectors taken on the experiment are listed in table 1 and the electronics used for the data acquisition.

Detector & Data Acquisition Device
LaBr(Tl) 2x2 & CAEN DT5730
Polysiloxane & CAEN DT5730
BF-3 Proportional Counter & Quaesta NPM 3100
He-3 Proportional Counter & Quaesta NPM 3100
Boron Lined Proportional Counter & Quaesta NPM 3100

Table 1. Radiation Detectors and Electronics used

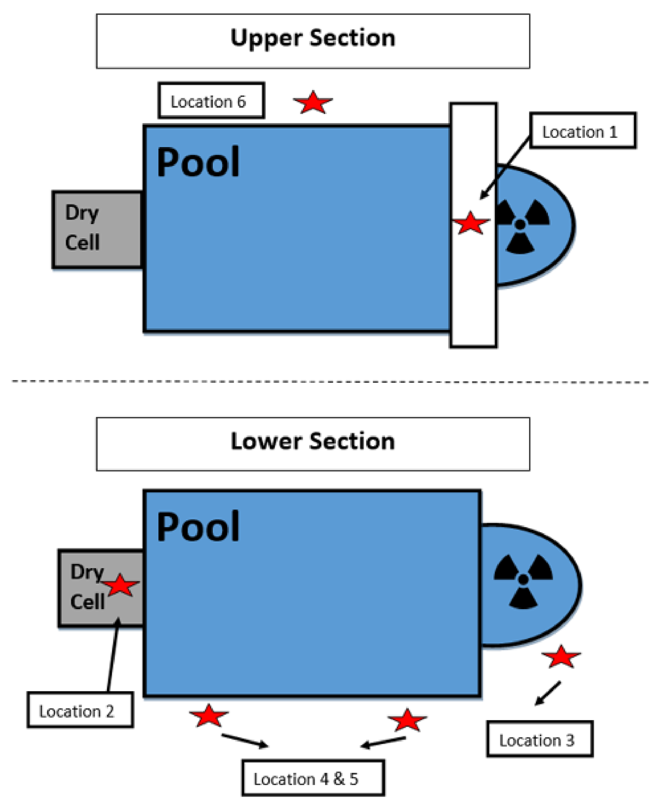

Figure 1. Detector positions (indicated by red star) with respect to reactor core

Results

All data was acquired during normal reactor operation with radioactive materials being moved and removed in the facility that could cause inconsistencies in the data. During the acquisition data was recorded live and changes in data could be noticed live. It was also noticed on the oscilloscope that there are multiple waves per waveform which creates problems when performing pulse shape discrimination of neutrons; this can be seen in figure 2. It was discovered after the experiment that this was caused by the building power supply not having a noise filter. This is easily solved by using Isolation Transformer.

Figure 2. Waveform from Polysiloxane Scintillator

To acquire data CAEN CoMPASS software was used for data collection and processing, using this software we were able to see PSD versus ADC Channel, Count Rate versus time, Counts versus ADC Channel allowing for a wide range of data visualization to see changes in detector noise. The most noticeable changes were seen in the count rate versus time plots; an example is shown in figure 3 which was acquired during a 1 MW to 5 MW power increase. Based on this it was determined that correlating power is possible. To determine more, a PSD versus ADC Channel plot was looked at from a EJ-309 detector shown in figure 4, from this figure it is evident that the neutron field is almost non-existent in comparison to the gamma-ray field demonstrating the effect that the shielding is focused on neutron attenuation rather than gamma attenuation. The final piece of information that was looked at was the results from gamma-ray spectroscopy. In this figure, there are noticeably distinguishable peaks at lower and mid energies that are from the reactor core as well as neutron interactions producing prompt and delayed gammas in the shielding.

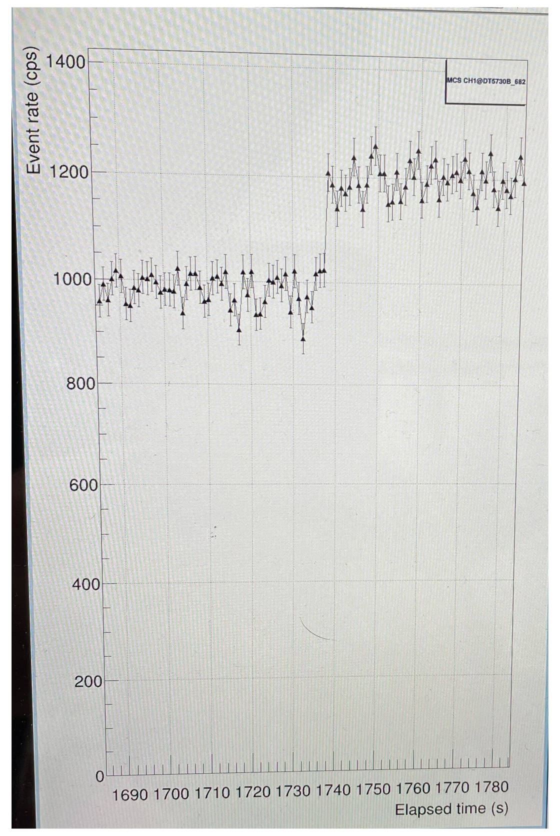

Figure 3. Count rate versus time graph for detector placed above reactor during 1 MW to 5 MW power change.

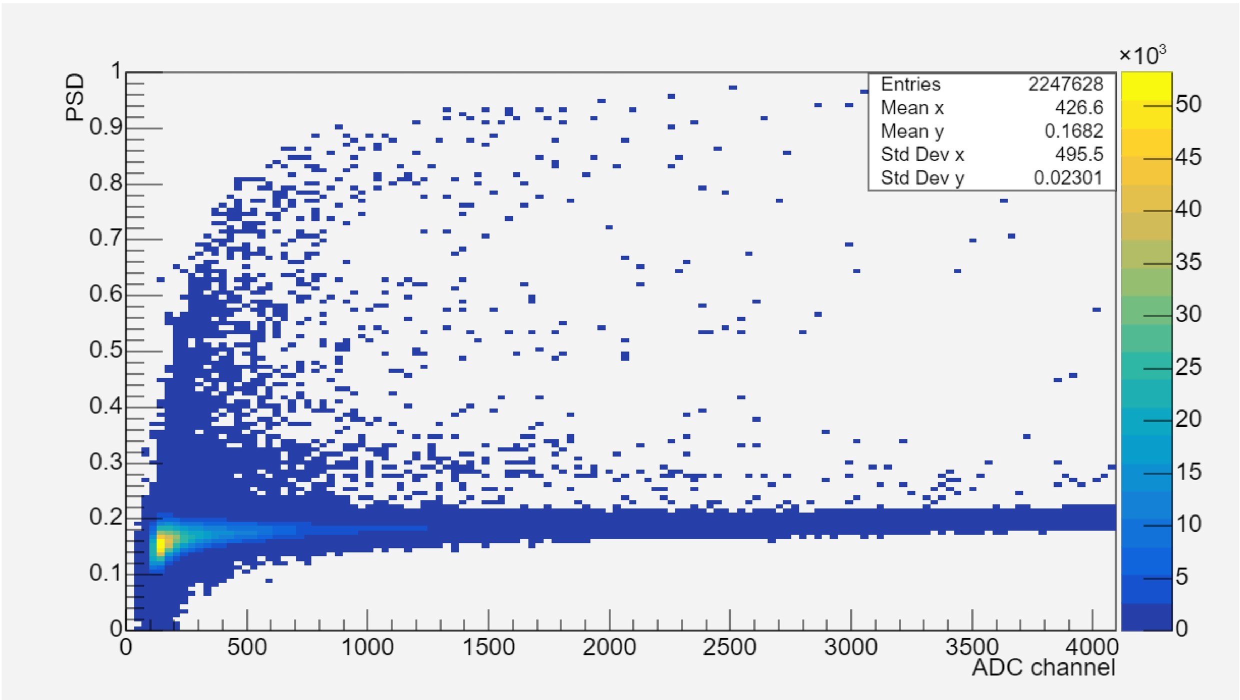

Figure 4. PSD versus ADC Channel for EJ-309 above reactor core

Conclusion

Based on the data gathered from the experiment at Texas A&M University, it is evident that the possibility of correlating reactor power to detector noise is possible and should be furthered explored. Based on the results, the most probable detectors to be used for correlating power should primarily be gamma-ray detectors with good efficiency for collecting counts but for performing research, also have good resolution to allow more use of the data. Nonetheless, neutrons should not be neglected in the subsequent studies since neutron fields are larger at larger reactors.

For the continuation of this research different methods may be applied such that the dependent use of a research reactor is avoidable. For future experimentation, data will be collected using neutron and gamma sources with variable shielding to resemble the spectrum and strength of a reactor outside of primary shielding. From this, change of power is based on distance from source since the source intensity decreases with increasing distance.

References

[Harrer and Beckerley] Harrer, J. M. and Beckerley, J. G. Nuclear power reactor instrumentation systems handbook, volume 1.