Los Alamos NATIONAL LABORATORY

IER-579 Pile Oscillator Experiments at NCERC

Cole Kostelac

12/4/24

2025 Annual NCSP Technical Program Review

Introduction

- Pile oscillator experiments can be used in two unique ways

  - **Kinetics Information:** Periodic reactivity oscillations into a critical system, relate the systems response to the Reactor Transfer Function. Fit experimental data to get $\boldsymbol{\beta_{eff}}$ and $\boldsymbol{\beta_i}$ groups.
    - Kinetics parameters can be used to validate nuclear data and computational methods

  - **Integral Cross Section Measurements:** Repeatedly moving a sample of interest from a region of low to high flux in a critical system
    - Useful for nuclear data validation

Oscillators were used at TA-18

- Early oscillator measurements were performed at TA-18 to measure the reactor transfer function
- Later integral cross section measurements in 1980s and 90s

INSTRUMENTATION AT THE LOS ALAMOS CRITICAL ASSEMBLY LABORATORY*

Herbert H. Helmick
University of California
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

Assembly Site has been tailored for specific experimental investigations. One such device is an oscillating control rod, synchronizing an RIDL 400 channel analyzer which stores counts from an internal fission chamber. Figure 5 diagrammatically shows the experimental setup for measuring the zero power

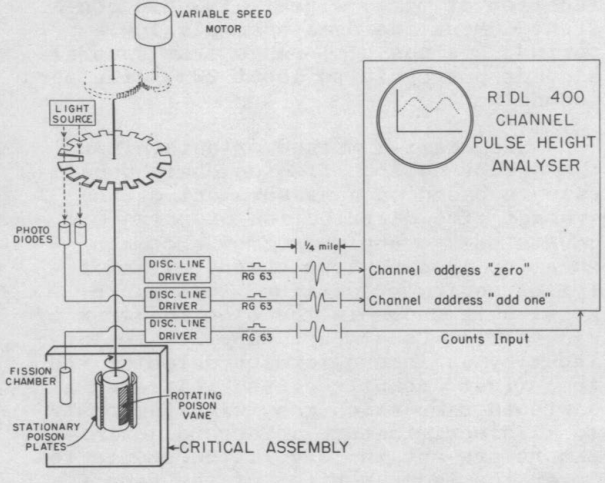

Fig. 5—Diagram of oscillator rod experiment.

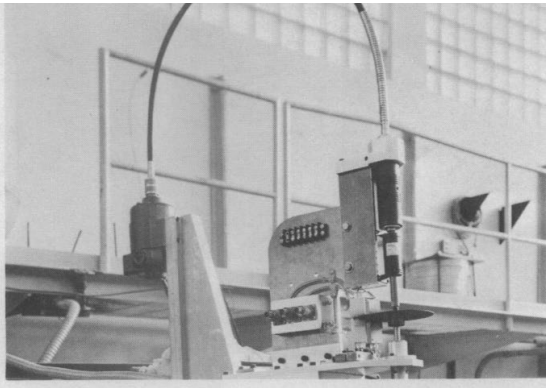

Fig. 6—Oscillator rod drive and notched synchronizing wheel.

transfer function of an assembly. The oscillator rod rotates continuously in one direction, alternately shading and unshading a set of poison vanes in the core. This causes a change in the reactor reproduction factor of $\Delta K \cong A \sin \omega t$. A notched wheel rotating with the control rod (shown in Figure 6) interrupts a light beam 100 times per revolution causing the channel address of a 400 channel analyzer (operating in the externally synchronized time analyzer mode) to be advanced 100 channels. One of the notches is deeper and triggers a second light beam once per revolution, causing the channel address to be reset to zero, thus synchronizing the channel address with oscillator rod angle. Stored counts are then displayed as a function of time, since ω is held constant during the data accumulating period. Values of ω range from several seconds per cycle to about 20 cycles per second.

Oscillators were used at TA-18

Motor

Encoder

Rotating Neutron Poison

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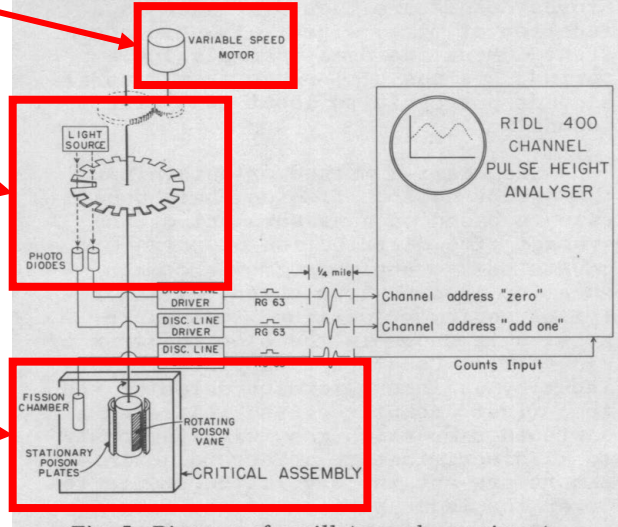

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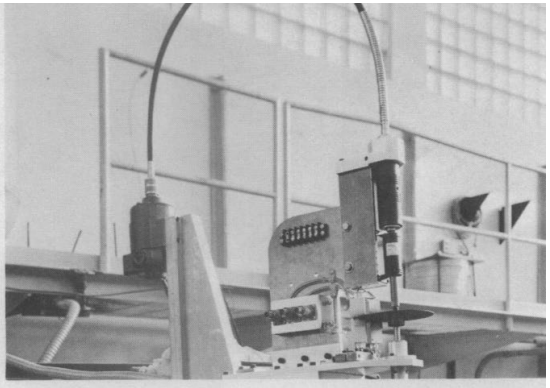

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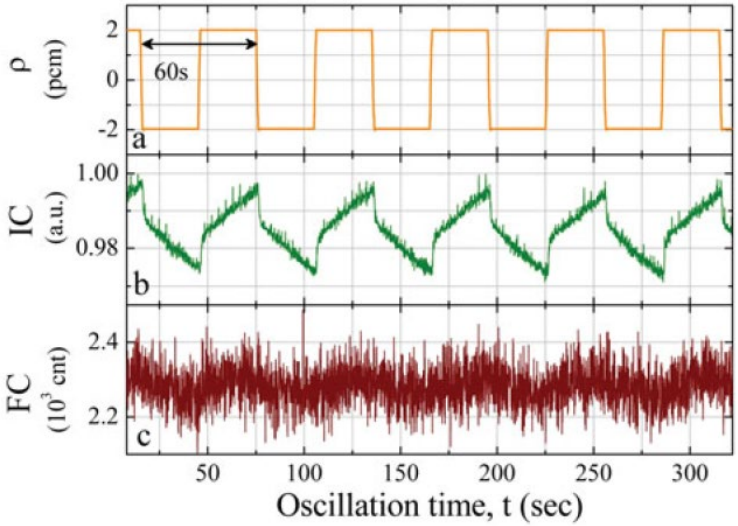
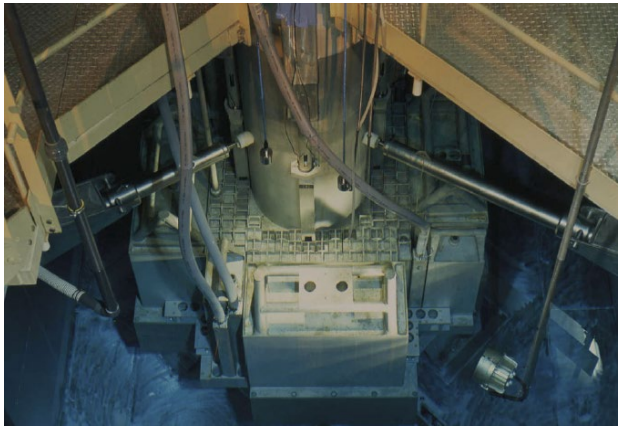
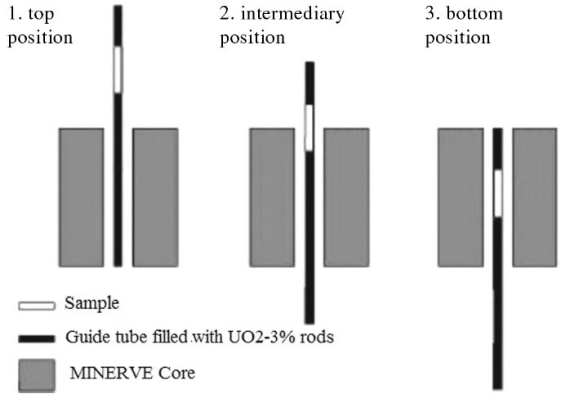
The Last 10 Years of Pile Oscillators Around the World

Pile Oscillator at MINERVE

- CEA research reactor at Cadarache
- Extensive experiments for kinetics measurements and sample worth measurements for burnup credit
  - Sm, Mo, Eu, Gd



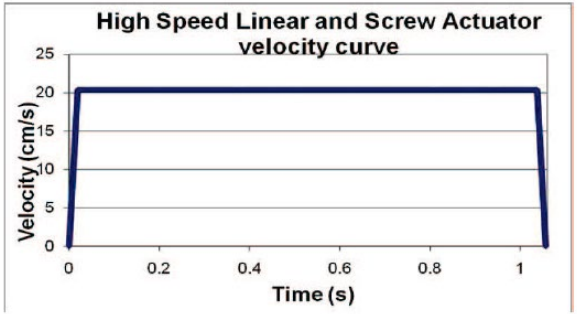


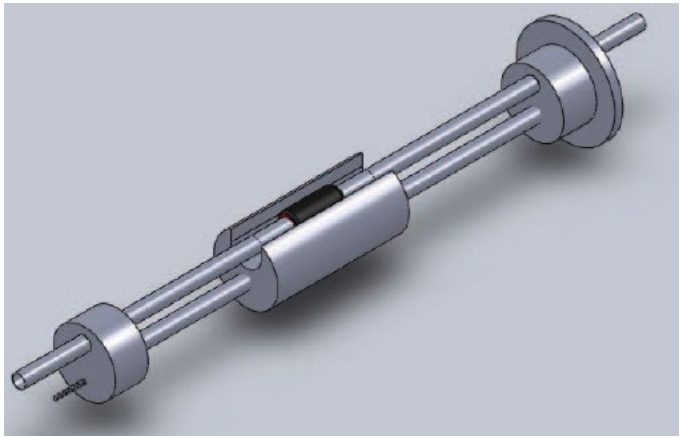


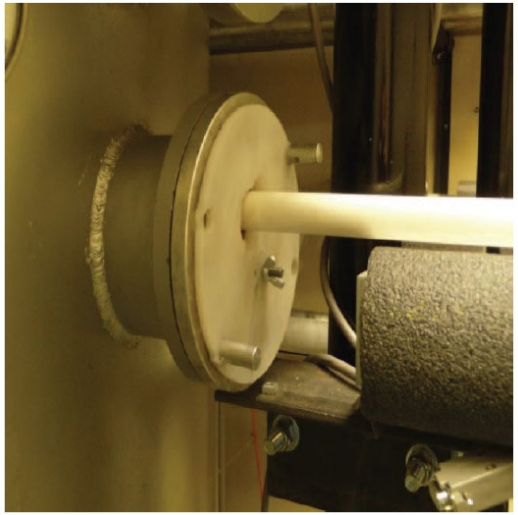
Gilad, E., Rivin, O., Ettedgui, H., Yaar, I., Geslot, B., Pepino, A., … Blaise, P. (2015). Experimental estimation of the delayed neutron fraction β_{eff} of the MAESTRO core in the MINERVE zero power reactor: Physor2014. *Journal of Nuclear Science and Technology*, *52*(7–8), 1026–1033

Pile Oscillator at Idaho State University

- Linear oscillator for sample worth measurements in Idaho State's AGN-201 research reactor



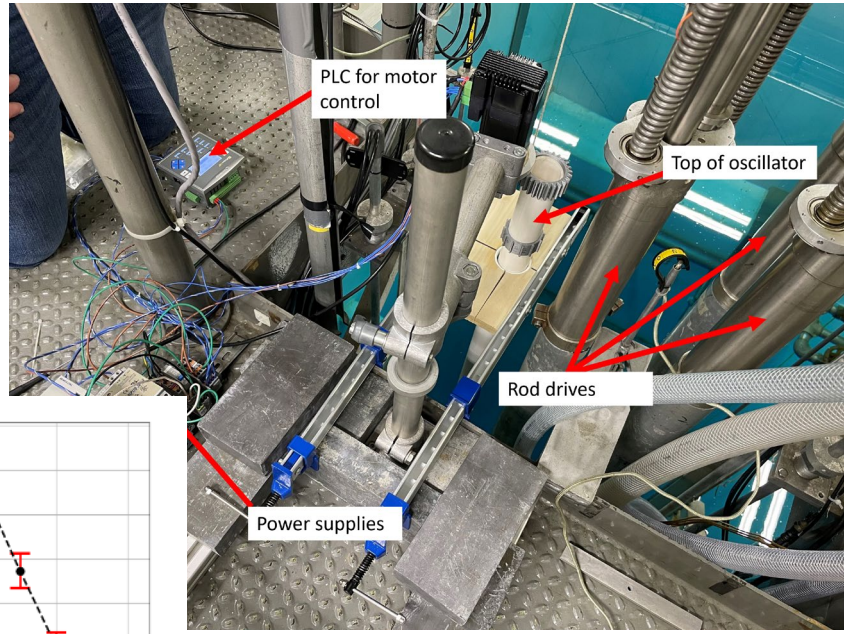


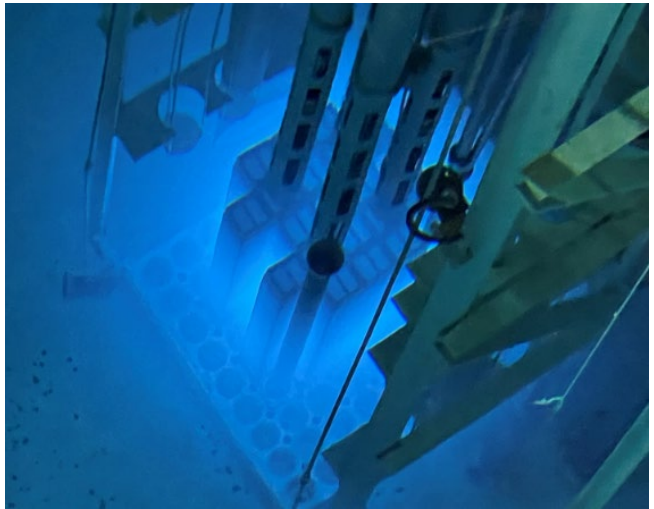


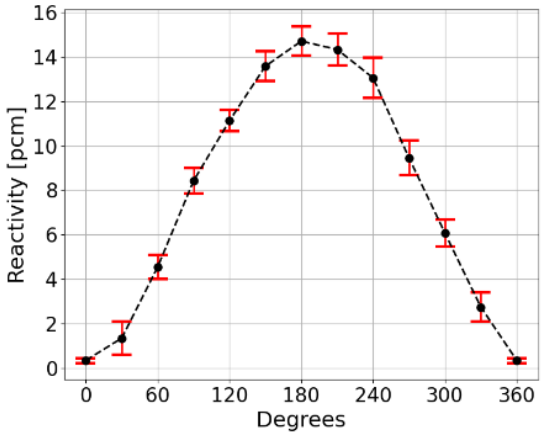
G. R. Imel, B. Baker, T. Riley, A. Langbehn, H. Aryal and M. L. Benzerga, "Study of the open loop and closed loop oscillator techniques," *2015 4th International Conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications (ANIMMA)*, Lisbon, Portugal, 2015, pp. 1-8

Pile Oscillator at Missouri S&T (2023)

- Oscillator for kinetics measurements
- Used rotating piece of Cadmium metal on core periphery



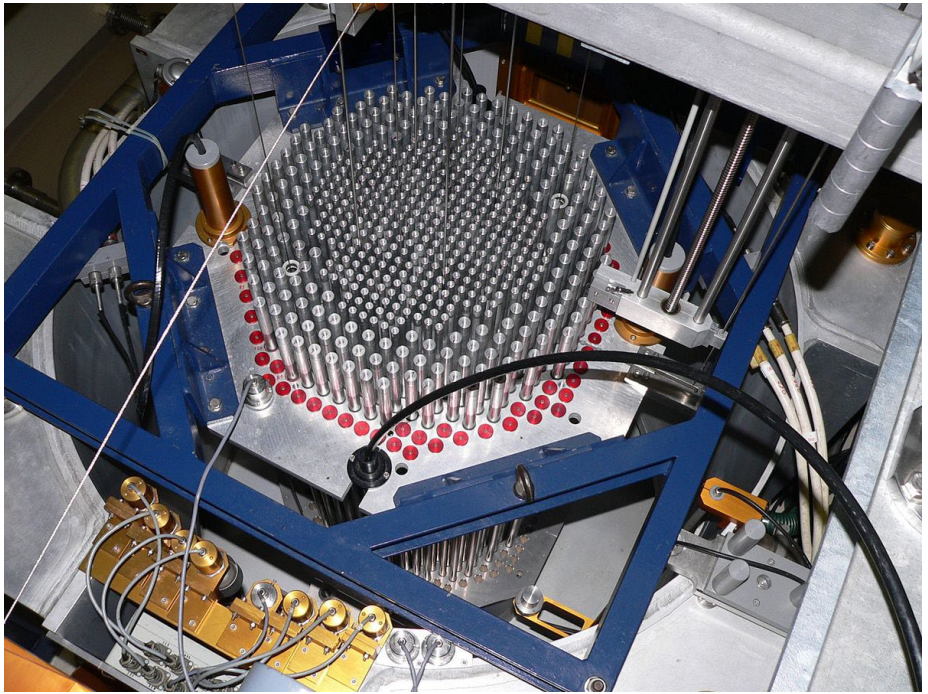




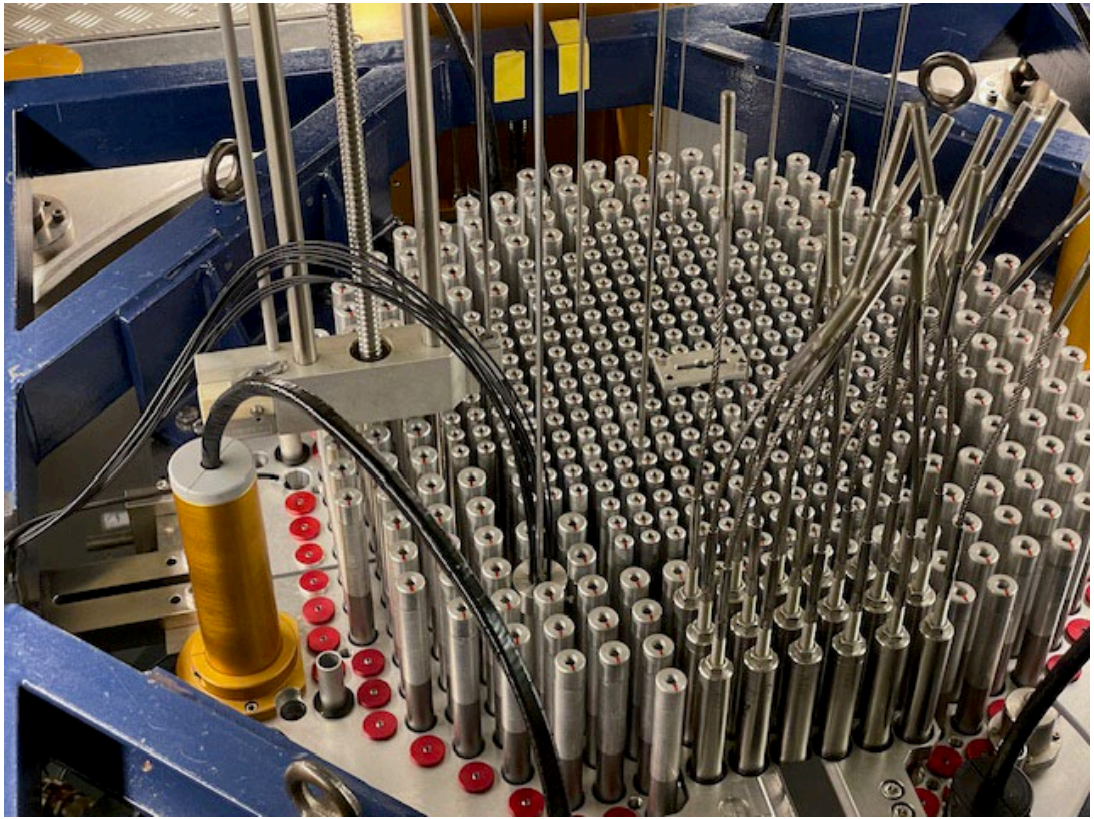
(b) Integral Oscillator Worth

Pile Oscillators at CROCUS

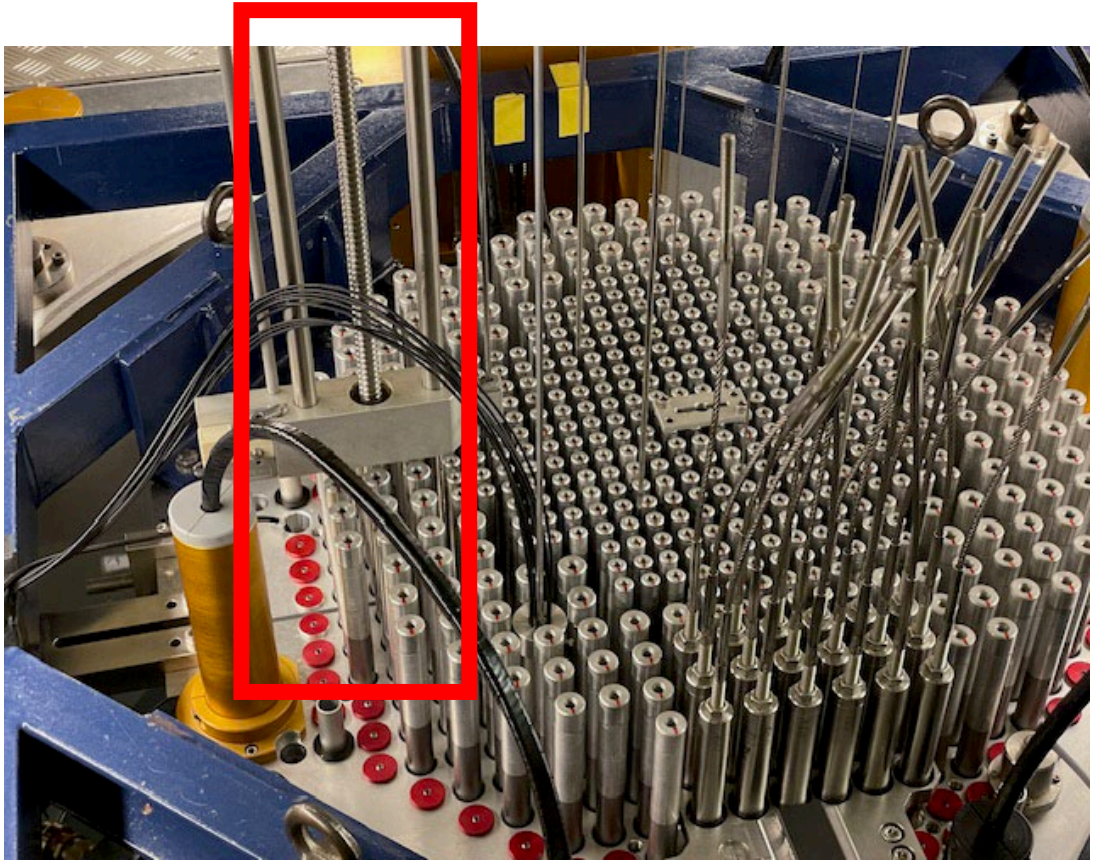
- 100W research reactor at EPFL in Lausanne, Switzerland
- Included in the International Handbook of Evaluated Reactor Physics Benchmark Experiments (IRPhE)
- Three unique oscillator systems currently installed in CROCUS

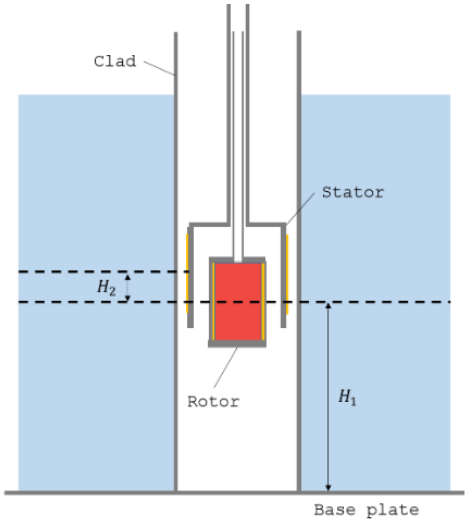


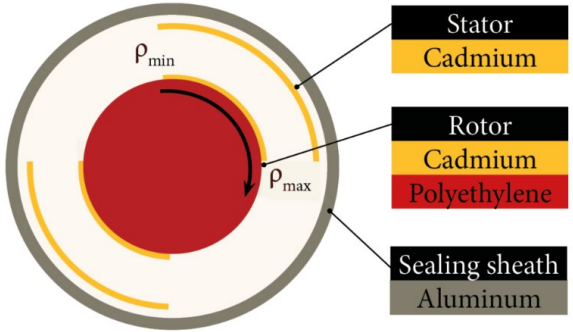
Pile Oscillators at CROCUS



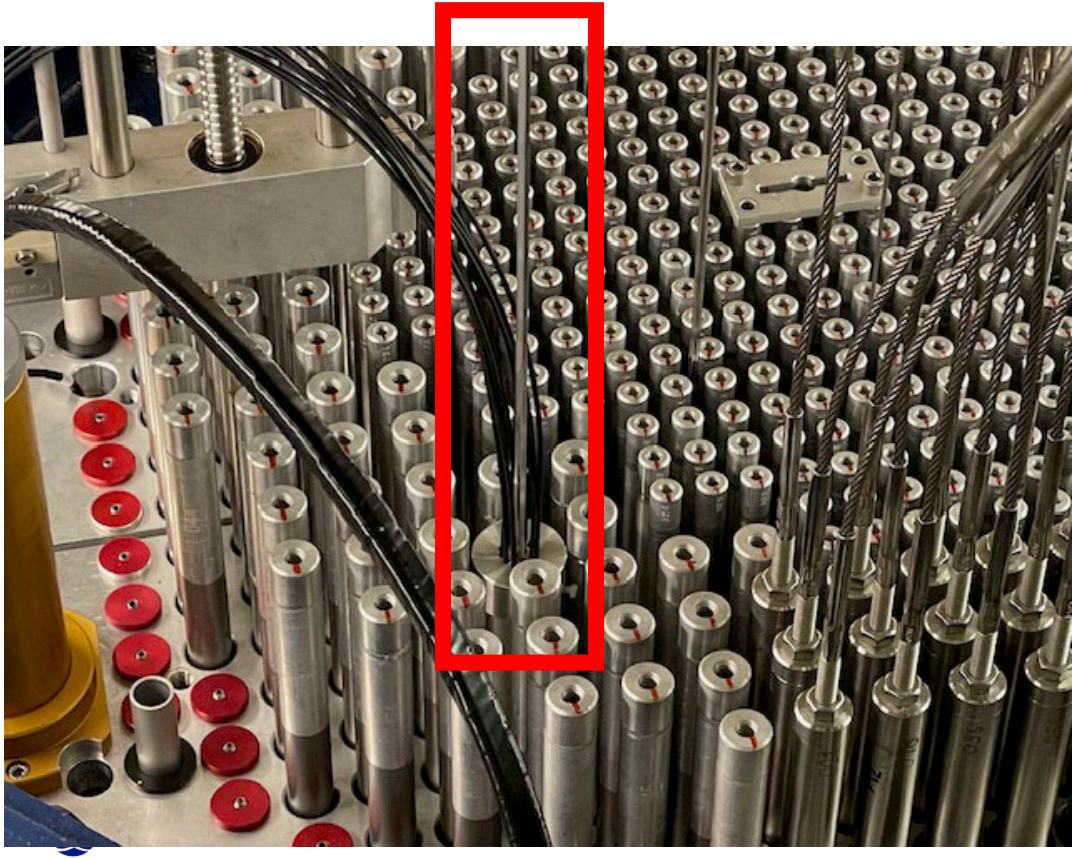
Pile Oscillators at CROCUS (PISTIL)

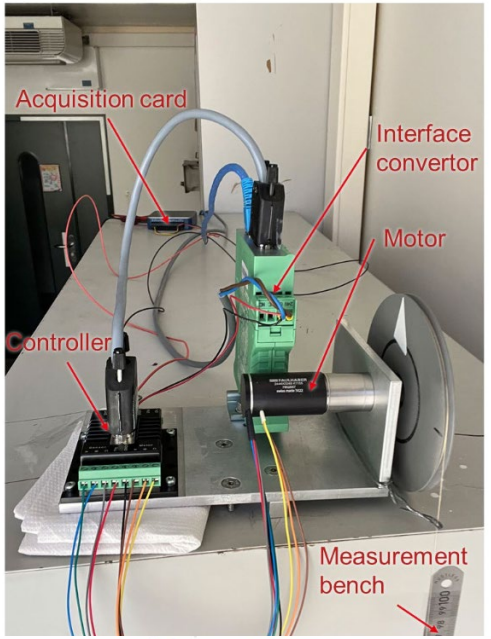


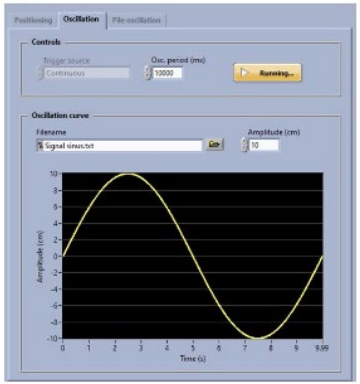


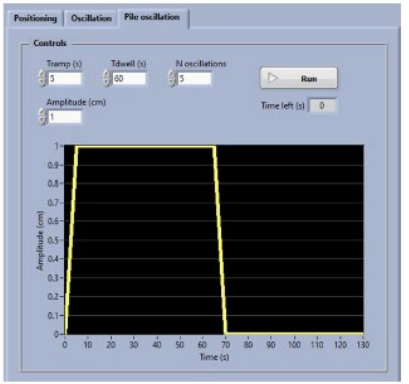


Pile Oscillators at CROCUS (POLLEN)

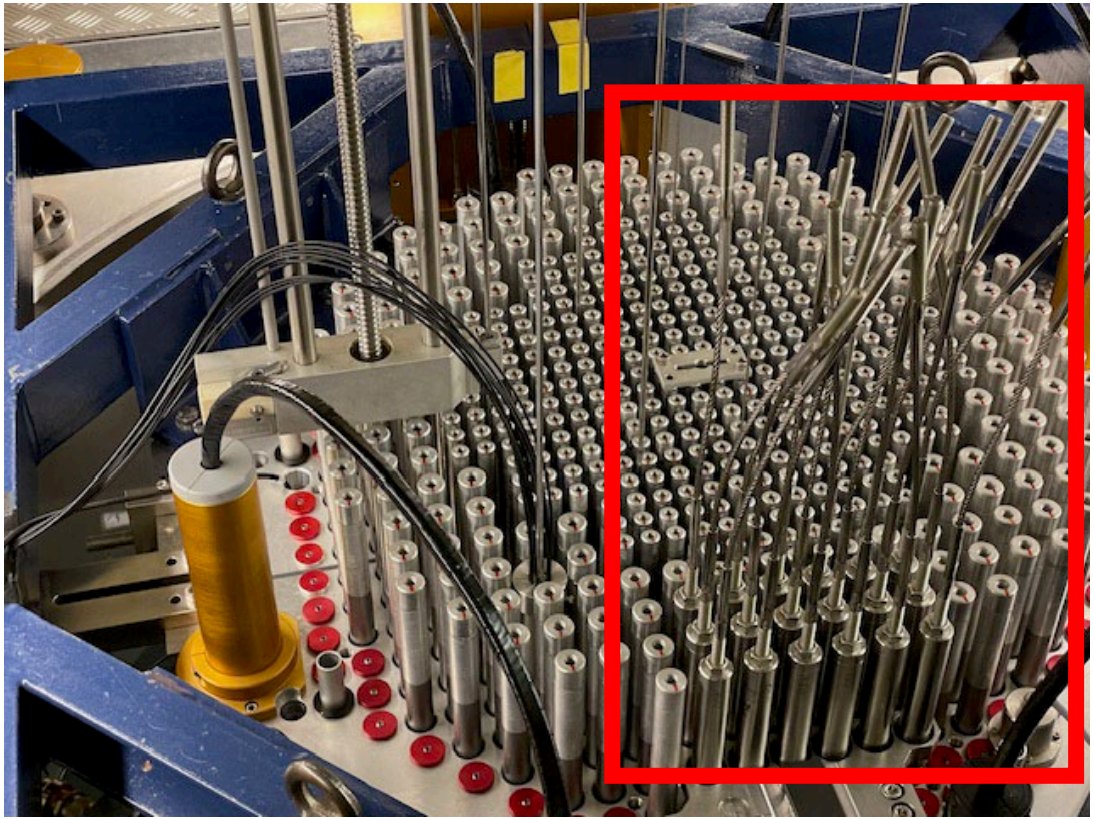


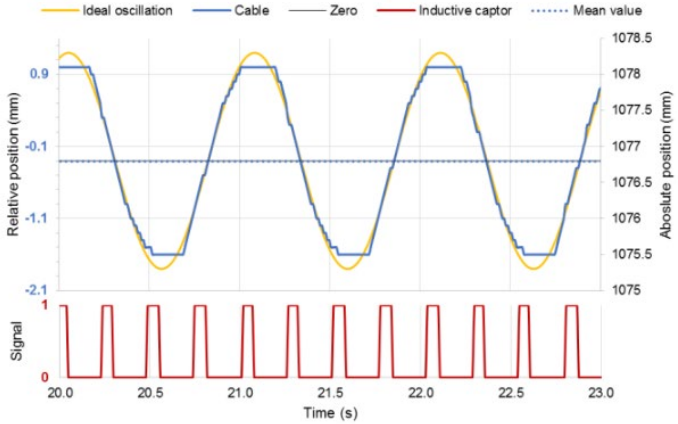






Pile Oscillators at CROCUS (COLIBRI)





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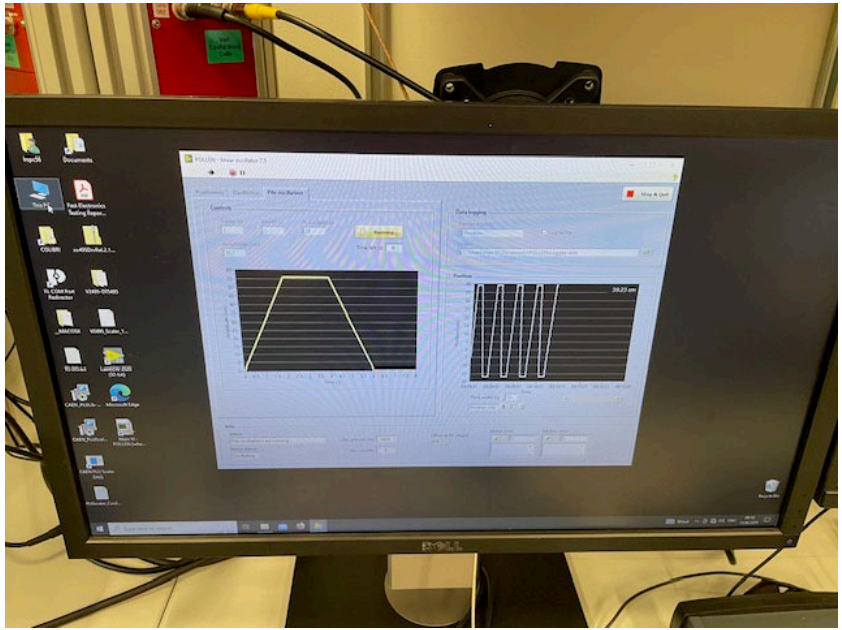
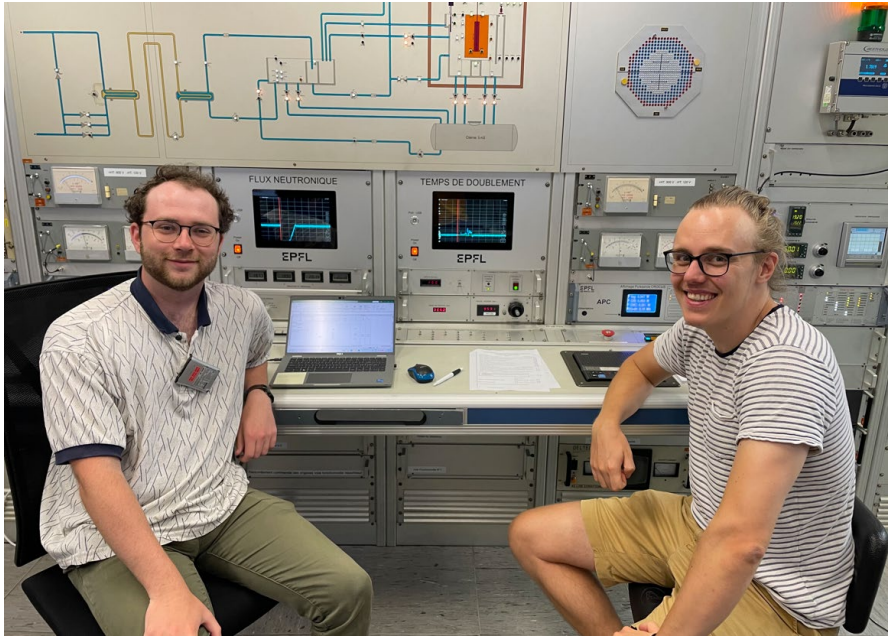
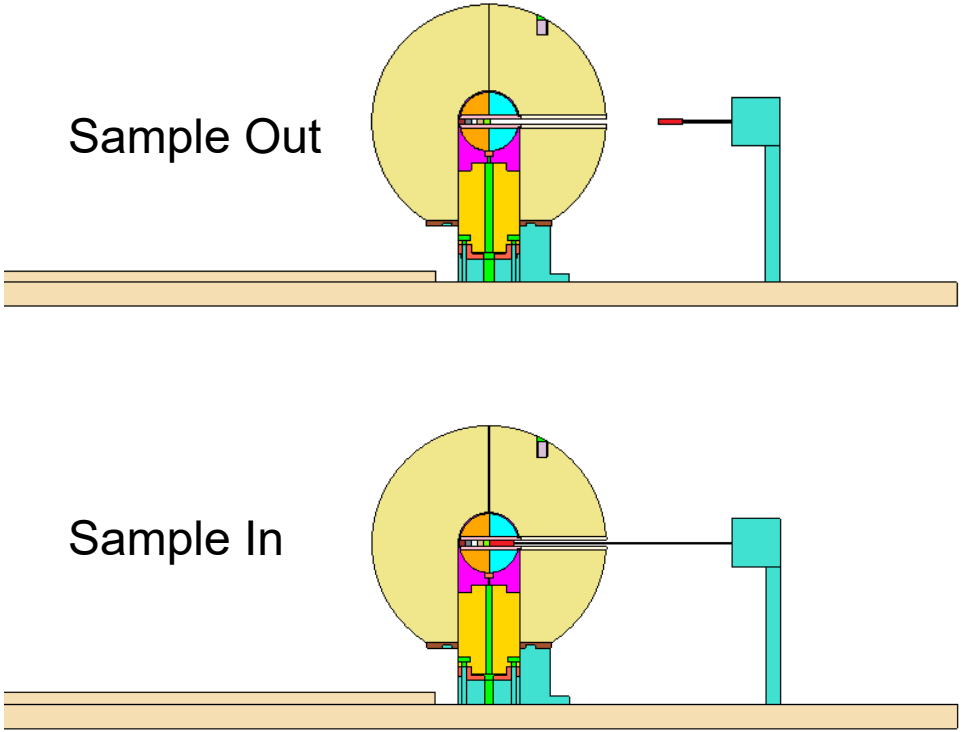




Future of Pile Oscillators

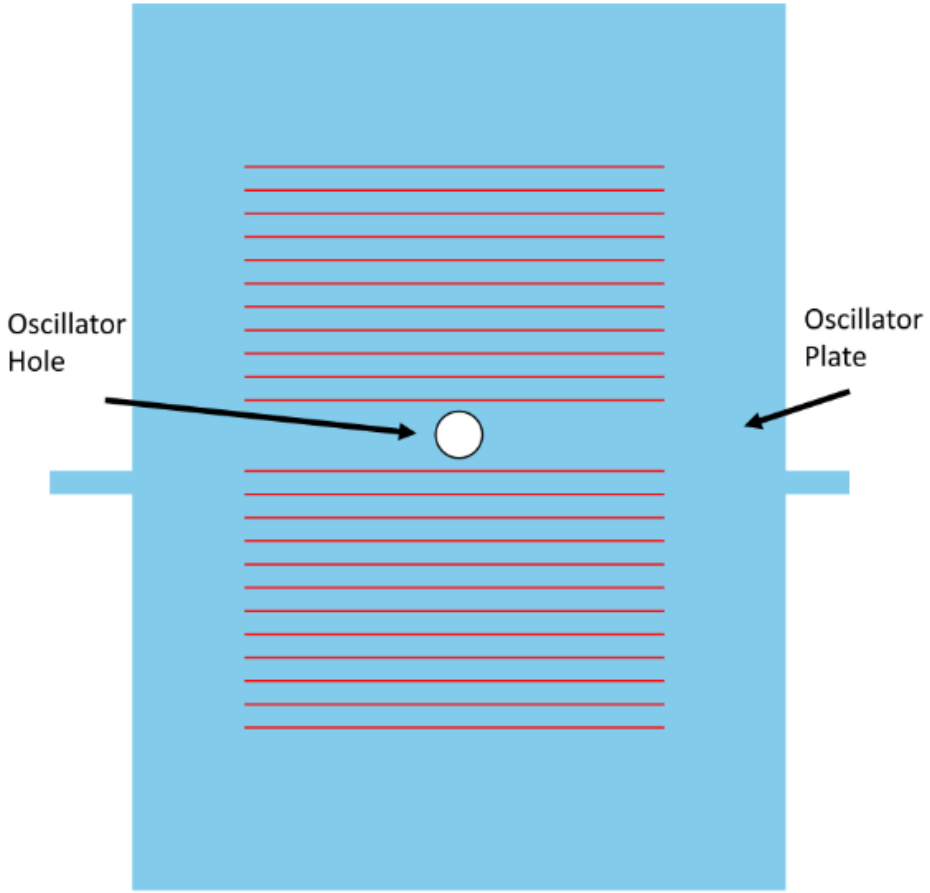
Flattop

- Our existing benchmark assemblies with glory holes (Godiva-IV and Flattop) can easily accommodate a linear oscillator



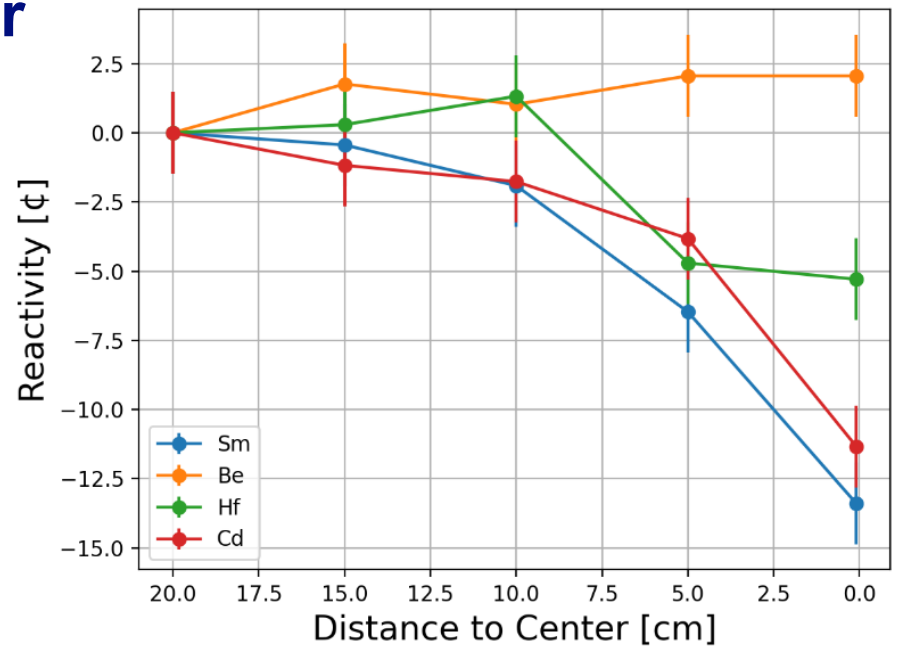
Class Foils

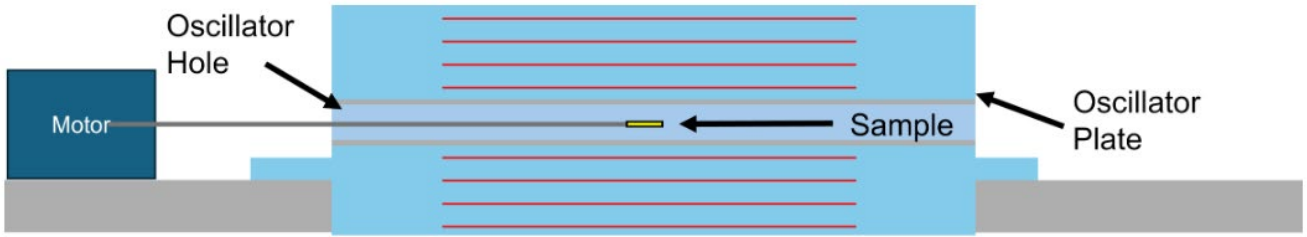
- Lucite Class Foils experiments with additional central plate with a 1” diameter thru hole to accommodate a rotary or linear oscillator



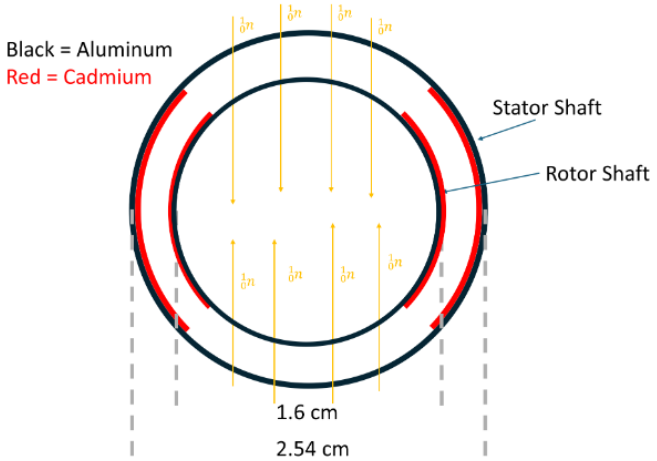
Class Foils – Linear Oscillator

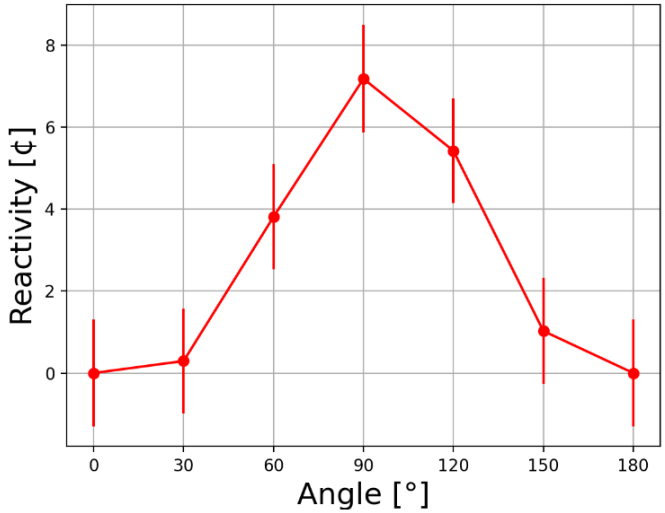
- Simulations of the linear oscillator were performed using a small sample of various materials of interest to NCSP as per the 5 year plan.
- These samples include Cadmium, Hafnium, Samarium, and Beryllium.
- For simplicity, all samples were long, modeled as a 3 cm 2 mm thick wire.

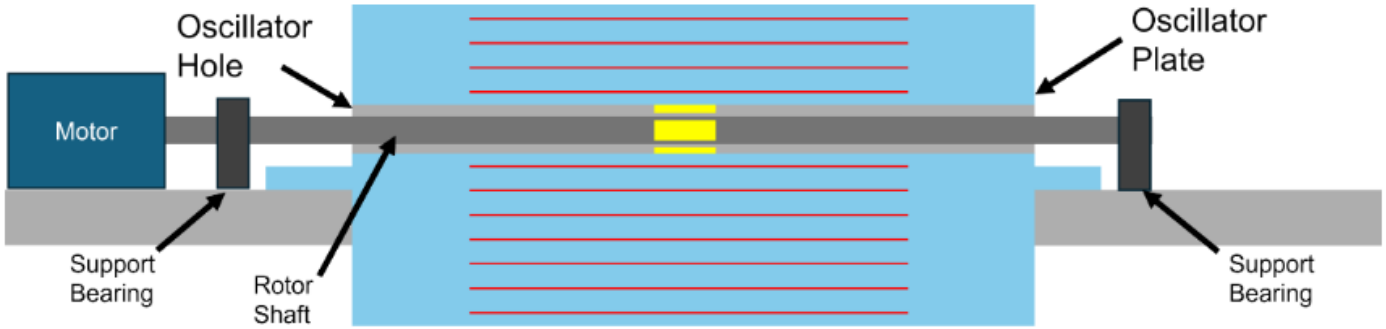




Class Foils – Rotary Oscillator

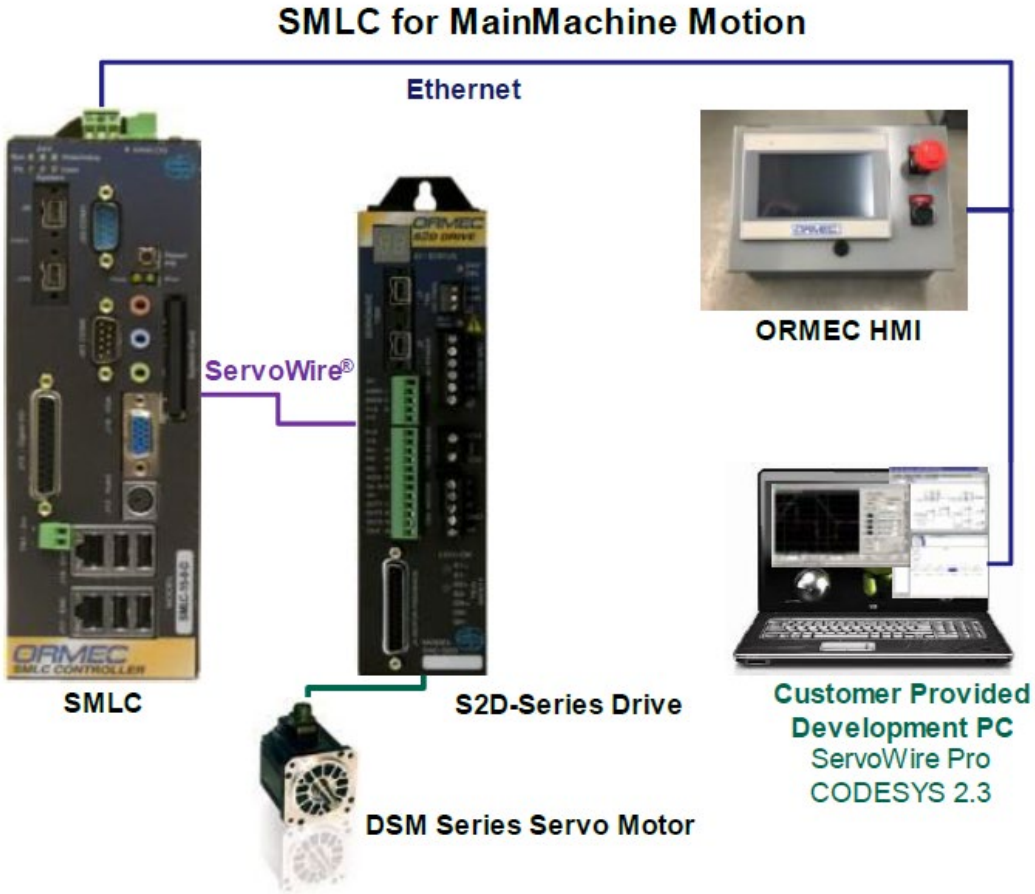






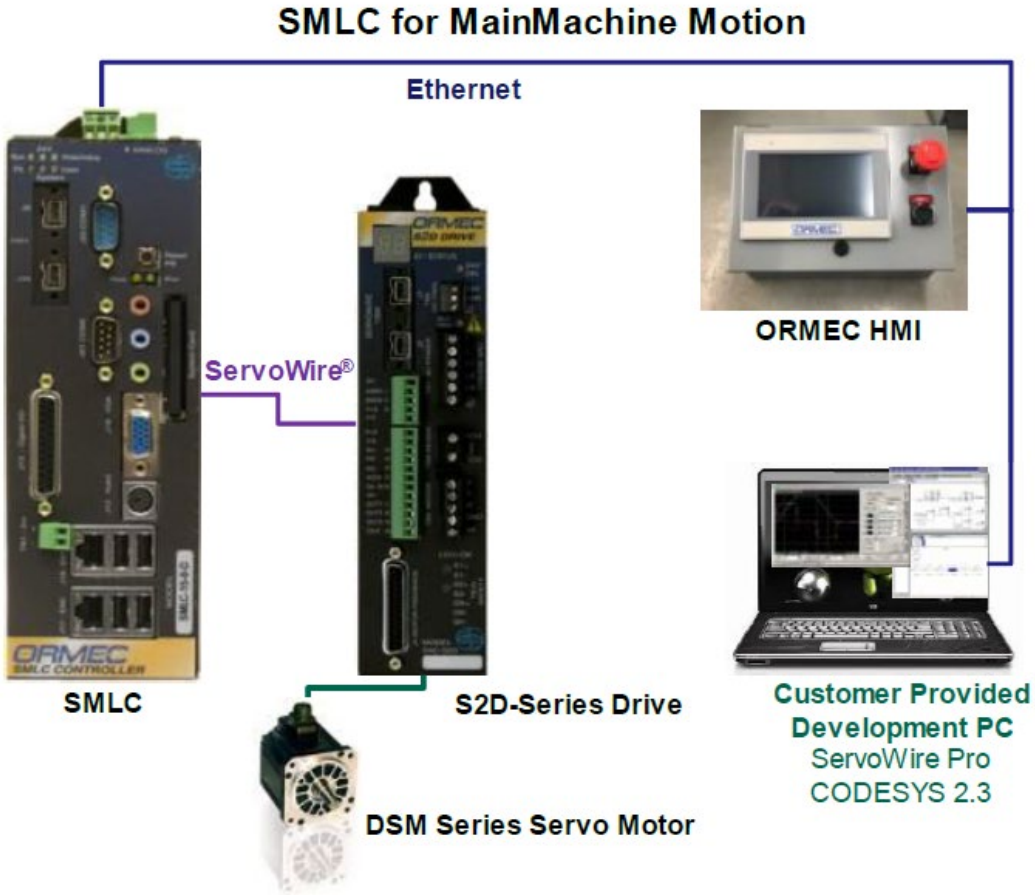
Proposed System

- Quote received from ORMEC for system that could meet our needs at NCERC
- Can provide linear and rotary oscillations with the same motor and control system



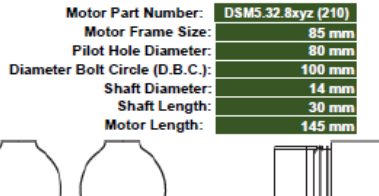
Proposed System

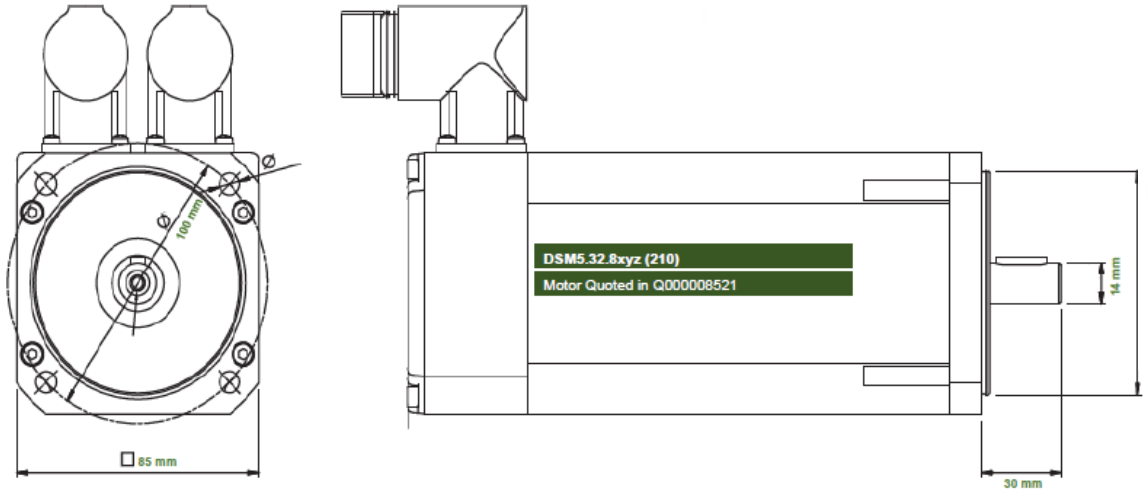
- Motor and motor controllers housed in room with the critical assemblies
- Communication via Ethernet to control room
- Oscillator controlled by HMI and/or Laptop

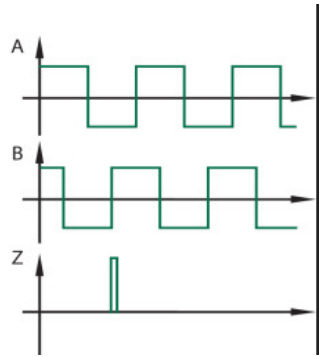


Proposed System - Motor

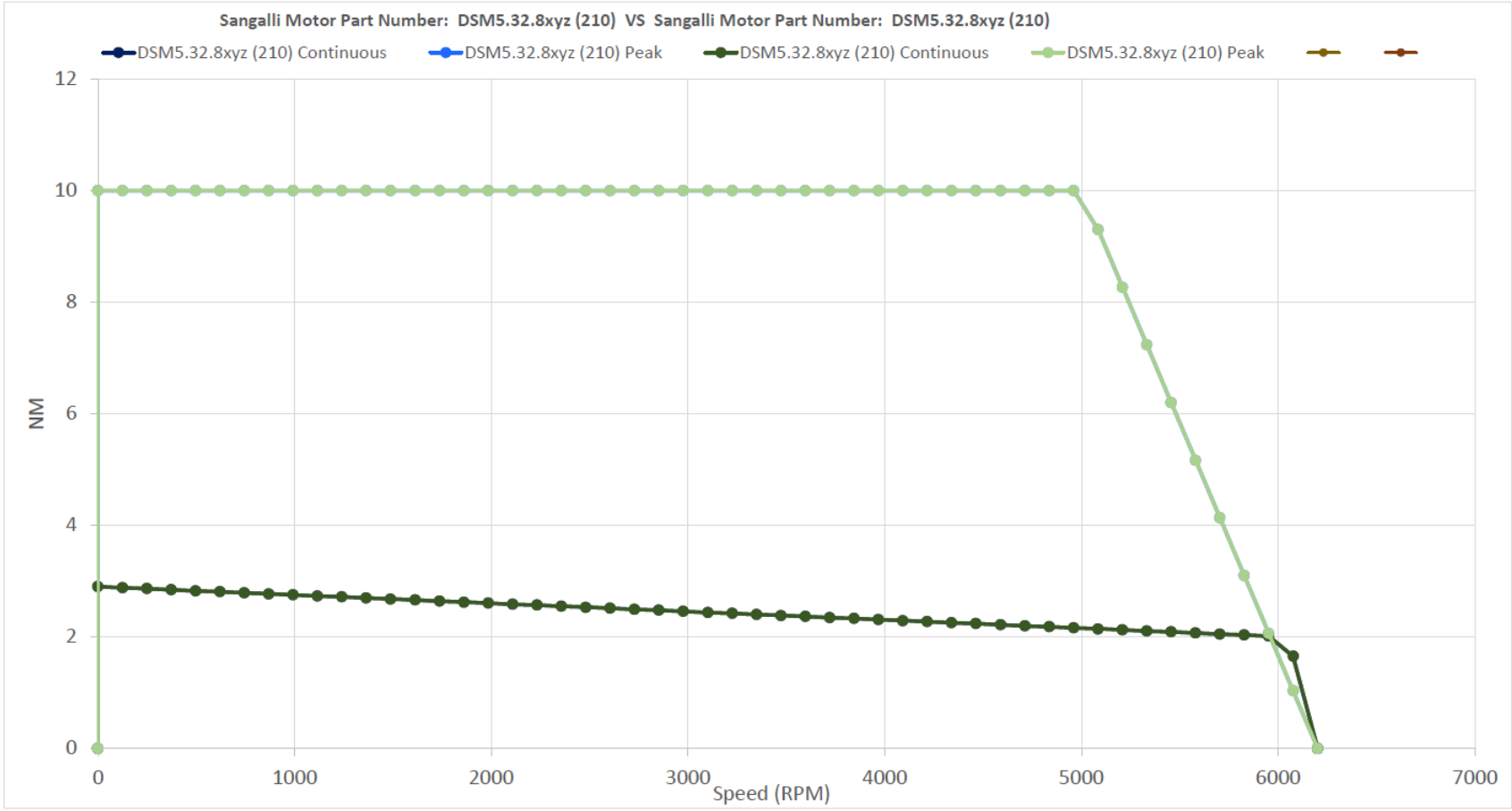
- Motor will have an integrated optical encoder that provides 16,384 pulses per rotation. ORMEC is modifying this to allow us to receive these pulses to our radiation detection equipment to allow the synchronization of the oscillator position to detector responses







Proposed System - Motor



Conclusions

- Oscillator experiments can be performed at NCERC.
- These experiments have been proven to be useful for nuclear data measurements for criticality safety purposes and kinetics measurements for code and nuclear data validation at other facilities.
- A simple oscillator system can be procured and demonstrated on an existing experiment.

Acknowledgements

- This work was supported by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy.

Questions?

Reactor Kinetics Measurements

- Oscillator Method
  - Periodic reactivity oscillations into a critical system, relate the systems response to the Reactor Transfer Function. Fit experimental data to get $\boldsymbol{\beta_{eff}}$ and $\boldsymbol{\beta_i}$ groups.

$$H(\omega) = \frac{N(\omega)}{\rho(\omega)N_0} = \left(\omega\Lambda + \sum_i \frac{\omega\beta_i}{\omega + \lambda_i}\right)^{-1}$$