U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

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Title: **Miniature, Scintillation-Based, In-Core, Self-Powered Flux and Temperature Probe for HTGRs**

Currently available instrumentation will not function at the core temperatures of high-temperature, gas-cooled reactors (HTGRs). The traditional response to this is to move core-monitoring instrumentation out-of-core. However, more accurate flux and temperature profiles can be obtained from distributed point measurements located directly within the core. In-core distributed point measurements improve the assurance of core integrity by immediately indicating a local flux or temperature excursion. Core physics models can be made more accurate and precise with point in-core measurements. This allows higher fuel burn-up and more efficient loadings as well as more uniform power distributions that potentially allow a higher overall power rating.

The objective of the proposed project is to develop a miniature scintillation-based, in-core, self-powered neutron flux and temperature probe. The probe would be generally applicable to any reactor technology, but would be specifically designed for the higher temperatures of HTGRs. The scintillation assembly consists of a thin layer of neutron converter (boron, uranium, or a lithium alloy) placed against a few microns thick film of scintillator. Both the converter layer and the scintillator are segmented as shown in Figure 1 to allow for the roughly ten orders of magnitude flux variance from source to power range operation. The scintillator for the source range operation is excited by a relatively large amount of converter to provide a high number of pulses under source range operation. The power range scintillator has a smaller amount of neutron converter to allow pulse mode operation under extremely high fluxes. The scintillators for the two different regions produce different wavelength light allowing independent readout of the scintillation pulses. Neutron flux is indicated by a weighted sum of the number of scintillation pulses produced by each scintillator. The weighting function yields a continuous measure of flux thereby preventing range transfer offset errors. Total pulse count history is used to compensate for burn-up of the converter atoms. The detector will have minimal gamma pulse response due to the thinness of the scintillation layer. The thinness of the scintillator layer also minimizes the effects of the increased self-absorption (radiation darkening) with use of the scintillator material.

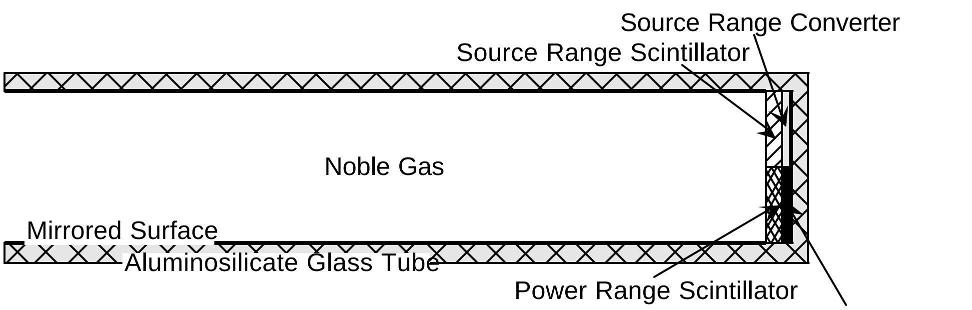

Figure 1—Probe Tip Structure

The scintillation light is guided out of the core by a hollow core optical fiber. Hollow core optical fibers are tubes with interiorly mirrored surfaces. For the temperature region of HTGRs, an aluminosilicate glass tube (likely filled with a noble gas) mirrored with either a platinum or molybdenum alloy will serve at the hollow core fiber. Upon exiting the reactor vessel (reaching an appropriately low temperature and dose region) the fiber will transition to a flexible hollow core fiber. Finally, at the containment boundary, the fiber will again transition to a large core, high radiation tolerance (pure silica core, fluorosilica clad) optical fiber which will transmit the scintillation light to a benign environment. At the equipment cabinet, the light will be separated by wavelength, the scintillation pulses converted to electrical signals, and the number and shape of each type of pulse recorded.

The scintillator temperature determines the shape of the scintillation pulses. The scintillation pulses become progressively shorter in duration with increasing temperature. The scintillators used will be selected so as to have a pulse duration/shape variance over the temperature range occurring in the reactor when they are producing temporally separated scintillation pulses. The scintillator coupled to larger amounts of neutron converter (source range scintillator) will have pulse shape variance from roughly twenty-five to a few hundred degrees Celsius. The power range scintillator will have a pulse shape variance with temperature from roughly 500 °C upwards. If possible a simple analog signal processing scheme will be implemented based upon relating fluorescence decay rate to an easy to measure amplifier timing property (zero crossing time for example). If necessary, however, more advanced signal processing (Fourier transform or Wavelet based analysis) will be implemented, digitally relating details of the pulse shape to the fluorescence decay rate.

The major project tasks will be as follows:

- Develop the scintillator materials necessary to cover the full core flux range in pulse mode.

  The major subtasks of this task will be to design an appropriate refractory lattice and activator combination (Y_2O_3:Ce for example) with an appropriate scintillation pulse duration, shape, wavelength, and intensity, produce films of the material, measure the film performance, and correlate the performance to the material form and fabrication characteristics.

- Develop the requisite pulse measurement, processing and recording logic, electronics, and optics.

- Develop the hollow core optical fibers necessary for insertion into the reactor core.

- Experimentally verify the system performance and endurance in an HTGR environment.