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


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**Institution: Ohio State University**

**Collaborators: University of Akron, Westinghouse Electric Company**


**Title: An In-Core Power Deposition and Fuel Thermal Environmental Monitor for Long-Lived Reactor Cores**


The three Generation IV reactor designs currently supported by the DOE have the common characteristic that they are expected to operate up to 15 years with a sealed core. These reactors will be built, operated and disposed of without access to the core, minimizing opportunities for proliferation and for servicing. Monitoring the power distribution and coolant conditions of such a reactor poses a challenge. Serviceable ex-core sensors can only monitor neutron flux on the periphery of the core. Existing in-core sensors do not have sufficiently long lifetimes, with the possible exception of low-sensitivity platinum SPNDs. We therefore propose to develop a new sensor that is particularly well suited for use in a sealed reactor core, and to apply this sensor to produce a robust in-core monitoring system that is suitable to all three reactor designs.

The sensor is fabricated from a small kernel of actual reactor fuel sealed in a metal tube that provides a thermal conduction path to the coolant. A small electric heating element surrounds this fuel/tube assembly. The total heat flux from the fuel kernel and electric heater is measured by differential thermocouples placed on the conduction path. The heater is then controlled by feedback from the thermocouples, such that a constant heat flux is maintained regardless of the nuclear energy generation in the fuel kernel. The input electrical power provided to the heater is thus inversely related to the actual nuclear energy generation. Because the temperature of the sensor remains nearly constant, the sensor will have a better time response than that of a similar uncontrolled sensor.

This controlled calorimeter concept, denoted the constant-heat flux power sensor (CHFPS), is well-suited for use in a sealed core. It will give the local nuclear power generation, including decay heat, so it can be used to monitor thermal limits during operation, post-shutdown, and in permanent storage. The sensor will be fixed to, and will deplete with, the local fuel, so no compensation for depletion will be required. The sensor will simply act like the surrounding fuel over the entire core lifetime. Unlike any other sensor, this sensor is in a feedback control loop. This means that the sensor dynamic response can be monitored, allowing measurement of the heat transfer characteristics of the coolant while simultaneously measuring the generated power. In addition, feedback control combined with modern signal processing techniques offer a means of evaluating the sensor calibration and performance *in-situ.* We expect that the sensors could operate with substantial degradation given this capability, an important feature in a sealed-core reactor. The basic performance characteristics of this type of sensor, very high sensitivity combined with good bandwidth, have already been proven through testing of an earlier design of controlled calorimetric sensor.

We thus propose to design, fabricate, and test CHFPS sensors, along with the supporting digital control and signal processing capabilities, using fuel materials specific to the DOE-supported Generation IV reactor designs. The sensor design will include a high degree of internal redundancy. This sensor will then be incorporated, with other complementary neutron flux or temperature sensors if advantageous, into an integrated in-core monitoring system with a high degree of external redundancy and *in-situ* diagnostic capability. This final monitoring system is expected to provide a high degree of reliability, safety, operating efficiency and flexibility for each of the three DOE-supported Generation IV reactors.