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Self-powered sensors to monitor nuclear fuel rod status

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Japan's Fukushima Dai'ichi nuclear disaster that occurred in 2011—a result of the strongest earthquake on record in the country and the powerful tsunami waves it triggered—underscored the need for a method to monitor the status of nuclear fuel rods that doesn't rely on electrical power.

During the disaster, the electrical power connection to the nuclear reactor failed and rendered back-up electrical generators, coolant pumps, and sensor systems useless. The nuclear plant's operators were unable to monitor the fuel rods in the reactor and spent fuel in the storage ponds.

To address this issue, Penn State researchers teamed with the Idaho National Laboratory to create a self-powered sensor capable of harnessing heat from nuclear reactors' harsh operating environments to transmit data without electronic networks. The team will present their research at the Acoustical Society of America's upcoming 164th Meeting, October 22-26, 2012, in Kansas City, Missouri.

"Thermoacoustics exploits the interaction between heat and sound waves," explains Randall A. Ali, a graduate student studying acoustics at Penn State. "Thermoacoustic sensors can operate without moving parts and don't require external power if a heat source, such as fuel in a nuclear reactor, is available."

Thermoacoustic engines can be created from a closed cylindrical tube—even a fuel rod—and a passive structure called a "stack."

"We used stacks made from a ceramic material with a regular array of parallel pores that's manufactured as the substrate for catalytic converters found in many automotive exhaust systems. These stacks facilitate the transfer of heat to the gas in a resonator, and heat is converted to sound when there's a temperature difference along the stack," Ali elaborates.

When a thermoacoustic engine operates, an acoustically driven streaming gas jet circulates hot fluid away from the heat source—nuclear fuel—and along the walls of the engine and into the surrounding cooling fluid.

Penn State and Idaho National Laboratory are also investigating using thermoacoustic sound to monitor microstructural changes in nuclear fuel, measure gas mixture composition, and to act as a failsafe device in emergency situations.

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