

NUCLEAR FUEL POST-IRRADIATION EXAMINATION EQUIPMENT PACKAGE

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ABSTRACT

Hot cell capabilities in the U.S. are being reviewed and revived to meet today's demand for fuel reliability, tomorrow's demands for higher burnup fuel and future demand for fuel recycling. Fuel reliability, zero tolerance for failure, is more than an industry buzz. It is becoming a requirement to meet the rapidly escalating demands for the impending renaissance of nuclear power generation, fuel development, and management of new waste forms that will need to be dealt with from programs such as the Global Nuclear Energy Partnership (GNEP).

Fuel performance data is required to license fuel for higher burnup; to verify recycled fuel performance, such as MOX, for wide-scale use in commercial reactors; and, possibly, to license fuel for a new generation of fast reactors. Additionally, fuel isotopic analysis and recycling technologies will be critical factors in the goal to eventually close the fuel cycle. This focus on fuel reliability coupled with the renewed interest in recycling puts a major spotlight on existing hot cell capabilities in the U.S. and their ability to provide the baseline analysis to achieve a closed fuel cycle.

Hot cell examination equipment is necessary to determine the characteristics and performance of irradiated materials that are subjected to nuclear reactor environments. The equipment within the hot cells is typically operated via master-slave manipulators and is typically manually operated. The Oak Ridge National Laboratory is modernizing their hot cell nuclear fuel examination equipment, installing automated examination equipment and data gathering capabilities.

Currently, the equipment has the capability to perform fuel rod visual examinations, length and diametrical measurements, eddy current examination, profilometry, gamma scanning, fission gas collection and void fraction measurement, and fuel rod segmentation. The used fuel post-irradiation examination equipment was designed to examine full-length fuel rods for both Boiling Water Reactors and Pressurized Water Reactors.

Introduction:

With an increasing demand for energy worldwide, it is incumbent upon the nuclear industry to operate economically and safely. “The current fleet of U.S. nuclear power plants produces some of the country’s most economical electric power, largely because of the relatively low cost of nuclear fuel. But new operating strategies aimed at enhancing plant and fuel performance have also led to increased fuel failures in recent years – a problem that threatens nuclear’s cost competitiveness,” states Taylor Moore in an Electric Power Research Institute Journal entitled *The Challenge of Nuclear Fuel Reliability*. While these fuel failures do not impair the safe operations of the plant, they do require an understanding of why they happen and how they can be prevented. Often the best way to understand fuel performance is via destructive testing...a hot cell examination.

Oak Ridge National Laboratory (ORNL), managed by UT-Battelle LLC, contracted with AREVA NP Inc. in May 2005, to design and build a nuclear fuel post-irradiation examination (PIE) equipment package for installation in ORNL’s Irradiated Fuels Examination Laboratory Building 3525, Oak Ridge, TN. The purpose of this equipment is to provide automated and remote capability for non-destructive and destructive examinations of full-length irradiated nuclear fuel rods and control rods entirely within a hot cell. Most of the U.S. hot cells that can perform fuel rod examinations cannot accommodate 12- to 14-foot (3658 to 4267 mm) fuel rods. The equipment is designed to accept most types of Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR) fuel rods with fuel rod outside diameters from 0.375 to 0.630 inches (9.53 to 16.00 mm), and 12 to 170 inches (305 to 4318 mm) in length.

The equipment is a modular design to allow assembly and calibration in the hot cell without human intervention. Many of the PIE equipment in-cell components can be installed through a 10-inch (254 mm) diameter hot cell port opening. The remainder will be installed through a 4-foot by 8-foot (1219 by 2439 mm) opening in the roof. This modular design will permit discrete portions or components of the package’s individual work stations to be removed from the hot cell and placed in a connecting glovebox for maintenance and repair or replacement. The modular concept will also accommodate future expansion to perform inspections and examinations that may be improvements or that were not specified in the original equipment specification.

Capabilities:

The package provides the capability to perform the following automated and remotely operated examinations:

- Visual examination
- Accurate end-to-end length measurements
- Indexing for precision length cutting
- Profilometry (multiple diameters and lengths)
- One-dimensional axial Gamma scanning
- Eddy-current examination (encircling coil and pancake surface coil)
- Fission gas capture
- Fuel rod void fraction measurement
- Fuel rod cut-off capability

Data from the examinations is recorded and archived electronically in a stand-alone state-of-the-art computer system designed and assembled by AREVA NP. The data will be oriented to the fuel rod axial and radial positions.

Summary and Results:

The design phase of the Nuclear Fuel Post-Irradiation Examination (PIE) Equipment Package is complete. The fabricated parts and procured components have been assembled into their respective modular systems. The subsystem and integrated system have completed their operational diagnostics. The fully assembled and operational package has undergone acceptance testing in late 2006. The results of the tests indicate that the equipment was able to accurately measure, acquire and record fuel rod parameters from calibrated test samples. Installation of the package in the Oak Ridge National Laboratory, Irradiated Fuels Examination Laboratory Building 3525 is scheduled for early 2007.

Package System Equipment Descriptions

Runways

There are three runway sections, each approximately 10 feet (3048 mm) in length that are doweled and bolted together to form a 30 foot (9144 mm) long platform to permit axial movements of the fuel rods for the various inspections and examinations to be performed. After placement of the runways within the hot cell, a laser is placed in the collimator and is used to vertically align the collimator and the fuel rod centerline at the Measurement Station. After alignment of the Measurement Station, the remaining modules can be installed on the runway. The runways form the base for the modular measurement station, cut-off saw station and the fission gas capture station.

The runways contain roller assemblies, which support the fuel rods. Each roller assembly is independent and can be removed or replaced for repairs.

Cut-Off Saw

The cut-off saw is used to cut areas-of-interest segments from the full-length fuel rod. The electric driven saw has a diamond impregnated blade that is used to make the cuts. The blade rotates at a low speed to reduce the spread of contaminated materials and fuel particles. A shallow pan of water is used to cool and lubricate the blade, and helps to collect particles for the cutting. Remote manipulators are used to position the fuel rod in the clamping vise and are used to operate the saw during cutting.

Gamma Detector and Collimator

The collimator and gamma detector are mounted in a hot cell port penetration that is aligned with the measurement station. After the laser alignment of the runway and the measurement station, the laser is removed and the sodium iodine detector is mounted in the collimator. The stainless steel collimator is sealed in the penetration with o-rings. The hot cell end of the collimator has a sapphire window covering this aperture and is also sealed with an o-ring. A negative air pressure between the contaminated and non-contaminated sides of the hot cell, seals prevent radioactive materials and shine in conjunction with a sliding wedge actuator from the worker area. The electronics to support the detector is contained in the electronic equipment rack.

Fission Gas Capture

Fuel rod fission gas is collected via a rod puncturing device and collection system that is under a vacuum at all times. The fuel rod is positioned in the puncture device with remote manipulators. After the rod is sealed in the puncture device, the system is evacuated with a vacuum pump to purge the system and verifies the system is in a leaktight condition. Once the system determined to be leak tight and under a vacuum, the rod is punctured and the pressurized fission gas is captured in a specimen vial. The system is backfilled with an inert gas and any radioactive gas and particles are discharged into the hot cell where the hot cell off gas system can remove any radioactive material. Upon verification that the system is purged of all radioactive material, the specimen vial can be disconnected and transported to the chemical assay laboratory for analysis. The system is used to determine the fuel rod void fraction measurement using the Ideal Gas Law principles, and includes a thermocouple for measuring the fuel rod temperature and the hot cell ambient temperature.

Measurement Station

The measurement station is used to perform profilometry and ultrasonic (eddy current) non destructive examinations of the fuel rod. The station draws the fuel rod into the measurement zone using motorized pinch-rollers and moves the rod axially through the encircling eddy current coils or a flat pancake coil. The rod is rotated by the use of motorized slip rings and will acquire data while the rod is moved axially and rotated. Four linear variable differential transformers (LVDT) are equally spaced around the rod to measure the fuel rod diameter along its length. The axial and data measurements are acquired by resolvers as is the rotation orientations. All the data and power are transmitted to and from their respective components via protected wiring and through the slip rings to the electronic equipment rack.

Operator Console and Electronic Equipment Rack

All the hot cell external data acquisition hardware, computer and data storage, keyboard, motor/driver controllers, gamma detector unit, power supply are housed in a 2-bay wide rack. The rack has casters which permit the unit to be moved to a hot cell window and permits the operator to have a view of the hot cell activities and a convenient work station to operate and monitor the data collection.



Figure 1 - Runways



Figure 2 – Measurement station

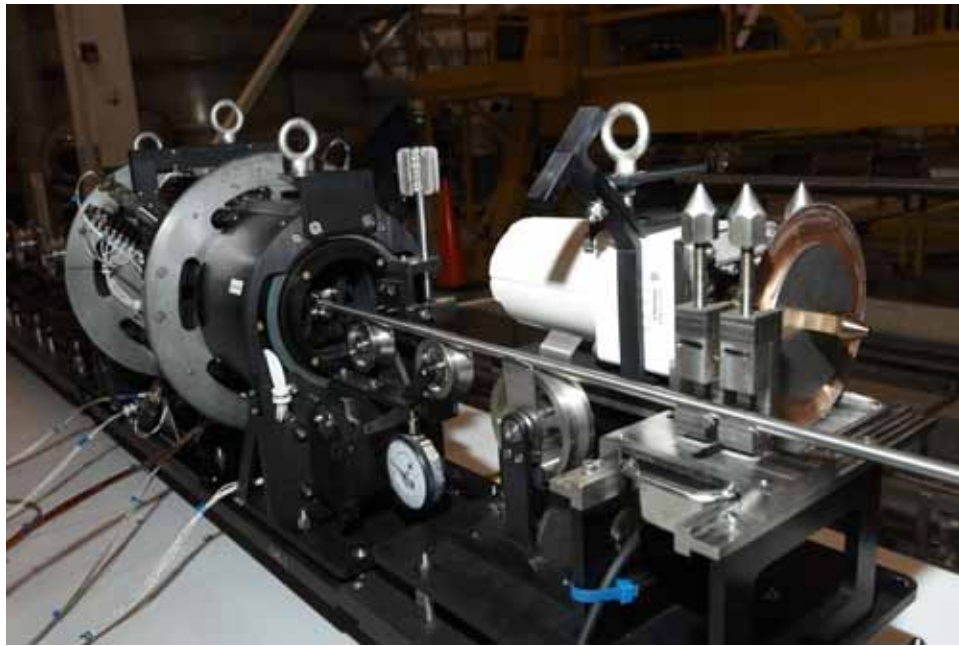


Figure 3 – Cut-off saw

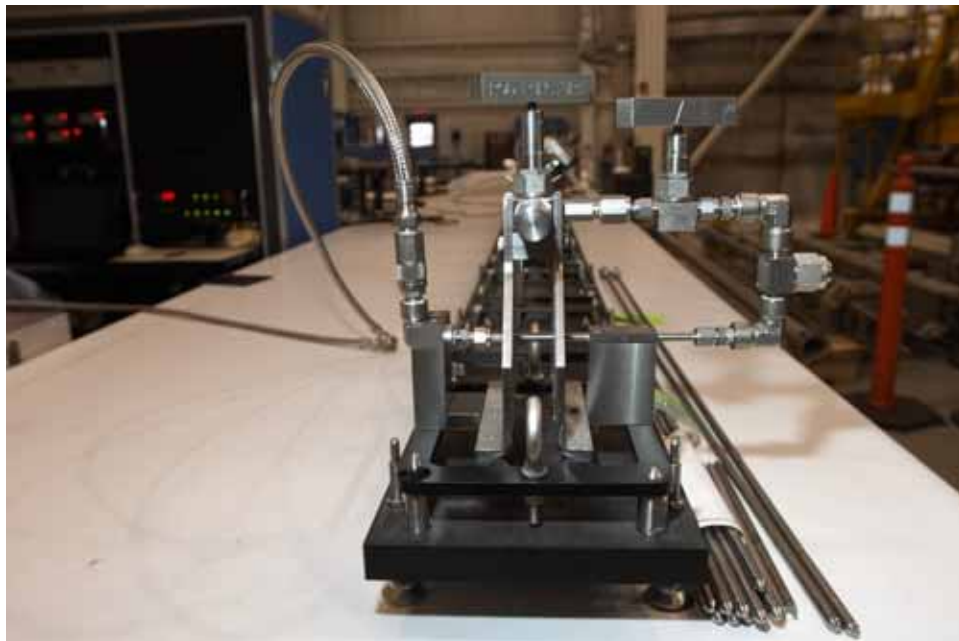


Figure 4 – Fission gas capture station hot cell



Figure 5 – Fission gas capture console

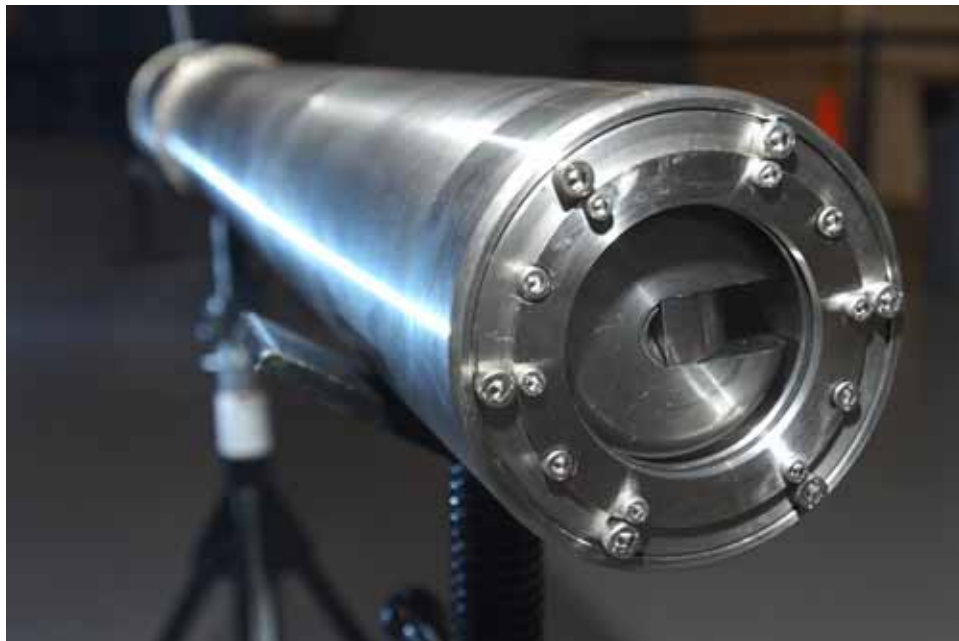


Figure 6 - Collimator

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Figure 7 – Operating console and electronics equipment rack