3/11/2014
79FR13685

6

May 4, 2014

Ms Cindy Bladey
Chief, Rules, Announcements, and Directives Branch (RADB), Office of Administration
U.S. Nuclear Regulatory Commission
Mail Stop: 3WFN0644M
Washington DC, 20555-0001

Subject: Comments on "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," Docket ID NRC-2014-0040

Dear Ms Bladey:

In response to the subject NRC draft generic letter about degradation of neutron-absorbing materials in spent fuel pools, our Comments, "Monitoring Spent-fuel Pools," are submitted in the attachment.

Please advise when a public meeting is scheduled.

Sincerely,

Alexander DeVolpi, PhD
Nuclear Applications Company, 1391 Corte Paguera, Oceanside, CA 92057
(Nuclear.Applications.Company@gmail.com; 760 637 2858)

MS
Mehdi. Sarram, PhD,
Energy Security Consulting Group, 6760 Estrella De Mar Road, Carlsbad CA 92009
(msarram@energyscg.com; 508 298 8100)

Attachment: "Monitoring Spent-Fuel Pools"

MONITORING SPENT-FUEL POOLS

Summary

Sealed vertical arrays of gamma-radiation detectors are proposed in order to fulfil the requirements of Generic Letter NRC-2014-0040, issued March 11, 2014, requesting submittal of information regarding surveillance of neutron-absorbers in spent fuel pools (SFPs) at nuclear-power plants (NPPs).

Such radiation-monitoring instrumentation would not only provide surveillance of SFP neutron-absorbing materials, the instruments would simultaneously measure changes in water level and density. The addition or improvement of SFP water-level monitoring devices has been called for (or mandated) by national and international regulatory authorities.

The monitors advised herein would consist of one or more vertical arrays of R&D-proven collimated ("hodoscope") gamma-ray detectors, arranged at uniform underwater elevations from top to bottom of SFPs. The hermetically-sealed, highly-redundant vertical detection array could be placed at any available spent-fuel storage-grid location, and could be shifted by crane as needed to other locations.

These radiation monitors in the SFP would also provide comparative information about reactor fuel-burnup profiles.

Technology Making Use of Spent-Fuel Decay Radiation

Nuclear-decay radiation provides a tangible, reliable, and enduring means of monitoring some stored-fuel-assembly properties, as well as SFP water level.

Irradiated NPP spent fuel releases decay heat initially with intensity of many kW/tonne, down after ten years to 1 kW/tonne, as illustrated in Figure 1. Fuel-rod decay heat is largely the result of beta and gamma radiative emission from fission and actinide buildup.

Long-term decay radiation from each fuel rod and fuel assembly depends on specific burnup history, which will be affected by fuel location and repositioning in the reactor core.

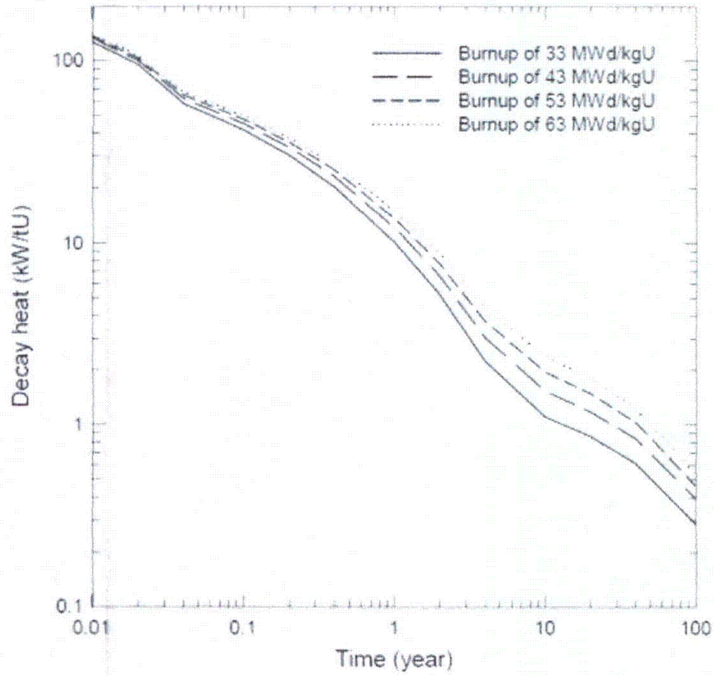

Figure 1. Typical reactor decay heat after shutdown

Nuclear fuel transferred to the SFP has usually undergone at least a year of burnup in a power reactor. Thus, the spent fuel constitutes an inherent source of ionizing and non-ionizing radiation, all of which might lead to secondary forms of penetrating emissions detectable at a distance after transmission through the materials and water inside the SFP.

Although most spent-fuel gamma radiation has energies in the order of a few hundred keV, some emission extends up to several MeV. High-energy gamma rays have a substantial transmission range before being absorbed in water. Typical 500-keV gamma-attenuation coefficients are in the order of 10% per cm of water. Thus, depending on the lateral distance of travel, a vertical hodoscope-type array of gamma detectors will respond to a radiation-profile related mostly to the nearest spent-fuel assembly.

One or more vertical arrays of collimated gamma-ray monitors stationed within the SFP grid would be situated near the most proximate sources of penetrating radiation from spent-fuel assemblies in the pool.

Relevant information on hodoscope-type monitoring systems can be found primarily in three published sources: "High-Resolution Radiography by Means of a Hodoscope," U.S. Patent 4,092,542 issued May 30, 1978 (expired); "Monitoring system for a liquid-cooled nuclear fission reactor," U..S. Patent 4,649,015 issued March 10, 1987 (expired); and "Applications of Cineradiography to Nuclear-reactor Safety," *Rev. Sci. Instrum.* *55* (1984).

Because of long storage durations in SFPs, gamma-ray data can be accumulated over lengthy recording intervals. Signal/background ratios can be improved as needed by systematically shuffling hodoscope gamma-ray monitoring arrays and/or fuel assemblies in the SFP. Recently irradiated spent-fuel assemblies will naturally have higher emission rates.

SFP Neutron-Absorber Monitoring

Spent fuel emits neutron radiation that is tangibly related to the (very small) risk of self-sustaining nuclear criticality in the water-filled pool. Neutron absorbers mounted around fuel assemblies in a SFP might degrade in time, thus increasing the nominally small risk of criticality. Any local increase in potential reactivity would result in added fission and capture radiation, leading to detectable gamma emission from the fuel.

NRC-2014-0040 Letter, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," requested information regarding technologies for monitoring neutron-absorbing materials in spent fuel pools (SFPs) with the goal of obtaining "reasonable assurance that the materials are capable of performing their intended safety function."

By making use of uninterrupted around-the-clock spent-fuel gamma-ray monitoring, as proposed herein, safety-related changes in subcritical reactivity that might result from reduced neutron absorption would be directly and reliably discernable during a time period commensurate with potential impact and response.

Hermetically-sealed vertical assemblies of the proposed collimated gamma-radiation-monitoring detectors, positioned at strategic radial grid locations in the SFP, would serve to monitor safety-related changes that might occur as a result of neutron-absorber deterioration.

Inasmuch as data would be analyzed over long periods of time, significant incremental or sudden deterioration of neutron absorbers would result in detectable radiation-source changes.

By monitoring over long periods of time any systematic changes in gamma emission, this proposed method would provide timely and continuous "reasonable assurance that the materials are capable of performing their intended safety function."

The same gamma-ray monitoring equipment, without additional equipment or modifications, can also serve to simultaneously inform other SFP safety-related and fundamental NPP operation parameters.

SFP Nuclear Water-Level Instrumentation

According to the U.S. NRC Tier 1 Spent Fuel Pool Instrumentation Order, "Plant operators [at Fukushima] couldn't determine how much water was in the pools during the accident."

National and international regulatory authorities have mandated or called for added or improved water-level monitors to be installed in SFPs. NRC issued an Order on March 12, 2012, requiring all U.S. nuclear power plants to install water-level instrumentation in their spent fuel pools. "The instrumentation must remotely report at least three distinct water levels: 1) normal level; 2) low level but still enough to shield workers above the pools from radiation; and 3) a level near the top of the spent fuel rods where more water should be added without delay."

The precipitating incident leading to the NRC Order was experience at Fukushima Dai-Ichi, where water level and water temperature in the seven spent fuel pools were unknown to the operators. No instruments had been required or installed to provide that data, even if power had been available.

To avoid that situation at U.S. nuclear plants, NRC has ordered plant owners to install instrumentation that would monitor water level down to a foot above where spent fuel assemblies are stored in pools.

In SFPs, an hermetically-sealed gamma-ray radiation-monitoring diagnostic system could be installed — similar or identical to that which would be implemented for neutron-absorber monitoring.

The radiation-monitoring diagnostic system would have a vertical detection range that extends, as needed, to both the top and bottom of the SFP, as well as preferably to provide uniform radial and circumferential reportage of water content. Each gamma-ray monitoring system would consist of self-contained, hermetically sealed units that would operate on minimal external power.

National and international regulatory authorities have mandated or called for added or improved water-level monitors be installed for SFPs — because of the large irradiated-fuel inventory stored in SFP facilities at reactor sites, and because of concerns that arose from the tsunami-induced loss-of-power at Fukushima Dai-Ichi.

If normal electrical power supply were lost, the SFP gamma-ray water-level monitoring system would be operable using emergency power supplies for a requisite extended period of time. The system would also be qualified to meet seismic, radiation, and other NRC requirements.

As previously described, the well-proven hodoscope nuclear-diagnostic system has consisted primarily of one or more arrays of collimated radiation detectors. Such vertically-arranged arrays record specific and continuous radiation data that is transmitted via wired or wireless circuitry for analysis to a computer.

The gamma-ray water-level monitoring system of this proposal would be installed at available fuel-assembly grid locations within the SFP. Such water-level monitoring is intended to be simultaneously sensitive to a full energy spectrum of incident radiation, typically from a few hundred keV to several MeV.

For many years after reactor shutdown or removal from the reactor and placement in a SFP, spent fuel is radiating with a useful percentage of its maximum steady-state irradiation level based on reactor burnup history (as illustrated in Figure 1).

In a SFP, changes in water level or density at any given elevation would sufficiently and promptly influence transmission of the lower-energy gamma radiation emitted from fuel rods. Upper-level radiation detectors would sense boundary conditions at the water-air interface, while detectors at progressively lower levels would be responsive to radiation proportionate to spent fuel burnup.

Moreover, radiation transmitted to detectors at different elevations would be responsive to and indicative of changes in other parameters — such as water density, turbidity, debris, air entrapment, temperature, and pressure, as well as other phenomena that influence radiation transmission through the intervening medium.

The SFP vertical gamma-ray collimated hodoscope monitors would also be sensitive to direct leakage of radiation from any ruptured cladding, as well as radioactive contaminants either in gaseous or dissolved form, depending on solubility and duration of suspension.

If more than one hodoscope-type vertical gamma-ray array is installed at other circumferential or radial locations, comparative-distribution information would result from continuous analysis of the combined data.

Other potential operational benefits accrue by using such water-level gamma-ray detection arrays in SFPs, inasmuch as reactor fuel stored in the SFP constitutes a sub-critical nuclear-reactor configuration, with reactivity normally suppressed by geometric dilution and neutron-absorbing poisons.

For non-nuclear types of instrumentation, few feasible options — if any — are available to obtain data with the same or similar meaningful significance, resolution, and range.

Measuring Spent-Fuel Burnup Profiles

Much decay heat from SFP fuel corresponds to or is caused by penetrating radiation that can escape from an assembly and thus become detectable. Collimated hodoscope-type detectors would be sensitive to the most proximate sources of radiation from spent-fuel assemblies in the pool.

If installed in SFPs, the proposed monitoring instrumentation would be able to record comparative gamma-flux-emission data for all nearby and aggregate spent fuel. By moving to the one or more vertical gamma-ray radiation-monitoring diagnostic systems selected spent-fuel elements closer of this application — or vice-versa — statistically better and more detailed gamma-flux profile data would be obtained.

A representative axial fuel profile (for a single 90-cm-long fuel pin) is shown in Figure 2. This profile is derived from a vertical array of collimated neutron detectors positioned about five meters from a single fuel pin irradiated in the center of a test reactor operating at low, steady-state power.

In a SFP, the long storage time for fuel assemblies provides a unique — otherwise unavailable — opportunity on a timely basis at minimal added cost to obtain radiation-profile data. That data might be of economic value to reactor owners and operators in optimizing fuel-burnup cycles.

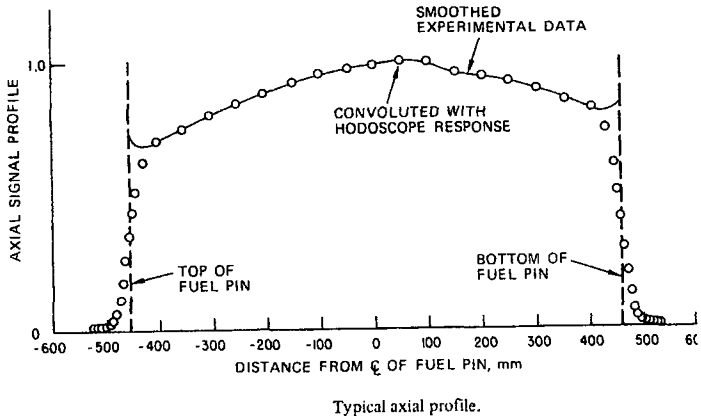

Figure 2. Axial radiation profile from a single fuel pin, as detected by a vertical hodoscope array.

Recap of Proposed SFP Instrumentation

Three significant and consolidated applications of gamma-ray monitoring in SFPs are proposed to meet current nuclear-safety and operational requirements, as well as provide ancillary benefits. The applications include surveillance of neutron absorbers, monitoring of water level, and profiling spent-fuel-assembly burnup. Vertical resolution in each application could nominally be 30-cm or less over the entire instrumented depth of the SFP.

C:\Users\Nac\Documents\NUCLEAR POWER\Nuclear Safety\NRC SFP\SFP Monitoring.013.wpd