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An In-Cell Alpha Detection System for Radioisotope Component Assembly Operations

Prepared for the U.S. Department of Energy
Assistant Secretary for Nuclear Energy

Westinghouse
Hanford Company Richland, Washington

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AN IN-CELL ALPHA DETECTION SYSTEM FOR RADIOISOTOPE COMPONENT ASSEMBLY OPERATIONS

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ABSTRACT

A remotely operated alpha detection system is being developed for use at the Radioisotope Power Systems Facility at the U.S. Department of Energy's Hanford Site. It will be used in hot cells being constructed to assemble components of Radioisotope Thermoelectric Generators for space power applications. The in-cell detection equipment will survey radiological swipe samples to determine smearable surface contamination levels on radioisotope fuel, fueled generator components, and hot-cell work areas. This system is potentially adaptable to other hot cell and glovebox applications where radiation dose rates and contamination levels are expected to be low.

INTRODUCTION

A remotely operated in-cell alpha detection system is being developed for use at the Radioisotope Power Systems Facility (RPSF). The RPSF is a new project currently under construction at the U.S. Department of Energy's Hanford Site located in southeastern Washington State. The facility will be located in the Fuels and Materials Examination Facility (FMEF) building, which is being modified for this new mission. The RPSF is being designed by and will be operated by Westinghouse Hanford Company[a] (Westinghouse Hanford) to produce radioisotope thermoelectric generators (RTGs) powered by ^{238}Pu for space power applications. The RPSF is being built for production of the same type of RTGs as those used by the National Aeronautics and Space Administration (NASA) to provide electrical power for the recently launched Galileo and Ulysses spacecrafts. The facility will have the flexibility to adapt its production capability as required to meet the needs of the DOE and NASA for production of other types of radioisotope-fueled power systems for both space and terrestrial applications.

The in-cell alpha detection system will be used to provide radiological measurements on swipes taken during hot-cell assembly operations in production of general purpose heat source (GPHS) modules used in RTGs. The design was conceived to simplify the radiological survey measurements and reduce operator exposure. This system is in keeping with the Westinghouse Hanford radiological design guidance, which promotes designs that reduce operator exposures to levels as low as reasonably achievable (ALARA). Mechanical and electrical

[a]Westinghouse Hanford is the operations and engineering contractor for the U.S. Department of Energy at the Hanford Site.

Fig. 1. RPSF Demonstration Hot Cell for GPHS Module Production.

design to support installation of the alpha detection system is being performed by Westinghouse Hanford. Pacific Northwest Laboratory[a] (PNL) Health Physics Instrumentation and External Dosimetry Section is providing hardware and documentation for operation, maintenance, and calibration of system instrumentation.

SYSTEM DESCRIPTION

Eight hot cells in the FMEF building currently are being remodeled to install the RPSF assembly line for production of GPHS modules. Figure 1 shows a view of the operations station at the face of one of the RPSF hot cells completed for testing and demonstration of GPHS module assembly capabilities. The in-cell alpha detection system will be used in six of these cells, four with argon and two with air atmospheres. Process specifications for smearable surface contamination levels are established for each assembly step to ensure product quality and prevent the spread of contamination, both between cells and outside of the cell boundaries.

Because the radioisotope fuel being handled in the hot cells is encapsulated in iridium cladding, loose or airborne contamination is not expected to be a problem for operation of an in-cell detection system. In-cell contamination control features such as ventilation hoods, fuel decontamination equipment and a dust collection unit will further ensure cell cleanliness. The design basis radiation dose for the fuel source was assumed to be 0.1 mSv/h gamma (10 mrem/h) and 0.6 mSv/h (60 mrem/h) neutron. The fuel source will be located approximately 2 m from the sample station enclosure, which will reduce the background activity to significantly below these levels. Shadow shielding also can be used at the radiation source location to reduce further the influence of background activity on process alpha survey measurements.

This in-cell alpha detection system was designed to simplify performing process alpha surveys while minimizing exposure of operations personnel to both radiation and contamination. The system consists of the in-cell sample handling and detection components, and the ex-cell detector controller and data acquisition system. A single RG58 coaxial cable provides the interface between the remote detector and the local controller/analyzer. The coaxial cable from the portable alpha monitor (PAM) detector is routed through the airlock penetration and into embedded conduit to the front face of the cell where it is terminated in a control console (see Figure 1). A portable controller/analyzer survey instrument is connected to the control console during hot-cell operations to provide a digital display of the alpha count. An Eberline Model ESP-2 smart portable ratemeter/scaler has been selected for use in this system. This controller/analyzer unit will be preprogrammed with a calibration factor determined by PNL to convert the counts per minute (cpm) to a digital display reading directly in disintegrations per minute (dpm) as required by process specifications.

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[a]Battelle Memorial Institute operates PNL, which provides technical, scientific, and other support services for the Hanford Site under contract DE-AC06-76RLO 1830.

In addition to providing a means for contamination control, the system will improve hot-cell operations by reducing the number of airlock transfers, which would otherwise be required to pass swipes out of the cell for process alpha surveys. Minimizing airlock transfers will reduce exposure to operations personnel by limiting interaction with potentially contaminated materials and by reducing task time for the assembly operations. It is estimated that the airlock transfer operation will take 5 to 10 min to complete purge and backfill, and material transfer operations. Each process step could require multiple surveys that would add significantly to operating times if an airlock transfer were required for each survey.

IN-CELL EQUIPMENT AND OPERATIONS

The in-cell equipment includes a remotely operated sample station enclosure with a hinged lid, shown in Figure 2. The enclosure contains the PAM detector probe and a sliding sample drawer with removable tray. The enclosure drawer is operated by a master/slave manipulator to remove and replace the sample tray. The hinged lid can be opened remotely to replace the PAM probe using a master/slave manipulator. The entire unit can be lifted and moved with the in-cell bridge crane for maintenance or removal from the cell through the airlock.

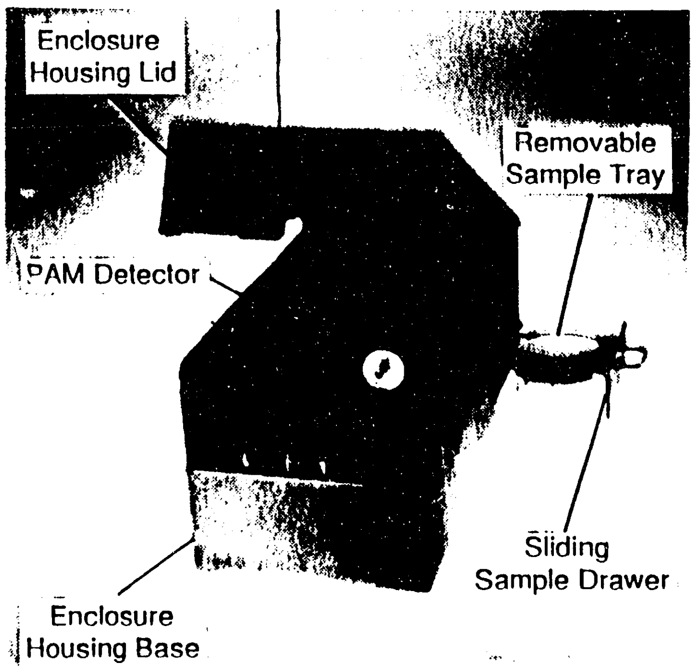

Fig. 2. Alpha Detection Enclosure.

To satisfy process quality requirements, swipes will be taken on iridium-clad ^{238}Pu fuel and fueled GPHS components during various stages of the assembly operation to determine surface contamination levels. The high temperature components are swiped with fiberglass filter paper either using a master/slave manipulator or in a gloveported workstation using forceps. The sample is placed on the tray in a disposable plastic holder lined with filter paper that can be changed between samples to prevent cross contamination. A master/slave manipulator places the tray into the drawer, which is closed to position the sample within 7 mm of the detector head. By controlling the positioning of the samples relative to the detector head, readings will be consistent and comparable.

PAM DETECTOR SELECTION

The PAM detector probe chosen for this application is a ZnS scintillation probe that routinely is used to detect and control contamination at the Hanford Site. These detectors are available from an instrument pool maintained for Hanford Health Physics operations. The PAM probe to be used has a 50-cm^2 active detection area, a 0.75-mg/cm^2 aluminized mylar light shield, and photomultiplier (PM) tube. The 10-stage PM tube is 3.8 cm in diameter and has a high efficiency bialkali photocathode. The major advantage of using this type of detector is that it is totally assembled and tested on the Hanford Site; consequently, detectors can be screened for low neutron and gamma sensitivity and are modified easily for use in nonroutine applications such as the RPSF in-cell system.

In this application where the detector and controller will be separated by a distance of more than 10 m, a preamplifier will be incorporated within the PM tube base to overcome signal cable capacitive losses. Furthermore, the argon environment in four of the hot cells will necessitate hermetically sealing the PM tube assemblies and equipping them with a special high voltage connector. The detector operates at a high voltage and if sealing precautions are not taken, the unit could be damaged as a result of the dielectric properties of the argon gas.

Since detector background counting rates could potentially mask lower levels of process detection, PAM probes will be tested to ensure that they exhibit low neutron and gamma sensitivities. Preliminary tests conducted to establish detector responses to fast neutron fields revealed a significant sensitivity difference between otherwise identical detectors. Specifically, PAM probe responses ranged from 50 to 350 cpm when exposed to a 0.6 mSv/h (60 mrem/h) unmoderated ^{252}Cf neutron source. The PAM probes are nominally 15% efficient for detecting unattenuated ^{238}Pu alpha particles. Monitoring 50 to 2,000 dpm process swipes will require the selection of detectors with neutron response characteristics at the lower end of this range. Although PAM probe gamma sensitivity is significantly less than that exhibited as a result of neutrons, alpha detectors also will be screened to minimize background counting rates due to gamma ray fields. Specifically, probes will be rejected as gamma-sensitive if any counts are observed from the probe when exposed to a .04 Sv/h (4 R/h) gamma field for 15 sec. In addition to selecting detectors exhibiting low sensitivity to neutron and gamma radiation, placing shadow shielding around the source can be used to minimize interference from background activity.

EX-CELL EQUIPMENT AND OPERATIONS

Electronic support of the in-cell alpha detector will be provided by a commercial microcomputer-based counting system designed to support portable contamination control detectors. The instrument will be connected to a control console at the operations station as each cell is prepared for GPHS module assembly operations (see Figure 1). Data from process alpha survey instruments will be recorded into the Production, Integration, and Certification System (PICS), a computer-based procedure and material tracking system. Data recorded into the PICS system for alpha surveys will become part of the process quality assurance record for each GPHS module.

This Eberline ESP-2 controller/analyzer unit will supply the in-cell detector with high-voltage excitation and then process, interpret, alarm, and log detector responses in either a scaler or ratemeter mode. The instrument is provided with an RS-232 port and can be operated from a remote computer or locally via a menu-driven LCD display. The fully duplexed communication port also provides a means of maintaining permanent records of process related measurements, either in electronic or printed hard-copy format. Being a microprocessor based system, this instrument fully documents the nature and type of data collected in pertinent engineering units. Information such as date, time, instrument number, user identification, detector selected, operating mode and calibration all are specified as a header to transmitted counting data. Each data point also is labeled with the necessary supporting information such as date, time, location, and instrument status codes.

One of the more powerful features of this smart counting instrument is its ability to store and use three independent sets of detector-specific setup and calibration parameters such as efficiency, dead time, high voltage, alarms, and data units. The detector parameters are password protected so that these critical settings cannot be inadvertently changed or altered. This combination of features is quite advantageous as it allows the capability to control process measurements within required specifications and provide data in a format compatible with RPSF quality assurance records requirements. Since the smart instruments support up to three separate detectors, the six process cells can be supported fully by only two portable counting instruments. The operator would be required only to select the appropriate location name to ensure the proper excitation and calibration of the monitoring detector being used.

The size of the smart controller/analyzer also is compatible with the portability and space limitation requirements of the RPSF cells. The unit is a hand-held (26.7 cm x 12.7 cm x 13.2 cm), battery-powered (six "C" cells) instrument that weights only 1.7 kg. The continuous service life of the alkaline battery power source is nominally 900 h, however the unit will shut down automatically and indicate a low battery condition to protect volatile memory when the battery source voltage begins to drop below 5.8 Vdc. Since the GPHS module assembly operation is a continuous process, the smart instrument was modified to allow it to be powered by either an external 9 Vdc power supply or its internal battery pack. The operating console at each cell will be designed with a compatible connector to supply power to the instrument when it is set up for operation.

SYSTEM CALIBRATION

Calibration of the PAM detectors will be conducted before the probes are installed in the process hot cells. Once in service, the probes will not be removed from the cells for laboratory calibration because of the potential for contamination. Periodic calibration readings for each probe will be taken using a ^{230}Th alpha check source supplied by PNL as a secondary calibration standard. The transfer standard will be placed into the sample tray to periodically verify detector performance. The verification data taken from the calibration check source will be used to establish response control charts for each in-cell detector. These charts will be used to statistically identify problems with the in-cell detection equipment and establish the basis for detector replacements.

The ex-cell controller/analyzer will be calibrated electronically before being deployed at the RPSF hot cells and subsequently at six month intervals. A spare unit will allow routine calibrations to be performed without an interruption in process monitoring service. The spare unit also will be on standby should an operating controller/analyzer unit fail or otherwise need to be replaced.

CONCLUSION

Design of the in-cell sample station enclosure has been completed and the prototype unit has been tested in the RPSF demonstration hot cell. The remote handling features of the enclosure have proven to work well. Some minor design modifications to improve remote operability and reduce fabrication costs have been identified and will be incorporated into the final design.

Selection, procurement, and modification of the smart controller/analyzer units has been completed. System operation, calibration, and maintenance instructions currently are being completed. Screening and selection of detector heads and preparation of in-cell calibration sources will not be completed until required for RPSF cell operations.

This system design should reduce significantly both startup and operations costs for process alpha detection surveys. The instrumentation selected provides the flexibility to use fewer instruments to support all the hot cells. The use of detectors from the Hanford Site instrument pool also represents a cost savings because of the potentially high rejection rate for detectors that exhibit high neutron and gamma radiation sensitivity. The continued availability of replacement detectors on special order basis and the spare controller/analyzer unit will ensure cell operations will not be disrupted as a result of survey equipment failures.

The RPSF in-cell alpha detection system design offers a significant advantage over previous systems used for radioisotope component assembly operations, where alpha survey samples had to be transferred out of a cell airlock and directly handled by operations personnel. Operator exposure to potentially contaminated materials is reduced by performing all survey operations remotely. Operator exposure to radiation also is minimized by simplifying survey operations and cutting down the overall operating time by reducing the frequency of airlock transfers. This type of in-cell system potentially is adaptable for other hot cell and glovebox applications where contamination and background radiation levels are expected to be low. The new commercially available smart instrumentation offers many features that allow ease of adaptation to varying system requirements.

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