Independent Oversight
Targeted Review of Radiological Controls
Activity-Level Implementation at the
Oak Ridge National Laboratory
Radiochemical Engineering Development Center
and High Flux Isotope Reactor Facilities

April 2014

Office of Safety and Emergency Management Evaluations
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Acronyms

ALARA	As Low As Reasonably Achievable
ARA	Airborne Radiation Area
CA	Contamination Area
CFR	Code of Federal Regulations
CRAD	Criteria, Review and Approach Document
DOE	U.S. Department of Energy
EPD	Electronic Pocket Dosimeter
ES&H	Environment Safety and Health
ESS	Experimental Safety Summary (or Summaries)
GM	Geiger Mueller
HFIR	High Flux Isotope Reactor
HP	Health Physics
HRA	High Radiation Area
HSS	DOE Office of Health, Safety and Security
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
ITEMS	Inventory Tracking of Equipment, Material and Sample (Database)
LAW	Large Area Wipe
LAA	Limited Access Area
NRPD	Nuclear and Radiological Protection Division
NScD	Neutron Sciences Division
OFI	Opportunity for Improvement
ORNL	Oak Ridge National Laboratory
MDA	Minimal Detectable Activity
PAS	Personnel Air Sampling
PPE	Personal Protective Equipment
RA	Radiation Area
Radcon	Radiological Control
RCT	Radiation Control Technician
REDC	Radiochemical Engineering Development Center
RER	Radiological Event Reporting
RPO	Radiological Protection Operations
RPP	Radiation Protection Program
RSS	Research Safety Summary (or Summaries)
RWP	Radiological Work Permit
SBMS	Standards Based Management System
TBD	Technical Basis Document

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1.0 PURPOSE

The Office of Enforcement and Oversight (Independent Oversight), within the Office of Health, Safety and Security (HSS), conducted an independent review of Radiological Control (Radcon) program activity-level implementation at the High Flux Isotope Reactor (HFIR) and the Radiochemical Engineering Development Center (REDC). The HFIR and REDC facilities at the Oak Ridge National Laboratory (ORNL) are managed by UT-Battelle under contract to DOE's Office of Science. Independent Oversight conducted the review on January 13-17, and February 3-7, 2014. The purpose of the Independent Oversight targeted review is to evaluate the flowdown of occupational radiation protection requirements, as expressed in facility radiation protection programs (RPPs), to work planning, control, and execution processes, such as radiological work authorizations, including radiological work permits (RWPs) and other technical work documents (TWDs). In regard to HFIR operations, particular emphasis was given to the management of neutron irradiated samples. This report discusses the background, scope, methodology, results, and conclusions of the review, as well as items identified for further follow-up by Independent Oversight.

Independent Oversight performed the review within the broader context of an ongoing program of targeted assessments of RPP work controls across U.S. Department of Energy (DOE) sites that have hazard category 1, 2, and 3 facilities. To meet the goals of the targeted reviews, Independent Oversight performs assessments that are primarily driven by activity-level observations. Once each facility specific review is completed, a compiled analysis will report on the performance throughout the DOE complex.

2.0 SCOPE

The scope of this review is defined in the document entitled, "Plan for the Independent Oversight Targeted Review of Activity-Level Implementation of the Radiological Controls at the Oak Ridged National Laboratory," dated December 20, 2013. The principal focus is on activity-level implementation of Radcon requirements at REDC and HFIR and the specific scope of the review included radiation protection program organization; work planning, exposure, and contamination controls; surveillance and monitoring; and irradiated sample hazard management. The review is based on selected lines of inquiry associated with activity-level work control contained in Sections A, B, and C of HSS Criteria, Review and Approach Document (CRAD) 45-35, "Occupational Radiation Protection Program Inspection Criteria, Approach, and Lines of Inquiry."

The Independent Oversight review is based on a sampling of data, is not intended to represent a full programmatic review of site RPPs, and does not fully evaluate some programmatic aspects of RPPs such as dosimetry assessment processes, radiological records keeping systems, or the implementation of training programs. The Independent Oversight team performed a limited review of dosimetry monitoring, as low as reasonably achievable (ALARA) reviews, and personnel training, only to the extent that these elements were encountered in the review of activity-level implementation or in certain cases, the inquiry pointed to possible weaknesses in certain other programmatic aspects of the radiation protection program.

The Independent Oversight team collected data at the HFIR and the REDC facilities and did not review implementation of the RPP at other ORNL facilities. While the results of this review provide one indicator of the effectiveness of the RPP programs implemented by UT-Battelle, the results and conclusions do not necessarily reflect the status of implementation at other ORNL facilities.

3.0 BACKGROUND

The Independent Oversight program is designed to enhance DOE safety and security programs by providing DOE and contractor managers, Congress, and other stakeholders with an independent evaluation of the adequacy of DOE policy and requirements, and the effectiveness of DOE and contractor line management performance in safety and security and other critical functions as directed by the Secretary. The Independent Oversight program is described in and governed by DOE Order 227.1, *Independent Oversight Program*, and a comprehensive set of internal protocols, operating practices, inspectors' guides, and process guides.

In a memorandum from the Chief Health, Safety and Security Officer to DOE senior line management dated November 6, 2012; HSS identified the implementation of radiological work control processes at the activity-level as an area for Independent Oversight targeted review. The memorandum also stated that the areas would be further defined in supporting Independent Oversight review plans and that the performance of DOE line oversight would be evaluated during the targeted reviews to provide input to the overall evaluation of DOE Federal nuclear safety assurance capability. This review of HFIR and REDC Radcon work control processes is one of the targeted reviews intended to satisfy these expectations.

ORNL is managed for the DOE Office of Science by UT-Battelle. HFIR is an 85 megawatt reactor originally designed for in-core or in-reflector irradiation of target materials. In-core or in-reflector locations are used to produce isotopes and to analyze material properties and trace element compositions. REDC laboratories produce many of the isotope production targets. Following activation, these targets are returned to other REDC laboratories for processing into specific isotopic sources for distribution to industry and for medical or research applications. Source term isotopes at REDC include alpha emitters, pure beta emitters, high energy gamma emitters, and neutron emitters, many with very high specific activity. Therefore, REDC facilities use substantial remote handling hot cell and glove box facilities. REDC processes include mechanical and chemical separations, as well as mechanical "Special Form" source encapsulation. Radiological work control processes at REDC flow from the Standards Based Management System (SBMS) requirements and are used to ensure the safety of the personnel and facility.

In addition to the in-core or in-reflector irradiation locations, HFIR has several thermal and cold neutron beam facilities used for studies of the material properties and molecular structures of a variety of research samples. These beam line material analysis activities are principally based on research proposals from outside users; in coordination with the facility staff, visiting researchers perform much of the work. The principal radiation hazards from these activities are the result of neutron scattering and prompt gamma production during the in-beam irradiations, and the residual induced radioactivity during post irradiation sample handling. The specific source term depends on the length of irradiation, the flux at the sample locations, the decay time after neutron irradiation, and the composition and mass of the irradiated material. While the majority of the activation is of relatively short half life, material handling and accountability must be controlled to prevent personnel exposures to the residual radioactivity and to prevent unauthorized release of the material. As with REDC, radiological work control processes at HFIR flow from the SBMS and are intended to ensure the safety of the personnel and the facility.

4.0 METHODOLOGY

The review process was driven by the inspection criteria identified in HSS Criteria, Review and Approach Document (CRAD) 45-35 Rev. 1 *Occupational Radiation Protection Program Inspection Criteria, Approach, and Lines of Inquiry*, dated December 4, 2012. Specifically, the Independent Oversight team evaluated selected lines of inquiry associated with activity-level work control contained in Sections A, B, and C of CRAD 45-35, which include the following primary inspection criteria:

- *Radiation Protection Organization and Administration: Radiation protection program design including organizational structure and administration are sufficient to provide for effective implementation and control of all radiological protection activities. (10 CFR 835.101)*
- *Radiological Work Planning, Exposure, and Contamination Control: Radiological work planning processes are formally defined, designed, and implemented in a manner that adequately defines work scope, integrates with other safety and health disciplines, minimizes the potential for spread of contamination, and ensures radiological exposures to personnel are maintained as low as reasonably achievable (ALARA). (10 CFR 835.101)*
- *Radiological Surveys and Monitoring: Adequate routine and non-routine radiological surveys and monitoring are performed for external radiation, fixed and removable contamination, and airborne radioactivity, as needed to characterize radiological conditions and ensure safety of personnel. (10 CFR 835.401; 10 CFR 835.403)*

Additional lines of inquiry from HSS CRAD 45-35 were also used for instances where the Independent Oversight team evaluated programmatic aspects of the RPP that are relevant to the primary focus of the review. The following secondary areas were reviewed only to the extent that they supported assessment of the primary criteria:

- Radiological postings, access, and materials accountability and controls
- External and internal dosimetry
- Radiological training and qualifications
- Radiological records.

The principal inspection activities included:

- Review of the SBMS documentation, radiation protection program documents, technical basis documentation, implementing procedures and records
- Interviews of personnel including central and line radiation protection managers, staff, and subject matter experts
- Review of selected in progress work packages, RWPs, Research Safety Summaries (RSS), Experiment Safety Summaries (ESS), implementing or standard operating procedures, Technical Safety Requirement (TSR) surveillance documents, and work authorization activities associated with implementation of radiological protection requirements and core functions of the Integrated Safety Management System (ISMS)
- Observation of plan-of-the-day and pre-job briefings where appropriate
- Observation of facility walk downs, inspections, and routine surveillances
- Observation of performance of selected radiological work activities including: irradiated sample handling, glove box operations, waste transfer operations, facility contamination and personnel monitoring, air sampling, Radcon job coverage, equipment or area decontamination and clearance, Radcon personnel training, facility users training, and other radiological support functions.

5.0 RESULTS

The results of the review are organized according to the three primary inspection criteria.

5.1 Radiation Protection Organization and Administration

Inspection Criteria: *Radiation protection program (RPP) design including organizational structure and administration are sufficient to provide for effective implementation and control of all radiological protection activities. (10 CFR 835.101)*

Assessment

Independent Oversight found that ORNL has an effective radiation protection infrastructure staffed by qualified and experienced personnel. The ORNL RPP is managed by the Director, Nuclear and Radiological Protection Division (NRPD), who is supported by six group leaders, three in the field Radiological Protection Operations (RPO) group, and one each in remaining health physics (HP) infrastructure support groups including Nuclear and Criticality Safety Services, Nuclear and Radiological Support Services, and Dosimetry Services. The two facilities reviewed by Independent Oversight are managed by different RPO groups within NRPD: the Neutron Sciences Facilities group for HFIR and the Non-Reactor Nuclear Facilities group for REDC. RPO group leaders manage RPO staff assigned to their facilities that include a field radiation protection first line manager at each facility, and a staff of radiation control technicians (RCTs). Program health physicists from the Nuclear and Radiological Support Services group provide RPO with additional support in radiological work planning and implementation. A significant number of NRPD managers and staff have professional certifications that include certified health physicist (CHP) and/or have advanced degrees in health physics or related disciplines, as well as years of applied radiation protection experience. Many RCTs also maintain National Registry of Radiological Protection Technologist (NRRPT) professional certification. Independent Oversight observed a selected section of the ongoing RPT training (covering Department of Transportation regulated off site shipping and receiving) and found that it sufficiently covers the regulatory requirements appropriate for the topic and positions. Observed performance of the HP and RCT personnel found them to be knowledgeable of the operational issues and capable of performing their responsibilities.

While some weaknesses are identified later in this report, Independent Oversight noted during this review that Radcon implementation had improved appreciably since the previous Independent Oversight integrated safety management (ISM) report. At that time, Independent Oversight identified a number of concerns with RWPs, radiological surveys, bioassay, and work control. Because of the length of time between inspections, Independent Oversight did not attempt to evaluate the specific corrective actions taken following that review; however, evaluation of performance during radiological work observed in this review did not indicate recurrence of the types or extent of radiological work control weaknesses documented in the 2004 Independent Oversight review. This 2014 Independent Oversight review also found that ORNL has regularly performed appropriate functional element audits of radiological control implementation, and that performance issues are being identified, tracked, and trended through ORNL's performance assurance processes as well as through supporting radiological control mechanisms such as the Radiological Event Reporting (RER) process and ALARA reviews.

The ORNL RPP is documented in the *UT-Battelle Radiation Protection Program for Compliance with 10 CFR Part 835, Occupational Radiation Protection*, dated October 2013. In support of this, ORNL has developed appropriate programmatic radiological protection documentation that includes management policy statements, implementing procedures, and technical basis documents (TBDs). ORNL also appropriately maintains a formal compliance matrix which links much of its programmatic radiological

protection documentation, including technical basis document (TBDs) and internal procedures, to the compliance commitments made in the RPP.

5.2 Radiological Work Planning, Exposure, and Contamination Control

Inspection Criteria: *Radiological work planning processes are formally defined, designed, and implemented in a manner that adequately defines work scopes, integrates with other safety and health disciplines, minimizes the potential for spread of contamination, and ensures radiological exposures to personnel are maintained as low as reasonably achievable (ALARA). (10 CFR 835.101)*

Assessment

The radiological hazards and controls at HFIR and REDC differ significantly. At HFIR, radiological hazards are primarily related to external exposures to gamma and neutron radiation from reactor operations, neutron beam lines, and the presence of activated samples and materials. At REDC, while external radiation exposures exist, a principal radiation hazard is the potential for internal exposures to high specific activity alpha radiation from transuranic source terms. Because of these differences, this section presents results from the review of radiological work planning, exposure, and contamination control separately for each facility.

HFIR

At the time of this review, HFIR was nearing the end of a run cycle. Observed radiological work primarily consisted of beam line associated experimental work and day to day reactor operations support. As discussed with the site during the initial planning visit, Independent Oversight focused most of its HFIR review efforts on assessing ongoing experimental research work that included current sample management practices, which underwent self-initiated changes following the Tc-99 contamination event that occurred at Los Alamos.

In general, controls at HFIR were found to be appropriate and used effectively to reduce potential for inadvertent access to high radiation areas (HRAs) that occur in neutron beam flight paths and in close proximity to in-beam materials like research samples or beam collimating apertures. Each worker granted access to posted radiation areas (RAs) is required to sign in on an RWP and wear an electronic personnel dosimeter with audible dose and dose rate alarming capabilities. Each beam experiment station has some form of audible and visual alarm, beam status indicator, and/or shutter interlock. Independent Oversight noted that the two main areas where beam line experiments occur vary greatly in layout and maturity of engineering controls to prevent unintentional exposures. The beam room, located within the HFIR reactor building, is relatively small for the number of available flight paths where beam experiments take place. Because of its small size and configuration, the beam room lacks the easy ability for shielded enclosures, locked entries, and automatic interlock systems to control the shutters at individual experiment stations. Light curtains or proximity detectors at each experiment station actuate audible and visual alarms to notify personnel of shutter status and also to warn individuals should they approach too close to the beam when the shutter is open. If an individual gets within close proximity (approximately three feet) of an active beam during operation, audible and visual alarms automatically sound to warn of the impending radiation hazard, at which point the individual is expected to retreat and manually close the shutter if beam line access is needed. The cold guide hall, the other area where experiments take place, is an annex to the HFIR Reactor building. The cold guide hall is much larger than the beam room, with more room to work in experimental areas. In the guide hall some of the beam line experimental locations are large enough to accommodate automated entry control mechanisms. In most of these areas, locked fence systems or similar interlocked devises have been installed that automatically close the beam shutter if the entry gate is opened. However, two experimental stations in the cold guide hall are not equipped with

locked fences. These areas are configured using light curtains to initiate audible and visual alarms, in a manner similar to those used in the beam room.

While the implemented processes appear to be effective at reducing potential for in beam exposures, it may not fully satisfy the regulatory requirements for physical controls to prevent access to high radiation areas (HRAs) where there is potential for an equivalent dose to the whole body of 1 rem in any one hour, as stated in 10 CFR 835.502. The physical controls required for access paths to HRAs are listed in 10 CFR 835.502. One or more of the listed physical controls must be implemented. The use of the automatic interlock systems for the fence enclosed areas appear to satisfy 10 CFR 835.502(b)(1) *"A control device that prevents entry to the area when high radiation levels exist or upon entry causes the radiation level to be reduced below that level defining a high radiation area."*

However, the proximity detection and alarm systems used for the beam room experiment stations and two of the guide hall experiment stations are intended to satisfy 10 CFR 835.502(b)(3) *A control device that energizes a conspicuous visible or audible alarm signal so that the individual entering the high radiation area* ***and the supervisor*** *of the activity are made aware of the entry.*

At the time of the review, the site was developing a draft position paper assessing the likelihood of an in-beam exposure exceeding 1 rem in an hour. The paper recognizes that a uniform whole body exposure is not feasible in a narrow beam and therefore the effective dose rates are determined based on summation of the organ specific equivalent dose using appropriate tissue weighting factors. Based on the calculated in-beam effective dose rates, the typical beam conditions significantly exceed the 1 rem equivalent dose potential in an hour. To ensure in-beam doses remain below the total effective dose of 1 rem, the occupancy at some locations must be limited to 1 minute.

After consulting with DOE Headquarters safety policy organizations regarding regulatory policy interpretation, Independent Oversight recognized that the conditions in the beam path constitute an HRA condition requiring implementation of the prescribed control set from 10 CFR 835.502. The regulatory control requirement for supervisory notification under (b)(3) is intended to ensure appropriate administrative controls (quick response) are implemented to limit occupancy and prevent excessive personnel exposure. While the first part of the regulatory requirement for a visible and audible signal is satisfied, and the sound can be heard throughout the beam room or guide hall which should invoke the appropriate user responses of exiting the area and closing the beam shutter, current operating practices would not be sufficient to ensure a supervisor (or on duty RCT) is notified and responsive to a potential entry by a single researcher working during off hours (see **Finding-01**).

Independent Oversight also observed that the controls, indicators, and process for accessing beam lines and sample positions have not been standardized. Using a variety of access controls for different beam experiment stations necessitates distinct researcher training for each experiment station and could increase the potential for misapplication of controls, confusion, or incorrect behaviors during beam access while working long hours on varied or new experiment stations (see **OFI-1**).

In addition to engineered controls, administrative controls such as electronic pocket dosimeters (EPDs), postings, permits, and procedures, and lastly, personal protective equipment (PPE) are used to control most radiological hazards at HFIR. Administrative controls such as postings are prevalent, appropriate, and prominently displayed at access points to each radiological area, including those associated with neutron beam experiments. Recent survey results are routinely updated and posted at entry points.

Work control documents, another required administrative control, are used at HFIR to control activity-level work. These required documents include RWPs, Research Safety Summaries (RSS), Experiment Safety Summaries (ESS), and operating procedures. Per SBMS, RWPs are required when performing

work in radiological areas, such as RAs, HRAs, and contamination areas (CAs). For experimental work at HFIR, SBMS also dictates the use of RSS and supporting documents such as ESS. Internal operating procedures, maintenance procedures, and/or maintenance work packages govern reactor operations and maintenance evolutions.

Other administrative controls including radiation worker and researcher experimental orientation training were found to appropriately cover the generally required content. However, Independent Oversight observed that in some cases the control sets expected in some ESS were not fully implemented, suggesting weaknesses in the training with respect to communication of the experiment specific controls to some facility users (discussed further below).

Because HFIR was in a run cycle, intrusive radiological work and higher radiological risk outage maintenance type evolutions were not ongoing at the time of the review, but several evolutions governed by RWPs were observed, including: sample sink primary coolant sampling, in-core rabbit sample removal, beam line RA entries in support of ongoing experiments, and refurbishment of a spent ion exchange resin transfer pump. RWPs associated with these evolutions adequately bound the scope of work and established generally appropriate radiological controls. Workers complied with the requirements in the RWPs. Independent Oversight observed RCT coverage during these operations and noted that direct readings and contamination checks were adequately performed at all appropriate points, for example removing items from hoods or clearing tools across Radcon boundaries, in a manner that suggested proficient and practiced experience.

Independent Oversight also observed a number of experimental support activities governed by RSS that included operations within various beam lines in the beam room and cold guide hall, as well as sample activities in the chemistry laboratory and sample environment laboratory. RSS associated with these areas and operations adequately bound the types of work being performed in these areas and provide a listing of the types of hazards to be expected as well as general control notes for consideration in development of subordinate work control mechanisms such as the ESS.

The following excerpts are taken from SBMS Subject Area, Work Control, "Implementing ISM in Research and Development", and apply to the use of ESS and/or other supporting documentation to an RSS:

- *"Achieving the necessary level of detail is important to ensuring an effective RSS. Work planning must be comprehensive, but RSS that are long and cumbersome potentially discourage use by participants. Rather than overload an RSS with detail, consider additional methods or tools for appropriate work planning that can be used under the umbrella of an RSS when an additional level of detail is needed to ensure appropriate focus on a sub-task or an individual's role in the work.*"
- "*Higher level descriptions used in the RSS may be too general for a specific activity. Supporting documentation, such as a procedure or an activity based hazard analysis, carries the RSS hazard assessment to the bench with additional detail. See the section below on Acceptable Forms of Supporting Documentation."*
- "*The RSS defines the scope within which an R&D work activity is authorized. If additional mechanisms, such as internal operating procedures, checklists, operator training and certification, etc., are used to define work controls, they must be referenced within the RSS. (See Acceptable Forms of Supporting Documentation in the Creating an Effective RSS exhibit.)*"
- "*When experimental review/acceptance processes are used to supplement an RSS, the process must include an evaluation of the activity-specific hazards, not just the scientific merit of the proposal. The review process must be consistent with the expectations in the exhibit Conducting an Effective RSS Review.*"

Consistent with these expectations, the ESS is the intended mechanism at HFIR for identifying experiment specific hazards and controls, and was appropriately referenced in the governing RSS for the various areas where work was observed, including the chemistry laboratory, sample environment laboratory, and individual beam lines such as HB3a, CG3, etc.

However, Independent Oversight identified a number of systematic concerns with the ESS process: some ESS failed to provide sufficiently clear and accurate information on hazards and controls associated with experimental work. The following examples of deficiencies in ESS were identified:

- Procedure NScD-USER-108, *NScD Experiment Safety and Health Review,* does not provide any specific process related information concerning proper conduct of ESS hazard analysis or specification of controls to achieve compliance with SBMS ISMS expectations for research and development work subordinate to the RSS. The review process noted above is expected to engage appropriate subject matter experts from environment, safety, and health (ES&H) disciplines, such as Radcon, when radiological controls are needed. However, no such requirement exists in Procedure NScD-USER-108.
- There was inadequate flowdown of radiological controls defined in procedures, such as the sample management procedure, to the ESS. For example, radiological labeling of post irradiation samples was not included in any ESS reviewed, and was not always performed as required by the sample management procedure, particularly for liquid samples. Unlabeled irradiated (potentially activated) liquid samples were sometimes left unattended in the chemistry laboratory. In some cases incorrect labels were applied to indicate potentially radioactive status of samples. These included stickers with the words "Exposed to Neutron Beam." This wording appears to be a holdover from a chemistry laboratory RSS requirement that has not been updated for consistency with the current sample management procedure.
- Numerous examples occurred in the sample information section of ESS where the hazard column lists "none" for sample materials that actually have inherent radioactive and chemical hazards, or that have a high affinity for activation: no specific controls were identified for these hazards.
- The safety and health information section of many ESS contained overly generic and unclear information on appropriate controls, which included use of generic and subjective language such as "*Wear appropriate PPE*", "*Do not open sample holders without further ES&H review*", "*All sample removal from instrument to be completed by qualified individuals*", "*Lead, cadmium and beryllium all require further controls. No grinding or cutting, handling permitted on these materials without extensive ES&H review*." Lack of specifics and clarity could result in incomplete communication of expectations to the users and inconsistent application of the controls.
- In some cases, sample environment staff load and unload samples on behalf of the researcher. However these individuals are not required to be part of the ESS development process or to read the applicable ESS, resulting in the potential for these workers to be unaware of sample specific hazards or controls from the ESS.
- In some cases, ESS specified the requirement to wear gloves, but observed workers did not wear gloves when handling samples. EPDs were often observed being worn incorrectly either in pants pockets or attached to belts rather than between the neck and chest area as expected by the procedures.

ISMS and the SBMS require that experiment specific hazards are identified and analyzed; specific hazard control sets are identified; hazards and controls are clearly communicated to the workers; and the control sets are implemented. With respect to experimental operations at HFIR, sets of radiation safety controls

have not been fully implemented for all beam operations as intended by the ESS process. Specifically, Neutron Sciences Division (NScD) has not ensured that ESS governing user proposal activities contain sufficiently clear and accurate information on hazards and controls applicable to user research work. NScD has not adequately communicated hazards and controls to the bench level users, and fully implemented the controls as required by the SBMS Subject Area, Work Control (see **Finding-2** and **OFI-2**).

Independent Oversight recognized that NScD and NRPD have proactively undertaken recent initiatives to strengthen sample management practices at HFIR following the Los Alamos Lujan Center Tc-99 contamination event, including development of a new sample management procedure, addition of dedicated sample management staff, creation of a sample management help desk, procurement of user friendly "smart" portable radiation monitoring instruments (Radeye series), and user training on the new initiatives. Independent Oversight was able to observe a variety of sample management activities that included sample retrieval from storage, Inventory Tracking of Equipment, Material and Sample (ITEMS) database tracking, sample handling, placement and removal from beam experiments, and sample movement between locations.

While the changes in the sample management processes are generally effective and appropriate, Independent Oversight identified some aspects of sample management activities that were not always effectively and consistently performed. The following vulnerabilities were identified (see **OFI-3**):

- While there is potential for activation of powder samples, there is currently no requirement in the sample management procedure for an RCT to assess contamination status of powder containing sample containers prior to or during removal from the beam. For one observed evolution that involved the removal of a powder sample from a cryogenic sample holder in the sample environment laboratory, RCT presence was required by IOP NS-SEI-2601. This is an internal operating procedure that governs operation of the equipment being used by HFIR sample Environment personnel. However a similar requirement is not addressed in the current sample management procedure or ESS for powder samples that may be removed directly by the researcher.
- For liquid and some solid samples such as foils, etc., multiple samples are often assigned to a single ITEMS sample identification number (ID) However, the multiple samples with the same ITEMS Sample ID were not always effectively stored together and/or labeled as an aggregate set.
- Sample movements from one location to another within the HFIR facility, such as from a storage location to the beam line, or from the beam line to the chemistry laboratory, or back to a storage location, etc., are generally not being tracked in ITEMS. There is no requirement for this level of tracking, but the capability exists in ITEMS to provide for better sample movement tracking.
- While samples are generally being stored in locked cabinets, the sample security process is informal and lacks documentation that clearly defines responsibility for chain of custody or cabinet and key control expectations. The process is not addressed in the sample management procedure.

REDC

Engineering controls at REDC Facilities are robust and used extensively to mitigate radiological hazards associated with operations. Hot Cells, Limited Access Area (LAA) containments, glove boxes, and laboratory hoods serve as the principal engineered controls and contain the radiochemical analytical process, radioactive materials, and waste management activities. Independent Oversight observed work in building 7920 and 7930 laboratories, including routine analytical activities (e.g., in glove box preparation of oxides and liquid samples, in hood low level sample preparation, sample transfer, bag-in/bag-out operations), maintenance activities (e.g., relocation of glove box, off-gas header connections),

production activities (e.g., Neptunium pellet production, Europium separation, Actinium processing) and routine waste handling (e.g., waste box loading, transferring waste to storage, packaging waste).

SBMS requirements drive a graded approach to the level of independent review of RWPs and radiological hazards, based on a set of predefined radiological criteria. All radiological work must be characterized as level 1 through level 4 based on potential collective and individual doses and other conditions specified on the Radiological Work Review Checklist. The majority of the work available at REDC for observation during the Independent Oversight review was level 2, and therefore enhanced work planning activities such as comprehensive formal pre-job briefings or post job ALARA reviews were not required for these activities. Several work evolutions were observed at REDC where hazard controls were effectively implemented and employed without incident, including several bag-in/bag-out evolutions (including the bag-out of samples from cubicle 8 through the Lazy Susan glove box), glove box relocation and conduct of analytical work in glove boxes and RCT coverage of work in CAs and Airborne Radiation Areas (ARAs). Administrative and computer based access controls, electronic dosimeter and RWP issuance are all used for confirmation of training status and ensuring individuals are made aware of and acknowledge RWP requirements prior to conduct of radiological work.

Glove box bag-in/bag-out activities at REDC can affect contamination levels and required postings in the area of the activity. Several changes (enhancements) to the work practices associated with these types of activities, implemented since the 2004 DOE Independent Oversight review, have helped to ensure that contamination of the laboratory spaces is maintained ALARA. These enhancements include the requirement for providing RCT coverage during bag-in/bag-out evolutions, increased vigilance when transferring samples to new containers while still in glove boxes, and a change to heat sealing practices to minimize potential of seal/bag failure by using a triple seal method.

While most RWPS are generally effective, Independent Oversight identified a few examples (maintenance, waste handling, laboratory, etc.) that are too broadly written to apply hazard specific controls for each allowed work evolution on the RWP. Grouping ARAs, RAs, and CAs on the same RWP with varied controls for each can lead to confusion when applying task specific controls, which can cause unnecessary exposure or failure to appropriately conform to intended RWP requirements, and/or work instructions (see **OFI-4** and **OFI-5**). For example:

- During waste packaging and transfer from the LAA (posted CA) in building 7920 cubicle 8, a worker was observed reaching into the CA from the radiological buffer area step off pad, to retrieve a change area waste bag. The individual had been assigned routine waste handling activities under RWP REDC-21653-2. While the RWP authorizes reach over retrieval and the worker did don gloves (in addition to the normal work uniform), the RWP was not written to allow for the type of more intrusive waste handling that was observed. Specifically, the worker standing at the step off pad leaned over the CA and reached into the bag to compact the waste with his gloved hand, while wearing a short sleeved shirt (bare armed). The worker then closed the bag without changing gloves and over packed it into a new "clean" waste bag at the step off pad. The worker's uniform shirt was unbuttoned with his personal undershirt potentially contacting waste materials while leaning into the CA and compacting waste. The only survey requirement (directions posted at the area) for egress from the step off pad was for hands and feet. Furthermore, the Radiological Work Review Checklist (which supports the associated technical work document for this activity OWP030618), states (in the comment section) "Waste packages surveyed by RCTs and/or over packaged when crossing Contamination Area boundaries." However, the actual RWP did not reflect this survey requirement.
- Independent Oversight observed a worker using poor doffing techniques while exiting a radiological area (Building 7920, Room 201 up-posted to a CA during bag-out activities). The worker removed all anti-contamination PPE including shoe covers prior to exiting the CA and stepping on to the step off pad. Additionally, during this activity, workers were observed handling items such as telephones

and ancillary surfaces. RCTs do not normally survey such items after work unless they are aware of the incidental contact. There were multiple workers and one RCT who was continually surveying individuals removing hands from glove boxes and work areas, as well as taking large area wipes (LAWs). It is unlikely the RCT observed or was made aware of incidental handling of objects out of his field of vision. In a second observation in the same laboratory (during another day but also while up-posted to a CA for sample transfer), Independent Oversight observed a worker exhibiting poor contamination control technique when compacting waste into the container after doffing his or her outer coveralls (in a short sleeved shirt) by pushing the waste down into the waste container at the CA transition.

- Some ambiguous, incorrect, and/or potentially confusing language was noted in an RWP associated with glove box moves. RWP REDC-21846-3 included requirements for respiratory protection and air sampling. The RWP section set aside for Personnel Air Sampling (PAS) states "Not Required – Duration of job less than 20 minutes." This RWP statement was not correct. Contrary to the statement and requirement in the RWP, the glove box move observed by Independent Oversight took more than 20 minutes and PAS was used in accordance with the provisions established in ORNL Implementing Guide NRPD-IG-2004 *Monitoring for Airborne Radioactivity*. Additionally, in the special instructions of the RWP, the wording in two instances is ambiguous and could result in undesired action. The following statement that "*Respiratory protection and air sampling required only during breaching of containment off-gas header and pending contamination survey after breach is closed,*" did not specify the type of air sampling or required survey/sample type needed for down posting. According to an interview with RCT line supervision the intent of the statement was that respiratory protection and "PAS" air sampling is required "only" during breaching of containment off-gas header and pending analysis of the air samples and contamination surveys for down-posting after the breach is closed.

In addition to specific written RWP controls, hazards associated with using radioactive materials in laboratory hoods and glove boxes were generally well controlled through typical good laboratory hygiene and radiological work practices; however, Independent Oversight noted a few items of concern. For example, use of common household scissors to cut plastic bag materials during the heat sealing processes associated with bag-in/bag-out was observed at numerous glove boxes throughout REDC. The scissors introduce a potential sharps hazard in areas controlled as a CA. The potential for lacerations or the breach of PPE is not listed as a hazard in the work documents and no controls are specified. Blunt point or shielded blade cutting devices were not provided and should be considered as safer alternatives. Additionally, work was observed in one laboratory hood managed as a CA while waste material (i.e., a nearly full plastic radiological disposal bag) was being stored on an unplugged hot plate, in a location that potentially impacted air flow within the hood (see **OFI-4**).

5.3 Radiological Surveys and Monitoring

Inspection Criteria: *Adequate routine and non-routine radiological surveys and monitoring are performed for external radiation, fixed and removable contamination, and airborne radioactivity, as needed to characterize radiological conditions and ensure safety of personnel. (10 CFR 835.401; 10 CFR 835.403)*

Assessment

Radiological surveys and monitoring are generally being conducted appropriately at both HFIR and REDC. These activities are governed by radiological surveillance plans, which are developed annually at each facility by using internal RPO implementation guides. These mechanisms form the basis for conduct of routine radiation and contamination surveys, and air sample collection for all facility locations. Survey

frequencies established in the surveillance plans are sufficient given the nature of the facilities, radiological status, and operations. For example, at HFIR, comprehensive gamma and neutron radiation surveys are required upon each reactor startup to establish baseline radiation levels in occupied areas including the beam room and cold guide hall. Less exhaustive daily radiation surveys are then performed throughout the run cycle to ensure radiation levels have not changed unexpectedly from baseline levels.

Radiological survey and monitoring instrumentation is also appropriate for the radiation hazards. External gamma exposure rates are measured with ion chambers and energy compensated Geiger Mueller (GM) radiation detectors. The procurement of the user friendly Radeye series of GMs at HFIR was found to offer a means for simple effective monitoring. Visiting researchers are trained in the use of these instruments and expected to use them prior to closed beam line access and sample handling. If the built-in alarm threshold of two millirem per hour is exceeded, RCT presence is required for sample removal.

Neutron dose rates are measured with moderated BF3 (boron trifluoride) and/or He3 (helium isotope) detectors such as the Snoopy and REM Ball instruments. Bare BF3 or He3 neutron measurements are also taken at HFIR to recognize the qualitative impact of the spectrum shift from fast to thermal or cold neutrons. Note: calibration conversion factors to dose rates from count rates vary substantially based on the neutron spectrum and may be assessed by use of a bare versus moderated detector. Typical instrument calibration procedures depend on use of a moderated californium spectrum that approximates a fission spectrum and may over estimate dose rates from a highly thermalized or cold neutron beam spectrum. Independent Oversight did not evaluate the instrument calibration process to ensure accuracy of quantitative neutron dose rate survey measurements or the impact of this spectral shift on neutron dosimetry evaluations, since these are typically a small fraction of the dose received at HFIR.

At HFIR weekly contamination surveys are also performed even in areas that are not expected to be used for contaminated materials work. At REDC, frequent contamination surveys are taken with LAWs and quantitative smears in areas where contamination potential exists. Large area wipes at HFIR and REDC are evaluated in the field with handheld scintillation and GMs and quantitative smear samples are counted in low background gas flow proportional counters.

Fixed air monitoring is used at selected locations in both facilities. At REDC, air monitoring is accomplished through a system that consists of a network of ICAMs and stationary air samplers located in each of the laboratory areas (positioned based on work activity, smoke testing and/or known airflow patterns). Fixed air samples are collected twice a week and counted in proportional counters, or via gamma spectroscopy based on RWP requirements. RCT routine radiological surveillances and RCT job coverage at both facilities was observed and found to be effectively performed. Survey documentation associated with these efforts was also thorough and complete. In addition to radiation surveys, all personnel on RWPs authorizing entry into RAs and HRAs are required to wear alarming EPDs. Use of these systems was viewed as a positive initiative which ensures tracking and real time assessment of external dose and dose rates. Additionally the alarming features provide better facility coverage than would be accomplished by fixed area radiation monitors.

Independent Oversight viewed NRPD's establishment and use of electronic data systems to manage radiological information and implementing requirements, including large amounts of survey and monitoring data as a programmatic strength. A centerpiece of this process is the establishment and use of the Radiological Application Database System (RADS). This system provides easily retrievable electronic access to a variety of information and records, including RWPs, EPD dose tracking, radiological surveys, air sampling records, RERs, and RCT routine surveillance requirements/ticklers.

The presence of potentially activated samples and materials at HFIR presents special challenges with respect to radiological restrictions and radiological release of materials, including the need for

relinquishing certain samples back to individual users and facilities following removal from the beam. As a result, RPO has established a technical basis and internal procedures which define survey and analytical methods to be used by RCTs in assessing residual radioactivity in activated samples, for both restricted and unrestricted radiological release. This includes a combination of analytical methods (use of a sample activation calculator) and defined quantitative survey protocols that must be accomplished for any sample that is to be potentially released from HFIR. Samples meeting predefined thresholds as defined in the procedures may be authorized for release when accompanied by the paperwork demonstrating its non-radioactive status. Materials that do not meet the criteria must remain at HFIR or may be disposed of as radioactive waste.

While radiological surveys are mostly effective, a few potential weaknesses, vulnerabilities, or possible "added value" improvements associated with surveys and monitoring were identified (see **OFI-6**). These include:

- At both HFIR and REDC the conduct of routine radiological area surveys (including those used for area down-posting) included LAWs which are usually collected and field evaluated in high background (high Minimal Detectable Activity [MDA]) areas, before collecting technical smears at the same locations, to be counted in low backgrounds (low MDA). LAWs are typically implemented utilizing sheets of masslin (used as LAWs) affixed to a pad attached to a mop handle and walked over (in contact with) working area floor surfaces. Periodically throughout the process hand held detectors are used to monitor any residual radiological contaminants adhered to the LAW. While appropriate for use as an indicator, comprehensive LAW use may mask identification of contamination by technical smears, through the cleaning effect of the LAW, resulting in the potential to miss detection and/or trending of the spread of low level contamination below the MDA of hand held instrumentation, that could have been detected by technical smears prior to "cleaning" of the location with a LAW.
- Potential impact of neutron detection by scintillation based alpha detectors may raise the MDA during conduct of job coverage by RCTs.
- Following the Out of Service loss of one ARGOS contamination monitor at REDC, individuals were required to perform whole body frisks by hand. Due in part to a lack of experience and lack of adequate posted instructions for performing a proper whole body frisk, some individuals were observed performing inadequate frisking.
- There is no portal monitoring before exit from the beam room or guide hall at HFIR. Independent Oversight recognizes challenges exist with time varying backgrounds that can impede use of a portal monitor or whole body monitor in these locations, however, options for modified exit paths or shielded monitoring may enhance the ability to identify and prevent inadvertent transfer of activated or contaminated items.
- The current sample management process has no formal requirements for collection of swipe samples on powdered sample cans, etc., or monitoring of any samples for charged particle radiation (alpha, beta) prior to removal from the beam. Current practices rely solely on detection of indirectly ionizing radiation (x or gamma radiation) using tissue equivalent compensated GMs. While this is likely protective in the majority of cases, vulnerabilities could exist under some activation scenarios and/or the use of inherently radioactive samples such as pure beta emitters or dispersible transuranic samples.
- Survey results are often recorded as "less than" for values below posting thresholds. Since the survey measurements are performed, recording the more specific low level data may allow for identification of trends, emerging potential issues, or variations in performance of the surveillance prior to exceeding thresholds.

6.0 CONCLUSIONS

ORNL has a sound radiation protection infrastructure supported by appropriate programmatic radiological protection documentation, including management policy statements, implementing procedures, and TBDs. The ORNL Radiological Protection Organization is well qualified and staffed by experienced radiation protection personnel, many of whom have professional certifications and/or advanced degrees in HP or related disciplines.

HFIR and REDC make effective use of engineering controls to mitigate hazards associated with radiological operations. Appropriate levels of external and internal radiological exposure control measures are in place, including external and internal dosimetry and radiological surveys and monitoring for the specific radiological hazards encountered at each facility. However, at some HFIR experimental areas in the beam room and cold guide hall, Independent Oversight determined that audible and visual alarm systems used for HRA access control, while effectively warning the worker, do not appear to ensure notification of the activity supervisor, as specified by regulatory requirements.

In the area of radiological work control, Independent Oversight noted performance improvements in implementation of radiological controls since the previous Independent Oversight ISM review. In this 2014 Independent Oversight review, some concerns were identified, including systematic weaknesses in the ESS process, resulting in experiment specific hazards that were not fully identified and analyzed, and specific hazard control sets that were not clearly identified, communicated to workers, and effectively implemented. A few vulnerabilities were also identified with respect to refinement of sample management practices at HFIR and with respect to clarity and specificity of some broadly written RWPs at REDC. Additional effort in these areas should be exercised to maintain effectiveness in meeting all Radcon program objectives.

7.0 FINDINGS

Findings indicate significant deficiencies or safety issues that warrant a high level of attention from management. If left uncorrected, findings could adversely affect the DOE mission, the environment, the safety or health of workers and the public, or national security. Findings may identify aspects of a program that do not meet the intent of Federal regulation, DOE policy or DOE orders. Findings may identify specific failures to conform to safety regulations, DOE policies, or DOE orders, or they may identify systemic failures to conform to internal procedures, standards, or guidance that are invoked by contracts or the facility safety basis as the means to satisfy the requirements in the regulations or orders.

Finding-01: NRPD and NScD have not ensured that audible and visual alarm systems used to control access to HRAs in the beam room and cold guide hall are sufficient to meet the requirements of 10 CFR 835.502(b)(3), which includes warning to activity supervisors in addition to the worker of the impending hazard upon entry.

Finding-02: NScD has not ensured that ESS governing user proposal activities contain sufficiently clear and accurate information on identifying hazards and implementing controls applicable to the specific research work, as required by the SBMS Subject Area, Work Control.

8.0 OPPORTUNITIES FOR IMPROVEMENT

Opportunities for Improvement (OFI) are not intended to be prescriptive or mandatory, and do not require formal resolution through the corrective action process. Rather, they are suggestions offered by

Independent Oversight that may assist site management in implementing best practices, or provide potential solutions to minor issues identified during the conduct of the review. In some cases, OFIs address areas where program or process improvements to enhance safety best practices can be achieved through minimal effort. In other cases they may represent identification of weaknesses or isolated behaviors that may become systemic over time and could degrade the safety of the facility resulting in a finding or deficiency. Independent Oversight anticipates that these OFIs will be evaluated by the responsible line management organizations and either accepted, rejected, or modified as appropriate, in accordance with site-specific program objectives and priorities.

Independent Oversight review identified six OFIs:

OFI-1: To the extent feasible, the access controls, beam status indicators, shutter controls, and processes for accessing sample positions should be standardized throughout HFIR to enhance consistency in user responses and to simplify workstation specific user training.

OFI-2: Improve the ESS process and implementation at HFIR such that ESS contain accurate and clearly defined information on hazards and associated controls. Specific actions to consider include:

- Revise Procedure NScD-USER-108 NScD Experiment Safety and Health Review to include process related information and expectations as to proper conduct of hazard analyses and specification of controls for radiological and other hazards. Ensure a mechanism exists to include appropriate subject matter experts, such as radiological protection are involved in the review and approval of ESS as appropriate when specifying radiological hazards and controls.
- Ensure hazards identification processes include recognition of potentially undesirable prompt gamma emissions from in-beam materials, and recognition of noteworthy sample activation or harder to detect charge particle activations.
- Ensure radiological controls specified in sample management procedures and other documents are appropriately flowed down to the ESS.
- Review and revise RSS for consistency with labeling requirements in the sample management procedure.
- Establish sample ESS that can be used as examples to users showing appropriate and inappropriate completion of hazard and control fields during initial completion of the Integrated Proposal Tracking System (IPTS) fields.
- Limit the use of generic terms and qualifiers such as “appropriate,” “qualified,” “without further review,” when specifying controls in the RSS and ESS.
- Establish a mechanism that ensures sample environment personnel review ESS as appropriate before handling user samples, unless the specific hazards and controls are identified in their operating procedures.
- Revise user and support staff training to include discussion of ORNL expectations for compliance with the information contained in the ESS, communication of potential experiment specific hazards and implementation of controls, as well as an expectation to bring errors or omissions to the attention of ES&H liaisons.

OFI-3: Continue existing efforts toward enhancing sample management practices for research work at HFIR. Specific actions to consider include:

- Reassess the advisability of performing sample activation calculations for certain types of samples prior to in-beam irradiation and communicating those results to the users for implementation of ESS controls.
- Reassess sample management procedures for the potential need to conduct swipe samples on sample containers holding inherently radioactive or dispersible activated radioactive materials.
- Reassess sample management procedures for the potential need to monitor sample containers for alpha or beta emitting activation prior to direct handling.
- Revise sample management procedures to include additional information on expectations for aggregating and labeling multiple samples as a single identifiable unit.
- Evaluate the desirability and feasibility of increased sample movement tracking within ITEMS, such as when samples are moved to various locations within HFIR (e.g., chemistry laboratory, sample environment laboratory, beam).
- Establish formal sample security or chain of custody expectations, responsibilities, and requirements.

OFI-4: Reinforce training for both researchers and operations personnel on proper conduct of radiological doffing, EPD placement (primarily for researchers at HFIR) , PPE use, radiological waste management practices, and maintaining contamination control for areas (primarily at REDC) when up-posted as CAs.

OFI-5: Review and enhance existing REDC RWPs. Specific actions to consider include:

- Consider subdividing some broadly written RWPs, such as those with varying radiological conditions and differing PPE requirements for RAs, CAs, up-posting, down-posting, etc. Alternatively, establish task specific activities on RWPs (e.g., task 1, task 2) that clearly define the specific radiological hazards and controls for each authorized task.
- Review and revise existing RWPs as appropriate to ensure that requisite RCT coverage, surveys and/or monitoring activities (i.e., PAS air sampling) are appropriately assigned to authorized tasks.
- Review and revise existing RWPs as appropriate to cover requisite PPE for CA or waste intrusive activities such as waste consolidation, additionally, consider this RWP for subdivision (see above bullet).

OFI-6: **Enhance radiological survey and monitoring practices in a few areas.** Specific actions to consider include:

- Evaluate current practices concerning the use of LAWs followed by technical smears, and the potential for masking low levels of contamination through the cleaning effect of LAWs.
- Post whole body frisking instructions at locations where individuals might use handheld instruments in lieu of automated systems.
- Evaluate the feasibility of modified exit paths or shielding for use of portal type monitors prior to exiting HFIR experimental areas such as the beam room and cold guide hall.
- Reevaluate whether current practices that rely solely on measurement of external gamma dose rates on samples being removed from the beam may need to be supplemented with alpha and/or beta measurements under some conditions. Revise procedures and ESS as appropriate.

9.0 FOLLOW-UP ITEMS

Independent Oversight will maintain operational awareness of site and contractor responses to the findings. Following completion of the site wide targeted reviews, Independent Oversight will prepare a summary report identifying DOE complex wide issues and trends.

10.0 REFERENCES

- 10 CFR Part 835, *Occupational Radiation Protection*
- DOE G 441.1-C, Radiation Protection Programs Guide, For Use With 10 CFR Part 835, *Occupational Radiation Protection*
- *HSS CRAD 45-35,* Rev. 1 Occupational Radiation Protection Program Inspection Criterion, Approach and Lines of Inquiry
- Plan for Targeted Review of Radiological Controls Activity-Level Implementation at Oak Ridge Science, December 20, 2013.

Appendix A
Supplemental Information

Dates of Review

Onsite Review: January 13-17, and February 3-7, 2014

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Appendix B
Key Documents Reviewed

Institutional

- UT-Battelle *Radiation Protection Program for Compliance with Title 10 Code of Federal Regulations Part 835 Occupational Radiation Protection*, October 2013
- UT-Battelle *Radiation Protection Program 10 CFR 835 Compliance Matrix (Verified Correct October 2013)*
- ORNL, NRPD, Nuclear & Radiological Protection Division Organization Chart
- Standards Based Management System, Program Description, *Radiological Protection Program*
- Standards Based Management System, Subject Area, *Radiological Work*
- Standards Based Management System, Subject Area, *Radiological Area Controls*
- Standards Based Management System, Subject Area, *Radiological Dosimetry*
- Standards Based Management System, Subject Area, *Radiological Labeling and Control of Materials*
- Standards Based Management System, Subject Area, *Radiological Monitoring of Individuals and Areas*
- Standards Based Management System, Subject Area, *Work Control*
- Various ORNL-NRPD Nuclear & Radiation Protection Division Procedures and Implementing Guides
- Various ORNL Radiological Event Reports 2012-2014 HFIR and REDC facilities
- Various ORNL Radiation Protection Department Technical Basis Documents
- Various ORNL 10 CFR 835 Functional Area Self Assessments, 2012-2014

REDC/NNFD

- REDC-21653-2, *ORNL Radiological Work Permit, Routine Waste Handling Activities*, Rev. 2, August 22, 2013
- REDC-21653, *ORNL Radiological Work Review Checklist*, Rev. 0, August 6, 2013
- REDC-21846-3, *ORNL Radiological Work Permit, Moving Glove Boxes, Off-Gas Header Connections etc.*, Rev. 3, April 19, 2013
- REDC-20968-5, *ORNL Radiological Work Permit, Actinium Processing*, Rev. 5, February 14, 2013
- REDC-20973-5, *ORNL Radiological Work Permit, Routine Analytical Activities*, Rev. 5, December 6, 2013
- REDC Protocol Evaluation Sheet, *CSD Bag OUT of Samples from Cubicle 8 through the Lazy Susan Glove box*, June 26, 2012
- REDC-21653-2, *ORNL Radiological Work Permit, Routine Waste Handling Activities*, Rev. 2, August 22, 2013
- REDC ALARA Review Checklist, *Routine Analytical Activities*, December 12, 2013
- REDC-22068-4, *ORNL Radiological Work Permit, Preparation of Ba-140…as tracers…*, Rev. 4, January 17, 2014
- REDC-22568-0, *ORNL Radiological Work Permit, Separation of Europium 155*, Rev. 0, November 4, 2013
- REDC-21899-6, *ORNL Radiological Work Permit, Neptunium 237 Pellet Production*, Rev. 6, December 3, 2013

- REDC-21569-3, *ORNL Radiological Work Permit, Holmium 166m/Uranium 238 Sphere Production*, Rev. 3, June 7, 2013
- REDC-21653-2, *ORNL Radiological Work Permit, Routine Waste Handling Activities*, Rev. 2, August 22, 2013
- RSS 2491, *REDC Development Laboratory and Transuranium Analytical laboratory Operation-Lab 210*
- RSS 2525, *REDC Cold Chemical/Low Level Hood Operations Laboratory-Lab 110*
- RSS 3812, *REDC Development Laboratory Operations-Lab 109*
- RSS 919, *REDC Building 7930 Development Laboratory Operations*
- RSS 989, *REDC Building 7930 Labs 4A and 4B Operations*
- RSS 11316, *Target Fabrication for Pu-238 Project-Pellet Production*
- RSS 2486, *REDC Development Laboratory Operations-Lab 209*
- RSS 2497, *REDC Development Laboratory Operations-Lab 211*
- RSS 590 and 6744, *Analytical Support for ORNL R&D programs*
- RSS 4710, *Cave and Glove Box Operations for Processing Actinium*
- SMWP, *Minor Maintenance*
- SMWP043208, *Glove Box Installation, Movement or Disposal*
- NNFD-REDC-001, *Glove Box Operations*
- OWP030618, *Daily Routine Waste Operations*
- OWP030214, *REDC Glove Boxes and associated waste Operations*

HFIR/NScD

- NS-ADM-1210, *Sample Management For Neutron Scattering Experiments*
- NScD-User-100, *Integrated Proposal Tracking System*
- NScD-User-103, *Experiment Operational Review*
- NScD-User-108, *Experiment Safety and Health*
- NRPD-TPP-6020, *NRPD Technical Position Paper: Release of Potentially Activated Items and Materials from HFIR and SNS*
- NRPD-TPP-6029, *Nuclear and Radiological Protection Division Technical Position Paper 6029, Use of Neutron Dosimetry for Neutron Scattering Research at the High Flux Isotope Reactor (HFIR)*
- *Radiological Protection Surveillance Plan At Research Reactors Division Facilities*, January, 2014
- HFIR 17003-16, *ORNL Radiological Work Permit, Neutron Beam Operations*
- HFIR 22353-2, *ORNL Radiological Work Permit, Neutron Beam Operations for HFIR Neutron Scattering User Program*
- RSS 8654.3, *Operation of HFIR HB-3a neutron four-circle diffractometer at the HFIR*
- RSS 8661.3 *Neutron Scattering Research at HB2A (Powder Diffractometer) and HB2C (WAND)at the HFIR.*
- RSS 9625.2 *CG-3 Bio-SANS Operations*
- RSS 7972 *Sample preparation in 7972 Lab 105 Chemistry lab for neutron scattering activities*
- RSS 8644.3 *Sample Environment Lab Operations at HFIR*
- ESS10989, *Utilizing SANS to Detect Moisture in Foamed Asphalt*
- ESS 10484, *Investigation of the low temperature magnetic structure in U4 (Ru1-xOs)7Ge6*
- ESS 10091. *Determination of the magnetic structure of Mn3-xCoxO4 spinel*
- ESS 11048. *SANS analysis of Membrane Proteins Encapsulated into Bicontinuous Microemulsions*

- ESS 9601, *Examination of colloidal structures in simulated intestinal fluids using General Purpose SANS*
- ESS 8277, *Quantum harmonic oscillator excitations in Uranium Sulphide*
- ESS 10845, *Recommissioning of the HB-2D Beamline*
- NOP-2110, *Sampling Of HFIR Water Systems*
- RWSD-18147, *Rwsd For I&C Calibration, Troubleshooting, Repair, & Testing Of Hfir Systems*