Nuclear Criticality Safety at Oak Ridge National Laboratory

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Abstract

This paper outlines the implementation of the Oak Ridge National Laboratory (ORNL) Nuclear Criticality Safety (NCS) Program. The ORNL NCS Program is implemented through a top-level NCS program procedure that assigns responsibilities for performing the program elements. A simplified set of program elements includes hazard screening, process evaluation, NCS approval implementation and maintenance, and NCS program maintenance.

The fissionable material inventory at ORNL includes hundreds of kilograms of ^{233}U and ^{235}U and much smaller quantities of Np, Pu, Cm, and Cf. Operations associated with this material include fresh and spent fuel handling, storage of large quantities of fissile uranium, and recovery of transuranium elements. In general, fissionable material operations are small batch, one-time-only operations occurring in isolated facilities.

At ORNL, formal process evaluations are required for facilities or operations having more than the fissionable equivalent of 250 g ^{235}U. Setting the Fissionable Material Control Limit (FMCL) this high is reasonable because movement of significant quantities of fissionable material around ORNL is non-routine; and this hazard screening level allows for inadvertent double batching and provides margin to cover the presence of special moderating and reflecting materials, such as beryllium, reactor-grade graphite, and heavy water. Process conditions considered include normal operations, operational failures and upset conditions, facility failures and upset conditions, and the impact of natural phenomena hazards.

The ORNL NCS Program requires operation/facility management to perform detailed self-assessments annually. The NCS staff performs independent annual reviews of fissionable material operations and of the continued validity of the process evaluations. The ORNL Criticality Review Committee performs an annual review of fissionable material operations and the ORNL NCS Program.

Some features of the ORNL NCS Program work well, while others work less well. Use of the 250-g ^{235}U fissionable equivalent FMCL works very well for NCS program hazard screening purposes. But, because of differing approaches to hazard screening, safety analyses, and acceptable level of risk, the NCS Program does not fit together well with the facility safety (SAR/TSR) program. Other problem areas include integration of detailed written operating procedures as required by ANSI/ANS standards, and the application of DOE guidance and directives, which are often written for application to large sites.

Challenges on the horizon at ORNL include the DOE-mandated NCS staff qualification program, a shrinking workload, and maintaining an effective NCS program on a multi-contractor site. The costs associated with developing and maintaining a formal NCS staff qualification program and for providing the required training and professional growth opportunities will be significant. The ORNL NCS staff is comprised of three NCS engineers with a total of 43 years NCS experience. It is not apparent that the additional cost is justified by the marginal benefit.

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Abstract

The Nuclear Criticality Safety (NCS) Program at Oak Ridge National Laboratory (ORNL) covers a variety of fissionable material operations involving large quantities of ^{233}U and ^{235}U and smaller quantities of Np, Pu, Cm, and Cf. This paper outlines the implementation of the ORNL NCS Program, shares thoughts on what seems to work and what does not, and presents the challenges seen on the horizon.

ORNL FISSIONABLE MATERIAL OPERATIONS

The fissionable material inventory at ORNL includes hundreds of kilograms of ^{233}U and ^{235}U, and much smaller quantities of Np, Pu, Cm, and Cf. Operations associated with this material include fresh and spent fuel handling at the High Flux Isotope Reactor, storage of large quantities of fissile uranium, recovery of transuranium elements, recovery of ^{229}Th from ^{233}U, and repackaging of spent nuclear fuel. Future fissionable material operations are expected to expand to include inspection and repackaging of ^{233}U material stored at the Radiochemical Development Facility, conversion of Molten Salt Reactor Experiment UF_6 to U_3O_8, and fabrication and post-irradiation processing of Np targets in support of a ^{238}Pu generation program.

Fissionable material operations at ORNL may be characterized as small batch-type operations. A typical handling or processing operation involves a few packages containing no more fissionable material than the single-unit minimum subcritical mass limits provided in American National Standards ANSI/ANS-8.1 and 8.15. Material not in-process is stored in solid form in containers in storage facilities providing effective physical protection and access control. Presently, there are no fissionable material operations at ORNL involving continuous processing.

Many of the operations are one-time-only or infrequent, short-duration operations occurring in isolated facilities. For example, work planning is in progress for removing about 5 kg of highly enriched reactor fuel from a multi-ton concrete monolith into which it had been disposed of in a 15 feet-deep hole in 1988. The fuel will be extracted from a steel vessel in the concrete monolith and repackaged into multiple containers for shipment off-site as spent nuclear fuel. Many ORNL fissionable operations are this sort of unusual one-time operation.

ORNL NUCLEAR CRITICALITY SAFETY PROGRAM

The ORNL NCS Program is implemented through a top-level NCS program procedure that assigns responsibilities for performing the program elements. A simplified set of program elements includes hazard screening, process evaluation, NCS approval implementation and

maintenance, and NCS program maintenance. The ORNL NCS Program is applicable to all ORNL-managed facilities and operations. In recent years the ORNL site has become a multi-contractor site. There are many facilities on the ORNL site that are managed by other contractors and are not within the scope of the ORNL NCS Program.

Formal process evaluation is required for facilities or operations having more than the fissionable equivalent of 250 g ^{235}U. For nuclides other than ^{235}U, the fissionable equivalent is set using the ratios of the single-unit, optimally moderated, and optimally reflected subcritical mass limits from ANSI/ANS-8.1 and ANSI/ANS-8.15. For example, the 250 g ^{235}U fissionable equivalent for ^{238}Pu is 1100 g ^{238}Pu, calculated as 250 g ^{235}U * (3000 g ^{238}Pu / 700 g ^{235}U). Setting the fissionable material control limit (FMCL) as high as 250 g ^{235}U is reasonable because movement of significant quantities of fissionable material around ORNL is non-routine. This hazard screening level allows for inadvertent double batching and provides margin to cover the presence of special moderating and reflecting materials available at ORNL, such as beryllium, reactor-grade graphite, and heavy water. Line management is responsible for performing initial hazard screening. NCS staff remains aware of hazard screening by involvement in Nuclear Material Control and Accountability (NMC&A) practices and by performance of triennial reviews. The Program also requires that facility management of the originating facility check with facility management of the receiving facility prior to fissionable material transfers to ensure that receipt of the fissionable material will not result in violation of NCS fissionable material limits or other NCS-related requirements.

A process evaluation is performed when the ORNL FMCL will or may be exceeded. These process evaluations address both double contingency and the need for or installation of a criticality accident alarm system (CAAS). Currently, there is no CAAS installed at any ORNL-managed facility. The process evaluation identifies controls and limits necessary for the operation to meet double contingency, controls and limits necessary to support a conclusion that occurrence of a criticality accident is not credible, and, if a CAAS is required (i.e., criticality is credible), the controls and requirements for the CAAS. Process conditions considered include normal operations, operation failures and upset conditions, facility failures and upset conditions, and the impact of natural phenomena hazards. Input from facility and operations personnel are considered in the process evaluation and in deciding upon effective and appropriate NCS controls and limits. Process evaluations are prepared consistent with the guidance provided in DOE standard DOE-STD-3007-93, Chg. Notice 1 (9-98) and are supplemented with information needed to address CAAS issues.

After the process evaluation is completed and the NCS controls and limits are implemented, an implementation review is performed. The implementation checks include physical verification, content and completion of NCS training, incorporation of controls and limits into operating procedures, and posting of NCS signs. Typically, the ORNL NCS Staff performs implementation reviews.

The NCS Program requires continuing surveillance of fissionable material operations. Line management has primary NCS responsibility, providing continuous day-to-day supervision. This supervision is supplemented with NCS staff involvement. In addition to daily supervision and NCS staff support, the ORNL NCS Program requires that operation/facility management perform

a detailed self-assessment at least annually. The NCS staff performs independent annual reviews of fissionable material operations and of the continued validity of the process evaluations. The ORNL Criticality Review Committee, reporting to Laboratory Management, performs an annual review of fissionable material operations and the ORNL NCS Program.

Required NCS maintenance includes revising process evaluations, limits and controls, and operating procedures as necessary to better reflect operations, to improve operational efficiency, and to improve NCS. Generic and facility/operation-specific NCS training and retraining is performed biennially or whenever operations change.

ORNL NCS PROGRAM EFFECTIVENESS

Overall the ORNL NCS Program works wells because there are only a few fissionable material operations, generally the fissionable material operation supervisors are very knowledgeable about NCS and their operations, transfers of fissionable material to ORNL and on-site at ORNL are non-routine, ORNL has an experienced NCS Staff, and ORNL Management is committed to maintaining an effective NCS Program. The ORNL NCS Program has the elements of integrated safety management built into the Program.

Some features of the ORNL NCS Program work well, while others work less well. Use of the 250 g ^{235}U fissionable equivalent mass fissionable material control limit (FMCL) works very well for NCS program hazard-screening purposes. The FMCL permits line management screening of operations involving small quantities of fissionable material that are present in radioactive sources, analytical samples, waste, small laboratory-scale operations, etc. Relying upon facility and operation management to perform screening at the FMCL level is cost-effective and convenient for operations and historically has proven to be very effective. Its success is due primarily to the nature of fissionable material operations at ORNL. Transfer of fissionable material between facilities is non-routine and generally involves small quantities of fissionable material. Facility or operation fissionable material inventories do not change much. The emphasis placed by facility safety basis document (e.g., SAR) processes on radioactive material inventory strengthens the use of the FMCL for NCS screening purposes.

A problem area is that, in some cases, there is resistance by line management to using written operating procedures as required by ANSI/ANS standards. They do not see written operating procedures as an operational aid and would rather rely on “skill of the craft.” Instead, operating procedures are sometimes seen as a significant administrative burden and liability with little operational value. In some situations the personnel involved have so much experience and are so highly trained, and the NCS controls and limits are simple enough that the use of written operating procedures purely to meet ANSI/ANS standard “shall” statements appears unwarranted. Perhaps the standards could be amended on this subject.

At ORNL hazard screening normally is evaluated at two risk levels. First is that fissionable material operations must meet the double contingency principle (DCP). Quantification of the criticality accident occurrence probability is not required at this risk level. The second risk level is associated with the evaluating the need for criticality accident alarm systems (CAASs). DOE

Order 420.1 does not require CAAS coverage if the criticality accident occurrence probability is no greater than 1×10^{-6} per year. A probabilistic risk assessment (PRA) type evaluation is not required. In fact, calculation of the probability or frequency of occurrence is not required. Use of the DCP and evaluation at these NCS risk levels does not fit together well with evaluation required by the DOE Facility Safety Program to support safety analysis reports (SARs) for nuclear facilities. NCS process evaluations are not required to produce accident frequencies, and unless a CAAS is required, the potential consequences of a criticality accident are not evaluated. This is not viewed as a weakness of either the DOE NCS Program or the Facility Safety Program. It appears instead to be a coordination issue. The author would prefer that guidance for SAR analyses of criticality accidents be modified to be consistent with the efficient, mature, and proven evaluation techniques required by the DOE NCS Program. For example, nuclear facilities might be classified as category 2 nuclear facilities for NCS reasons if CAAS coverage is required. Nuclear facilities might be classified as category 3 if NCS-related controls beyond simple facility inventory control are required.

Occasionally DOE directives and guidance have created some challenges. It appears as though some directives and guidance are written for application to large sites, creating a “One glove fits all!” problem. The most recent example of this is the NCS Staff Training and Qualification (T&Q) Program mandated by the latest change to DOE O 420.1. The ORNL NCS Staff is comprised of three nuclear engineers with a total of 43 years NCS experience. Considering the high experience level and small ORNL NCS staff size, DOE should permit application of a “graded approach” for the ORNL NCS Staff T&Q Program. Use of a graded approach for establishing NCS Staff T&Q Programs at ORNL and other sites would save money and NCS Staff time. Without relief, the continuing resource requirement for the training and qualification program will compete with other NCS program elements for a limited amount of available funding and NCS staff time.

TOMORROW’S CHALLENGES

Challenges on the horizon at ORNL include the DOE-mandated NCS staff qualification program, a shrinking workload, and maintaining an effective NCS program on a multi-contractor site.

The costs associated with developing and maintaining a formal NCS staff qualification program and for providing the required training and professional growth opportunities will be significant. DOE should permit application of a “graded approach” for NCS Staff Training and Qualification Programs DOE complex-wide.

The ORNL site has been changing over to a multi-contractor site, with Bechtel Jacobs Company, LLC managing a significant part of the ORNL site under a managing and integrating (M&I) contract arrangement. NCS responsibility for solid and liquid waste disposal, and nearly all environmental restoration and decommissioning projects has passed to other contractors. This presents challenges in form of a shrinking workload, and a fragmented and inconsistent approach to NCS at adjacent buildings. There are at least three contractors on the ORNL site with their

own NCS programs. It is not apparent that effort has been made to coordinate efforts to produce a comprehensive approach to NCS on the ORNL site.

Currently, there is enough NCS-related work to justify maintaining the NCS Staff at ORNL. This could change in the future. Much of the work that in the past was the responsibility of the ORNL NCS Staff has passed to other contractors. If additional workload is lost it will likely be necessary to address the question of what is an acceptable minimum NCS staff size.

CONCLUSION AND ACKNOWLEDGEMENTS

ORNL fissionable material operations are typically batch in nature and fissionable material transfers are non-routine. The ORNL NCS Program implementation has been described along with its strengths and weaknesses and the approaching challenges. The ORNL NCS Program implementation is effective due to the nature of ORNL fissionable material operations, the quality of ORNL personnel working with fissionable material, ORNL Management commitment, the experience and wisdom of the people who created the ORNL NCS Program, and the efforts of the ORNL NCS Staff.

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