Technical Basis for the Uranium Processing Facility Criticality Accident Alarm System

C. E. Gross
Paschal Solutions, Inc. PO Box 71346, Knoxville, TN, 37938, grossce@paschalsolutions.com

R.S . Brown, Jr.
Gem Technologies, Inc. 2033 Castaic Lane, Knoxville, TN 37932, rsbrownjr@gmail.com

K. H. Reynolds, Ph. D.
Consolidated Nuclear Security, LLC, Y-12 National Security Complex, PO Box 2009, Oak Ridge, TN 37831-8245, Kevin.Reynolds@cns.doe.gov

R.G. Taylor, Ph. D.
C. S. Engineering, Inc., 702 Foxfield Lane, Knoxville, Tennessee 37922, rtaylor238@comcast.net

INTRODUCTION

The technical basis for the Y-12 National Security Complex (Y-12) Uranium Processing Facility (UPF) Criticality Accident Alarm System (CAAS) 90% design has been completed. The CAAS design was evaluated for two primary processing facilities, the Main Processing Building (MPB) and the Salvage and Accountability Building (SAB), and for connected facilities known as the Personnel Support Building (PSB) and the Highly Enriched Uranium Materials facility (HEUMF) Connector (HCON), which connects UPF to existing Y-12 facilities. The evaluation focused on three primary areas to address requirements of ANSI/ANS-8.3 [1]: (1) detectability of the minimum accident of concern; (2) determination of areas where total dose could exceed 12 rad for the maximum anticipated accident yield; and (3) evaluation of the radiation tolerance of the detectors and associated control cabinets. The design was based on extensive analyses performed in MCNP6 [2].

DESCRIPTION OF THE ACTUAL WORK

UPF is a new enriched uranium complex under design and construction at the Y-12 site in Oak Ridge, Tennessee. The CAAS system design was completed in 2017 based on the 90% facility design which includes detailed structural and architectural design of every building, including interior walls and structures. All areas with credible fissile material presence were evaluated to identify candidate accident locations. Material that would affect accident yield and energy spectra were established so that conservative analyses could be applied for CAAS design. The analyses were divided to examine three key requirements:

1. Detectability: CAAS shall respond immediately to the minimum accident of concern (absorbed dose rate in free air of 20 rad/min at 2 meters).
2. 12-rad Boundary: CAAS annunciation must be provided in any area where personnel would be subject to an excessive radiation dose.
3. Radiation Tolerance: CAAS shall have sufficiently robust components to actuate the alarm signal when exposed to the maximum radiation expected.

RESULTS

Initial detector placement was established based on judgment by experienced Nuclear Criticality Safety (NCS) personnel. Each proposed detector location was then evaluated to show that the minimum accident of concern at any credible location would be seen by at least one detector located on the same floor. Interspersed shielding from walls and equipment was conservatively considered by a combination of homogenized loadings and detailed modeling. Detailed modeling was performed for large features such as building columns, internal walls, and some large equipment items. Features such as structural grid steel were conservatively represented using lattice options in MCNP based on detailed modeling of the largest beams and columns.

A site-wide model was developed to establish the 12-rad boundary. The worst-case combination of yield and energy spectrum was applied to various peripheral locations around the facility and the effects of reflection between facilities was observed to increase the 12-rad distance by roughly 30% in some areas.

The radiation tolerance of the CAAS components was established. For the detectors, vendor supplied test data providing the radiation tolerance limit of the detectors was used as the failure point for radiation exposure. MCNP6 analyses were then performed by locating an accident immediately below a detector location and scaling the dose received at that nearest detector to equal the radiation tolerance limit. The same calculation included the calculated dose at the remaining detectors in the area and was able to show that in all cases at least one additional detector would reach the detection threshold for alarm even if the nearest detector above the accident was assumed to fail immediately due to excessive radiation exposure.

Radiation tolerance for CAAS control cabinets was evaluated separately, and resulted in relocation of the control cabinets to a more distant and heavily shielded location outside fissile processing areas. MCNP6 analyses were again performed from the nearest credible accident location to the new control cabinet location. Shielding walls were specifically identified and a design change made to minimize the dose to the control cabinets to levels expected to ensure reliable CAAS system function. The determination of control cabinet radiation tolerance has led to identification of a need for additional testing of that hardware.

The engineering effort required to develop the original CAAS design for UPF has required coordination among structural, mechanical, instrument, nuclear safety, regulatory, and NCS personnel. Timely and robust completion of this work required the experienced judgement of NCS practitioners supported by detailed analyses to fine tune those initial judgments. The work required extensive application of MCNP6 modeling techniques and variance reduction methods to ensure reliable results. The end-product resulted in changes to plant design and some aspects of emergency planning.

REFERENCES

1. ANSI/ANS-8.3-1997, “Criticality Accident Alarm System,” American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois, 60526.
2. LA-CP-13-00634, Rev. 0, MCNP6 User’s Manual, Ver. 1.0, Los Alamos National Security, LLC, Los Alamos, N.M., May 2013.

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