June 5, 2014

Mr. B. Joel Burch
Vice President and General Manager
Babcock and Wilcox
Nuclear Operations Group, Inc.
P.O. Box 785
Lynchburg, VA 24505-0785

SUBJECT: BABCOCK AND WILCOX NUCLEAR OPERATIONS GROUP, INC. – U.S. NUCLEAR REGULATORY COMMISSION INSPECTION REPORT NUMBER 70-027/2014-203

Dear Mr. Burch:

The U.S. Nuclear Regulatory Commission (NRC) conducted a routine, announced nuclear criticality safety (NCS) inspection at your facility in Lynchburg, Virginia, from May 5-8, 2014. The purpose of the inspection was to determine whether activities involving special nuclear material were conducted safely and in accordance with your license and regulatory requirements. An exit meeting was held on May 8, 2014.

The inspection, which is described in the enclosure, focused on the most hazardous activities and plant conditions, the most important controls relied on for safety, and the principal management measures for ensuring controls are available and reliable to perform their safety functions. The inspection consisted of a selective review of safety basis documents, related procedures and records, examination of safety-related equipment, interviews with plant personnel, and facility walkdowns. The inspection found that your activities with regard to nuclear criticality safety were conducted safely and in accordance with regulatory requirements.

In accordance with Title 10 of the *Code of Federal Regulations* 2.390 of NRC's "Agency Rules of Practice and Procedures," a copy of this letter and the enclosure will be made publicly available in the public electronic reading room of the NRC's Agencywide Documents Access and Management System (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html.

If you have any questions concerning this report, please contact Christopher S. Tripp of my staff at 301-287-9153, or via email to christopher.tripp@nrc.gov.

Sincerely,

/RA/

Michael X. Franovich, Chief
Programmatic Oversight and
Regional Support Branch
Division of Fuel Cycle Safety
and Safeguards
Office of Nuclear Material Safety
and Safeguards

Docket No.70-27
License No. SNM-42

Enclosure:
NRC Inspection Report 70-027/2014-203
w/Attachment: Supplementary Information

cc w/encl:
C. A. England, Manager
Licensing and Safety Analysis
Babcock and Wilcox
Nuclear Operations Group, Inc.
P.O. Box 785
Lynchburg, VA 24505-0785

Steve Harrison, Director
Division of Radiological Health
Department of Health
109 Governor Street, Room 730
Richmond, VA 23219

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U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS

Docket No.:	70-27
License No.:	SNM-42
Report No.:	70-027/2014-203
Licensee:	Babcock and Wilcox Nuclear Operations Group, Inc.
Location:	Lynchburg, VA
Inspection Dates:	May 5-8, 2014
Inspectors:	Christopher Tripp, Criticality Safety Inspector Patricia Glenn, Fuel Facility Inspector
Approved by:	Michael X. Franovich, Chief Programmatic Oversight and Regional Support Branch Division of Fuel Cycle Safety and Safeguards Office of Nuclear Material Safety and Safeguards

Enclosure

EXECUTIVE SUMMARY

Babcock and Wilcox Nuclear Operations Group, Inc.
NRC Inspection Report 70-027/2014-203

Introduction

Staff of the U.S. Nuclear Regulatory Commission (NRC) performed a routine, announced nuclear criticality safety (NCS) inspection of the Babcock and Wilcox (B&W) Nuclear Operations Group (NOG), Inc., facility in Lynchburg, Virginia from May 5-8, 2014. The inspection included an onsite review of the licensee's NCS program, evaluations, audits, event review and follow-up, plant activities, and open items. The inspection focused on areas including fuel fabrication and machining, the uranium recovery area, the Research Test Reactor and Target area, and the Specialty Fuels Facility.

Results

- No safety concerns were identified regarding the licensee's NCS program.
- No safety concerns were identified during review of the NCS event review and follow-up.
- No safety concerns were identified regarding NCS audits.
- No safety concerns were identified during walk downs of plant operations.
- Unresolved Item (URI) 70-27/2013-204-01 related to an unanalyzed upset condition of "stacking" and potentially inadequate controls to prevent criticality in the Target Storage Cabinets was closed.

REPORT DETAILS

1.0 Summary of Plant Status

B&W NOG manufactures high-enriched uranium fuel, reactor core components, and reactor cores at its facility near Lynchburg, VA. During the inspection, the licensee conducted routine fuel manufacturing operations and maintenance activities in the fuel fabrication and uranium recovery areas.

2.0 Nuclear Criticality Safety Program (IP 88015 & 88016)

a. Inspection Scope

The inspectors reviewed the licensee's NCS program and analyses, to determine their adequacy for ensuring the safety of fissile material operations. The inspectors reviewed new and revised analyses, plant procedures, and a newly revised validation report. The inspectors interviewed licensee managers and engineers and accompanied licensee staff on walkdowns of facility operations. The inspectors reviewed selected portions of documents listed in Section 2.2 of the attachment.

b. Observations and Findings

The inspectors reviewed several new analyses, and determined that they adequately demonstrated subcriticality under normal and credible abnormal conditions, met the double contingency principle, and established controls and limits sufficient to ensure criticality safety in plant operations. The inspectors also reviewed accident sequences related to criticality hazards and items relied on for safety (IROFS) associated with the sequences, and determined that they were consistent with the underlying criticality evaluation. In response to inspectors' questions about discussions in some safety concern analyses (SCAs) regarding failure to meet the performance requirements or double contingency principle upon loss of a control or IROFS, the license stated that its preference is to provide an additional layer of protection so that an operation will remain subcritical following the occurrence of two contingencies, whenever feasible. While it is still in draft, the licensee showed the inspectors its new "PA [Process Analysis] Writer's Guide" that will govern the writing of analyses in the new format (see below), and makes reference to this added layer of protection. A process deviation that causes the loss of a single control, therefore, may trigger writing an SCA, but does not necessarily mean that the double contingency principle has been violated.

The licensee informed the inspectors that it is in the process of revising its system for performing and documenting criticality analyses. Previous inspections have noted that it can be difficult to determine the safety basis for an operation when it resides in multiple documents, and a new analysis is generated for each change. To address this difficulty, the licensee recently instituted its new "PA" process, whereby all the criticality analysis for a particular operation will be consolidated into a single version-controlled document. The inspectors reviewed the first analysis performed under the new process, NCS-PA-20-00001, covering poisoned container racks to address Event Report 49259 (closed in Inspection Report 70-27/2014-201). The inspectors determined that the PA included a comprehensive set of calculations for both normal and credible abnormal conditions, a

detailed discussion of double contingency, and a clear connection between the criticality analysis and scenario and IROFS tables in the safety analysis report (SAR). The double contingency discussion was particularly detailed, including a description of the scenario; primary, secondary, and in some cases tertiary contingencies; additional safety margin; and an evaluation of the potential for common-mode failure. The inspectors determined that the analysis was conservative in providing for added defense-in-depth beyond the minimum number of controls needed to meet double contingency (including "triple-contingency" as discussed above).

The inspectors did observe, in their review of NCS-PA-20-00001, that it was not readily apparent what was being assumed for normal versus credible abnormal conditions, in particular in regard to interspersed moderation. While the licensee evaluated excessive interspersed moderation as an operational upset, it was not apparent what the normal level of moderation, or maximum credible level of moderation, was assumed to be. In some calculations, the results of the moderator sweep were compared to the normal condition limit of 0.92; in others, to the abnormal condition limit of 0.95. In some cases, the calculated k_{eff} exceeded the abnormal limit of 0.95, but those values appeared to be part of a parametric study whose limits exceeded what the licensee considered credible. Although the licensee considered moderation a controlled parameter (with a control described as "permitted as necessary"), this control was not associated with a specific parametric limit.

The inspectors also observed that in SCA NCS-2014-031, dealing with the impact of an unauthorized portable container in specialty fuels facility, the licensee had assumed a worst credible interspersed moderation of 10%. The licensee's analysis justified this based on the presence of the workstations in a moderation-controlled area, the lack of airtight doors on the enclosures, and the presence of drains. As further justification, the licensee referred to the B&W paper, "Interspersed Moderation, What is Credible?" presented at the American Nuclear Society Topical Meeting in Wilmington, North Carolina in 2013. This paper evaluates the maximum water density resulting from fire sprinklers, fire hoses, foam, steam, and rain. For most upsets, k_{eff} peaked well before a level of 10% water density was reached. For other upsets, the moderator sweep involved another upset besides the presence of interspersed moderator, and the adjusted k_{eff} remained below 0.95. An upset involving a leak exceeded k_{eff} of 0.95, but this scenario ignored the presence of drains (which would require two failures in addition to the presence of excess interspersed moderator, which exceeds what must be shown to be subcritical in accordance with the double contingency principle).

The inspectors noted that the licensee recently completed its validation and verification of the SCALE-6.1 criticality computer code. As the use of raschig ring-filled vessels has been discontinued, the licensee removed raschig ring benchmarks from its validation database. The validation covers the 238-group and continuous-energy cross section libraries, but only with use of the KENO-V.a (and not KENO-VI) geometry package. The validation determined a calculational margin for three different subsets of calculations: those with enrichment less than 10 wt% ^{235}U, those with greater than 10wt% ^{235}U, and welded Naval Reactors clusters. The validation trended benchmark k_{eff} as a function of enrichment, hydrogen-to-fissile ratio (H/X), energy corresponding to average lethargy causing fission, and the thermal fission fraction. Enrichment relates to the isotopic composition, while the other three trending parameters all relate to the fission spectrum, as there is a strong dependence between the amount of moderator and the neutron

energy spectra. Based on the distribution of benchmarks and evaluation of trends, the licensee determined areas of applicability (AOAs) defined by the range in trending parameters, geometry, and material composition (moderators, reflectors, and absorbers). The range covered by the benchmarks matched the validation applicability in all cases except enrichment and H/X. Regarding enrichment, the inspectors note that almost all calculations are performed below 10 wt% ^{235}U or above 90 wt% ^{235}U, which are both ranges well-covered by benchmark data. Regarding H/X, while the inspectors observed that there were no benchmarks covering the high moderation end of the range, the spectrum is well-thermalized and thus the bias can only be affected by the amount of hydrogen, whose absorption cross section is well-characterized. The inspector agreed based on these considerations that extending the validation applicability to higher H/X was justified. The inspectors also observed that the AOA table for moderators and other isotopes (mainly absorbers) contained the statement that the validation applicability was acceptable "provided the constituents have been tested or the impact on the system can be assessed." Noting that a longer list of validated constituents was listed under these parameters than appeared to be contained in applicable benchmarks, the inspectors asked for an explanation.

The licensee staff agreed with the inspectors' statement that the mere presence of an isotope in the validation database does not mean its use should be considered validated for all applications or without regard to its quantity or worth. The licensee stated that the intent of this statement in the validation report is that if unusual materials are included in its criticality models, their use should be justified and documented in analysis. As an example of where this has been done, the licensee provided document NCS-2010-253, "Reactivity Uncertainty Associated with Modeling of Chlorine in PVC Applications" to justify use of chlorine as an absorber. While there are some benchmarks containing chlorine in the validation database, the licensee determined these were not a good fit to plant applications and additional justification was needed. The licensee's analysis NCS-2010-253 used the TSUNAMI sensitivity-uncertainty code (part of the SCALE-6.1 code package) to bound the largest effect that chlorine could have on the bias. The licensee did this by combining the integral sensitivity coefficient (confirmed by direct perturbation) with the known uncertainty, and showing that the maximum change in k_{eff} resulting from cross section errors was a small fraction of the calculational margin of 0.015.

The inspectors also compared the new SCALE-6.1 validation to the existing validation for SCALE-5.0, and determined that the method was at least as rigorous and conservative as was previously used. The inspectors also examined several verification reports and noted that verification has been performed as required on each individual workstation used to perform calculations, and no discrepancies in the output files were observed.

c. Conclusions

No safety concerns were identified regarding the NCS program, NCS analysis, or the SCALE-6.1 validation. Development of the PA process for consolidating and elucidating the criticality safety basis appears to be a significant enhancement.

3.0 Nuclear Criticality Safety Inspections, Audits, and Investigations (IP 88015)

a. Inspection Scope

The inspectors reviewed licensee internal audit procedure, and results of the two most recent NCS quarterly audit to assure that appropriate issues were identified and resolved. The inspectors accompanied a licensee NCS engineer on a routine weekly NCS inspection of the Container Storage Facility. The inspectors reviewed selected aspects of the documents listed in Section 2.3 of the Attachment.

b. Observations and Findings

The inspectors observed that the licensee's weekly NCS inspections were conducted in accordance with written procedures. The licensee's weekly NCS inspection observed by the NRC inspectors was performed by a qualified NCS engineers who researched NCS issues and or violations that occurred during previous audits of the Container Storage Facility; reviewed the adequacy of controls implementation; reviewed plant operations for compliance with license requirements, procedures, and postings; examined selected controls and operations to determine that past evaluations remained adequate; and identified NCS-related non-compliances. The NCS engineer conducting the inspection walked down the facility, discussed operations with the front line manager, inquired about NCS controls and postings, and reviewed the postings. The inspectors confirmed that non-compliances identified during audits were appropriately captured in the licensee's corrective action program.

c. Conclusions

No safety concerns were identified regarding NCS audits, inspections, and investigations.

4.0 Nuclear Criticality Safety Event Review and Follow-up (IP 88015 & 88016)

a. Inspection Scope

The inspectors reviewed the licensee's response to a selection of recent NCS related internally-reported events. No NCS related reportable events occurred since the last inspection. The inspectors reviewed the progress of investigations and interviewed licensee staff regarding immediate and long-term corrective actions. The inspectors reviewed selected aspects of documents identified in Section 2.4 of the Attachment.

b. Observations and Findings

The inspectors reviewed select licensee internally reported criticality safety related events that occurred since the last NCS inspection. The inspectors also reviewed the safety concern analyses and corrective actions for the selected events. The safety concern analysis provided additional detail about the events and documented the licensee's analysis for determining whether an event met NRC reporting requirements. The inspectors did not identify any safety concerns related to incorrect reportability determinations for the events reviewed during this inspection. The inspectors observed

that internal events were investigated in accordance with written procedures and appropriate corrective actions were assigned and tracked.

c. Conclusions

No safety concerns were identified during review of recent licensee investigation of internal events.

5.0 Plant Activities (IP 88015, IP 88016)

a. Inspection Scope

The inspectors performed plant walk downs to review activities in progress and to determine whether risk-significant fissile material operations were being conducted safely and in accordance with regulatory requirements. The inspectors reviewed documents, and interviewed operations staff and NCS engineers both before and during walk downs. The inspectors reviewed selected aspects of the documents listed in Section 2.6 of the Attachment.

b. Observations and Findings

The inspectors verified that controls identified in NCS analyses were installed or implemented and were adequate to ensure safety. The inspectors also verified that safety was maintained for the observed facility operations. The cognizant, NCS engineers were knowledgeable and interacted regularly with operators on the process floors. The inspectors verified the adequacy of management measures for assuring the continued availability, reliability, and capability of safety-significant controls relied upon by the licensee for controlling criticality risks.

During the walk downs the inspectors inquired with operators regarding current operations and criticality safety controls that were in place. Personnel interviewed were familiar with their operation and applicable controls used to implement criticality safety.

c. Conclusions

No safety concerns were identified during a review of the licensee's plant activities.

6.0 Open Item Review

URI 70-27/2013-204-01

During a nuclear criticality inspection conducted at B&W during August 2013 inspectors identified URI 70-27/2013-204-01 related to an unanalyzed upset condition of "stacking" and potentially inadequate controls to prevent criticality in the Target Storage Cabinets. The issue was identified during review of NCS-2013-070, "NCS Safety Analysis Revising the Safety Basis for the Target Storage Cabinets per CR-1038679," dated May 9, 2013. During review, the inspectors observed that the analysis did not evaluate the possible "stacking" of targets as disused in inspection report 70-027/2013-204.

The licensee conducted an analysis to determine how much k_{eff} would be increased by stacking and whether or not the existing controls are sufficient to maintain subcriticality for a stacking upset. The inspectors independently reviewed the licensee's analysis and walked down the target storage cabinets to evaluate the controls in place at the time of the URI and at the time of the follow-up inspection. The inspectors determined that a critical configuration resulting from stacking of targets in the storage cabinets was very unlikely due to the excessive number of errors that would be required by a material accounting and control technician or operator. Such errors would be upsets of controls existing at the time of the URI on piece count (for drawers without inserts) and moderation (for all drawers in general).

The inspectors determined that the licensee's revised analysis addresses and bounds the condition of stacking of targets in the container storage cabinets. Additionally, the licensee currently explicitly restricts stacking via NCS posting. At the time of the URI, the as found condition of targets in the storage cabinets was in compliance with NCS requirements and there was no stacking of targets present. The cabinets were maintained in a secure state that was not assessable without authorization. Currently, the storage cabinets no longer contain targets and there are no future plans to use the cabinets for target storage. The inspectors determined that there is no safety concern and the licensee documented, tracked, and addressed this issue in accordance with approved written procedures. URI 70-27/2013-204-01 is considered closed at this time.

7.0 Exit Meeting

The inspectors presented the inspection scope and results to members of the licensee's management and staff, including Joel Burch, during an exit meeting on May 8, 2014. The licensee stated that it understood the findings as presented.

SUPPLEMENTARY INFORMATION

1.0 List of Items Opened, Closed, and Discussed

Item Number	Status	Description
URI 70-27/2013-204-01	Closed	Unanalyzed upset condition of "stacking" and potentially inadequate controls to prevent criticality in the Target Storage Cabinets.

2.0 Key Documents Reviewed:

Inspectors reviewed selected aspects of the following documents. Documents that apply to multiple sections are listed in the section that is most applicable.

2.1 Plant Status

Not Applicable

2.2 Nuclear Criticality Safety Program (IP 88015 & 88016)

- NCS-2013-182, "NCS Safety Analysis Revising the Safety Basis for the Target Storage Cabinets per CR-1041709," January 15, 2014
- CR-1041709, "Revise Target Storage Cabinet NCS Posting (U)," December 11, 2013
- NCS-2014-052, "Safety Concern Analysis for a Missing Valve Functionality Test in MET LAB Savage Saw Room (CA-201400058)," March 19, 2014
- SAR 15.21, "Low Level Radioactive Waste Processes Waste Operations," Rev. 64, June 17, 2013
- NCS-2014-044, "Safety Concern Analysis for Degraded A1B Poison Fixture (CA-201400139) (U)," February 26, 2014
- NCS-2014-049, "Safety Concern Analysis for Improper Storage of an S8G Preassembly and Subassembly in a Single Location on a Cantilever Rack – CA-201400359," March 4, 2014
- NCSE-02, "Nuclear Criticality Safety Analyses & Quality Assurance Reviews," Rev. 36, March 31, 2009
- NCS-2014-031, "Safety Concern Analysis: Improperly Analyzed ≤ 2.5-Liter Container in Workstation 260 and Workstation 60 in SFF (CA201400219)," February 25, 2014
- Wetzel, L.L., O'Donnell, B.M., Ashworth, D.L., "Interspersed Moderation, What is Credible?", Proceedings of the American Nuclear Society 2013 Topical Meeting, September 29 – October 3, 2013, Wilmington, NC
- NCS-TR-00007, "Validation Report for SCALE 6.1 on Windows 7-Based PC's," Rev. 0, January 21, 2014
- NCS-TR-00007, "Validation Report for SCALE 6.1 on Windows 7-Based PC's," Rev. 1, February 7, 2014
- NCS-2006-055, "Validation Report for SCALE 5.0 on Dell 650 Dual Processors Computers," March 10, 2006

- NCS-2014-034, “SCALE-6.1 Verification for Windows 7 Workstation ESH-465,” February 5, 2014
- NCS-2014-037, “SCALE-6.1 Verification for Windows 7 Workstation ESH-464,” February 6, 2014
- NCS-2014-035, “SCALE-6.1 Verification for Windows 7 Workstation ESH-467,” February 5, 2014
- OP-1004709, “Operation of Savage Hotside Saw (U),” Rev. 07
- NCS-2000-256, “NCS Evaluation for Replacement of Met Lab Hot Saw per SER 00-062,” September 20, 2000
- NCS-2010-253, “Reactivity Uncertainty Associated with Modeling of Chlorine in PVC Applications,” December 7, 2010
- NCS-1989-305, “Anocut Saw Filtration System/LER89143/KIDD,” November 7, 1989
- NCS-PA-20-00001, “Nuclear Criticality Safety Evaluation of Poisoned ≤ 2.5-Liter Container Racks (4-Column Single Poison Plate, 4-Column Double Poison Plate, 2-Column Single Poison Plate),” Rev. 0, January 17, 2014
- Draft “PA Writer’s Guide”
- NCSE-11, “Verification and Validation of Computer Codes Used for Nuclear Criticality Safety Analysis,”

2.3 Nuclear Criticality Safety Inspections, Audits, and Investigations (IP 88015)

- NCSE-03, “Nuclear Criticality Safety Audits and Inspections,” Rev. 26, September 12, 2013
- NCS-2014-069, “NCS Violation and Observation Summary – 1st Quarter 2014,” April 21, 2014
- NCS-2014-001, “NCS Violation and Observation Summary – 4th Quarter 2013,” January 22, 2014
- NCS-2006-168, “NCSA New Container Storage Facility,” August 17, 2006

2.4 Nuclear Critically Safety Event Review and Follow-up (IP 88015 & 88016)

- CA 201400448, March 13, 2014
- CA 201400058, January 9, 2014
- CA 201400219, January 30, 2014
- CA 201400139, January 22, 2014
- CA 201400441, March 12, 2014
- CA 201400359, February 25, 2014
- CA 201302357, November 20, 2013
- COM 39893, February 28, 2014
- COM 39588, April 30, 2014
- NCS-2014-051 - Safety Concern Analysis, March 4, 2014
- NCS-2014-056 - Safety Concern Analysis, March 22, 2014
- NCS-2014-049 - Safety Concern Analysis, March 4, 2014
- NCS-2014-057 - Safety Concern Analysis, March 24, 2014
- NCS-2014-031 - Safety Concern Analysis, February 25, 2014
- NCS-2014-047 - Safety Concern Analysis, March 22, 2014
- NCS-2014-052 - Safety Concern Analysis, March 19, 2014
- NCS-2014-044 - Safety Concern Analysis, February 26, 2014

- NCS-2014-041 - Safety Concern Analysis, March 11, 2014
- NCS-2014-040 - Safety Concern Analysis, March 13, 2014
- NCS-2014-050 - Safety Concern Analysis, April 16, 2014

2.5 Open Items

- NCS-2013-182, "NCS Safety Analysis Revising the Safety Basis for the Target Storage Cabinets," January 15, 2014
- CR-1041709, "Revise Target Storage Cabinet NCS Posting (U)," December 11, 2013

2.6 Plant Activities

Documents listed in other sections were reviewed related to facility walk downs.

2.7 Exit Meeting

Not Applicable

3.0 Inspection Procedures Used

IP 88015 Nuclear Criticality Safety Program
IP 88016 Nuclear Criticality Safety Evaluations and Analyses
IP 88017 Criticality Alarm Systems

4.0 Key Points of Contact

B&W NOG

K. Kicky	Licensing Engineer
T. England	Licensing and Safety Analysis Manager
D. Faidley	NCS Manager
B. Burch	Vice President and General Manager
D. Ward	ESH&S Manager

NRC

P. Glenn	Fuel Facility Inspector, NRC RII
S. Subosits	Senior Resident Inspector, NRC RII
C. Tripp	Criticality Safety Inspector, NRC HQ

5.0 List of Acronyms and Abbreviations

AOA	area of applicability
B&W	Babcock and Wilcox
H/X	hydrogen to fissile ratio
IP	inspection procedure

IROFS	item(s) relied on for safety
NCS	nuclear criticality safety
NOG	Nuclear Operations Group
NRC	U.S. Nuclear Regulatory Commission
PA	process analysis
SAR	safety analysis report
SCA	safety concern analysis
SNM	special nuclear material
U	uranium
URI	unresolved item