ANL/NSE-C2019-19185

NUBOW-3D Demonstration on LFR

Final CRADA Report

NSE Division

About Argonne National Laboratory
Argonne is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC under contract DE-AC02-06CH11357. The Laboratory's main facility is outside Chicago, at 9700 South Cass Avenue, Argonne, Illinois 60439. For information about Argonne and its pioneering science and technology programs, see www.anl.gov.

DOCUMENT AVAILABILITY

Online Access: U.S. Department of Energy (DOE) reports produced after 1991 and a growing number of pre-1991 documents are available free at OSTI.GOV (http://www.osti.gov/), a service of the U.S. Dept. of Energy's Office of Scientific and Technical Information

Reports not in digital format may be purchased by the public from the National Technical Information Service (NTIS):

U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Rd
Alexandria, VA 22312
www.ntis.gov
Phone: (800) 553-NTIS (6847) or (703) 605-6000
Fax: (703) 605-6900
Email: **orders@ntis.gov**

Reports not in digital format are available to DOE and DOE contractors from the Office of Scientific and Technical Information (OSTI):

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
www.osti.gov
Phone: (865) 576-8401
Fax: (865) 576-5728
Email: **reports@osti.gov**

ANL/NSE-C2019-19185

NUBOW-3D Demonstration on LFR

Final CRADA Report

prepared by

Micheal A. Smith, Teak K. Kim
Nuclear Science and Engineering Division
Nick Wozniak, James J. Grudzinski
Experimental Operations and Facilities Division, Argonne National Laboratory

Participants: Westinghouse Electric Company LLC

10/20/2020

This page intentionally left blank

Argonne NATIONAL LABORATORY

Non Proprietary

Final CRADA Report

For the Office of Scientific and Technical Information (OSTI)

CRADA Number: **2019-19185**
CRADA Title: Extension of Core Restraint Design Code NUBOW-3D to Lead Cooled Fast Reactor Systems
CRADA Start Date 3/1/2020 – **End Date** 10/30/2020

DOE Program or Other Government Support
Program office: Technology Transitions
Program manager name: Steven Palmeri
Program manager phone or email: steve.palmeri@hq.doe.gov

Participant(s)

Participant 1 name: **Westinghouse Electric Company LLC**
Complete address: **4000 Town Center Blvd. Suite 210, Canonsburg, PA 15317**

Participant 2 name: Click or tap here to enter text.
Complete address: Click or tap here to enter text.

Participant 3 name: Click or tap here to enter text.
Complete address: Click or tap here to enter text.

Argonne National Laboratory

Argonne PI(s): Micheal A Smith, Nick Wozniak, James J. Grudzinski, Teak K. Kim

Funding Table

To add rows, right-click in bottom row and select “Insert” “rows above”.

	Planned Funding	Actual Funding	In-Kind
Government	$75,000	$75,000	
Westinghouse Electric LLC	$	$	$75,000
Enter Participant 2 here	$	$	$
Enter Participant 3 here	$	$	$
Total	**$75,000**	**$75,000**	**$75,000**

Nature of Work

Describe the research (summary of Scope of Work and principal objectives of the CRADA):

The NUBOW-3D software was developed to assist in designing a core restraint system for sodium-cooled fast spectrum reactors. Originally conceived during the FFTF design activities, the United States has been a proponent of limited free bow reactor design ever since to improve safety performance. In fast spectrum reactors, successful safety performance during reactor transients requires favorable reactivity feedback that leads to safe power stabilization or even natural system shutdown. In fast spectrum reactors, one key mechanism that designers use to improve the performance is to make thermal expansion inject negative feedback into the reactor system. While most fast reactor systems generally have a negative reactivity response to geometric expansion, the NUBOW-3D software allows the designers to better explore the impact on reactivity and optimize the system to maximize its impact.

The summary report provided to Westinghouse discussed the effort completed to modify NUBOW-3D and use it on the Westinghouse provided LFR design. Because the LFR design considers ducted fuel assemblies, relatively little modifications were required to NUBOW-3D. The major focus of the modifications were the incorporation of the material properties of the structural materials in the LFR design. As shown in that report, these correlations are not trivial (i.e. simple constants) and thus must be incorporated into the NUBOW-3D source code, especially given that the correlations for two different materials can be considerably different. The chosen correlations and references for the Young's Modulus, the thermal expansion coefficient, irradiation induced swelling and creep, and thermal creep were all discussed and displayed. They were further demonstrated to be consistent with similar structural materials to ensure they would yield accurate analysis results.

For the NUBOW-3D analysis itself, there were several missing details on the reactor design which limited the extent of the NUBOW-3D analysis. NUBOW-3D requires time point data and follows the assembly behavior over its residence time. In the provided model, no shuffling pattern was given and thus the equilibrium mode was used leading to a simple 2 year residence time (BOC and EOC). Further, the clearance and design information on the constraint system were not fully defined. While values from a typical SFR system were assumed, clearly the NUBOW-3D results are strongly dependent upon these design decisions. Finally, temperature distribution calculated by the DASSH software was used for the NUBOW-3D demonstration on LFR, even though additional effort is needed to properly model the LFR specific design (which is out of the work scope). These aspects are all important issues to resolve but are not essential for the NUBOW-3D demonstration work.

The discussion on NUBOW-3D focused on the main inputs it needs and the outputs it produces. The LFR analysis result demonstrated significant core compaction at the ACLP and TLP. The output figures from NUBOW provide a very easy to read assessment of how and why this compaction occurs at both points. The force plots follow in line with the deflection and do not indicate serious problems for the provided two-year modeled time frame although this is not relevant given the problems with DASSH and missing design details. Finally, the EOC results demonstrated the importance of considering irradiation induced swelling and creep although no severe issues were again found for the two-year irradiation. No demonstration of the radial expansion coefficient was provided as that feature has not been verified for the full core analysis capability and it was not the primary focus of this demonstration. Overall, the displayed work demonstrates the purpose of NUBOW-3D and demonstrates that the NUBOW-3D software was successfully modified to work with the LFR design.

DOE mission area(s):
Energy and Environmental Science and Technology
Choose an item.
Choose an item.

Conclusions drawn from this CRADA; include any major accomplishments:
The NUBOW-3D software was successfully updated and demonstrated on lead fast reactors. The next step requires additional work with Westinghouse to help them use the updated software in their ongoing design work.

Technology Transfer-Intellectual Property
Argonne National Laboratory background IP:
ANL-SF-14-116 NUBOW-3D INELASTIC.

Participant(s) background IP:
The Participant has identified that the following Background Intellectual Property that may have been used in the performance of work under this CRADA and may be needed to practice the results of this CRADA:
Participant's Background Intellectual Property:

- US Provisional Patent Application Serial Number 62/568,486; filed October 5, 2017; titled "Pool Type Liquid Metal Fast Spectrum Reactor Using A Printed Circuit Heat Exchanger Connection To The Power Conversion System"

- US Provisional Patent Application Serial Number 62/840,775; filed April 30, 2019; titled "Common Plenum Fuel Assembly Design Supporting A Compact Vessel, Long-Life Cores, and Eased Refueling In Pool-Type Reactors"

The Participant represents that the above-identified Background Intellectual Property is available for licensing as of the effective date of this CRADA. The Participant has used reasonable efforts to list all relevant Background Intellectual Property, but Intellectual Property may exist that is not identified. Neither Party shall be liable to the other Party because of failure to list Background Intellectual Property.

Identify any new Subject Inventions as a result of this CRADA:
None

Summary of technology transfer benefits to industry and, if applicable, path forward/anticipated next steps towards commercialization:
Our commercialization effort builds upon the existing NUBOW-3D capabilities to work with our industry partner and demonstrate its effectiveness on lead cooled fast reactor systems. The collaborative research that results will improve the knowledge base on lead cooled reactor technology at Argonne and deliver a valuable piece of design software to Westinghouse. It will further help other commercial entities that are either interested in or already pursuing sodium cooled or lead cooled reactor systems.

Other information/results (papers, inventions, software, etc.):
None

NSE Division
Argonne National Laboratory
9700 South Cass Avenue, Bldg. 208
Argonne, IL 60439

www.anl.gov