New & Advanced Reactors: Codes & Standards

APRIL 4, 2024
ROCKVILLE, MD

PUBLIC MEETING SUMMARY
PUBLIC MEETING NOTICE AND AGENDA: ML24065A472

On April 4, 2024, the U.S. Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research (RES) hosted a workshop jointly with the Idaho National Laboratory (INL) to discuss codes and standards (C&S) applicable to new and advanced reactors. Appendices to this summary include participating organizations, an agenda including links and ADAMS ML numbers for the presentations, and links to recorded videos of each session, live polling questions and results, and a summary of the open Q&A sessions.

The public meeting was a hybrid meeting. There were approximately 45 in-person participants and over 300 virtual participants including over 60 NRC employees. The attendees and participant organizations included the NRC, the Department of Energy (DOE) and other Federal Agencies, DOE National Labs, especially INL, academic institutions, advanced reactor vendors, current reactor licensees, researchers, industry consultants, and international regulators.

The objective of this event was to solicit input and identify opportunities to enhance aspects of the NRC's C&S program to increase the efficiency of NRC's licensing and oversight of new and advanced reactors. Further, the event sought insights on both needed C&S and the effectiveness of the NRC's program to provide timely review and endorsement. The wide group of attendees brought their diverse perspectives to the event, and the two-way engagement facilitated by questions, polls, and surveys during the meeting ensured a meaningful conversation as we considered important and innovative changes. The NRC staff will consider this feedback as it identifies actions for implementing innovative changes to enhancing NRC's C&S program.

Common themes included:

- Need to improve timeliness of the development, updating, and endorsement of C&S to support new and advanced reactor designs. Challenges include the need for consensus, while relying on volunteers that may not be funded by their employer.

- The NRC may need to consider a broad range of licensing and rulemaking tools to provide regulatory certainty, while not inhibiting innovation.

- Current standards specific to LWRs may be overly prescriptive and are not applicable to many advanced reactor designs, and first-of-a-kind and Nth-of-a-kind applications may require different approaches.

- There are significant gaps in C&S for certain technologies and material qualification.

- There is also a need for risk informed and performance-based standards which cover, among other things, passive designs.

- Existing material standards do not cover the higher temperature ranges and the new materials needed for several advanced reactor designs. In addition, existing graphite qualification standards are overly restrictive and grade-specific which make it harder for new vendors to enter the industry.

- Consider clarification of roles between vendors, DOE, and SDOs to avoid duplication of effort and ensure that we address all existing gaps.

1 MEETING ACTIVITIES

1.1 WELCOME AND INTRODUCTIONS

Michele Sampson, NRC's Standards Executive, and Director of the Division of Engineering in the Office of Nuclear Regulatory Research, and **Curtis Smith** the Director of the Nuclear Safety and Regulatory Research Division at INL, opened the meeting and welcomed participants, remarking on the importance of this dialog to help the NRC prepare for the future. Ms. Sampson noted the importance of identifying and prioritizing opportunities to enhance aspects of NRC's C&S program to increase the efficiency of NRC's licensing and oversight of new and advanced reactors. She also laid out a timeline for that enhancement with a goal of issuing an action plan in June 2024 which will be presented at the Fall Standards Forum in September 2024.

Mr. Smith emphasized that any solutions should be focused on the most important things needed for advanced reactors. He presented the concept of a keystone approach to C&S in nuclear power, and asked that we find novel solutions, and bring the important pieces together, and look beyond today's accepted practices to create solutions that are effective, innovative, and durable.

1.2 OPENING REMARKS

The Honorable **Christopher T. Hanson**, Chair of the NRC, and **Dr. Jess Gehin**, the associate lab director for the Nuclear Science and Technology directorate at INL both provided opening remarks. Chair Hanson reminded the participants that the NRC is an active participant in over 35 standards organizations, and that the NRC is successfully reviewing applications today for new and advanced reactors and endorsing new and updated C&S using our existing framework. He challenged the group to propose and implement changes in those areas that will streamline those efforts, right-size NRC's regulatory footprint, and recognize that advanced reactors are fundamentally different from the existing fleet of large light water reactors. The NRC should be able to scale reviews based on risk levels associated with new designs and be flexible regarding alternative standards. He asked that we quickly develop an action plan with milestones to accomplish these goals.

Dr. Gehin highlighted the big goals facing the domestic nuclear industry based on growth in electricity demand. We need to double capacity by 2050 and we won't get there solely by existing means and processes. He noted that we need to enable new nuclear growth in part by reducing over-conservatisms in existing C&S by leveraging new testing methods, computer models, and better risk characterizations.

1.3 Morning Theme: What codes & standards are needed to foster efficiencies (and their timeline)?

1.3.1 Summary of DOE-NE Codes and Standards

Jim Kinsey at INL discussed the regulatory development component of the DOE Advanced Reactor Demonstration Program. The subcomponent activities are modernization of the regulatory framework, especially for fast reactors, molten salt reactors, and gas reactors. The program engages with both industry and the NRC on items that are in the critical path for advanced reactor development and deployment to align on a flexible review process and key policy and technical issues.

1.3.2 DOE Laboratory Studies on Adv Rx Needs

Dr. Michael Muhlheim of Oak Ridge National Laboratory (ORNL) presented work initiated by DOE on the scoping of expanding the current regulatory framework to include Sodium Fast Reactors (SFRs) and Molten Salt Reactors (MSRs). After reviewing the applicability of over 800 standards to these technologies, his recommendations included development of a standard for passive mechanical equipment, a new/updated fire standard to cover molten salt reactor issues, and an update of the allowable materials including the use of helium as a cover gas.

Matthew Bucknor, Principal Nuclear Safety/Risk Analyst of Argonne National Laboratory (ANL) presented a summary of their review of sodium-specific consensus standards (American Nuclear Society (ANS) standards) from their June 2023 "Assessment of Sodium Fast Reactor Specific Consensus Standards and Recommendations for Future Regulatory Development for Standards Activities," ANL/NSE-23/36. He discussed the withdrawn ANS 54.8 "Liquid Metal Fire Protection in LMR Plants" and efforts to revive and update this standard to support design and licensing of liquid metal plants.

1.3.3 Advanced Reactor Codes and Standards Committee (including Roadmap)

Kate Hyam, Director of Nuclear, Clean Energy, Power and Facilities Codes and Standards, and co-chair of Advanced Reactor Codes and Standards Collaborative (ARCSC) at the American Society of Mechanical Engineers (ASME) presented on advanced reactor standards development under the North American Advanced Reactor Roadmap. She recognized gaps in the current standards framework, especially in risk-informed and performance-based standards, and limitations in their capacity due to the volunteer nature of their membership. The organization's goals are to share information to identify needs/gaps to be addressed by standards developing organizations, and identify actions and resources needed to meet those needs. They are in the information collection phase of their effort and received over 100 survey responses from a wide pool of stakeholders on topical areas for further standards work. The initial results of these surveys are in her presentation linked in the agenda below. Their aspirational goal is worldwide acceptance of C&S for advanced reactors allowing a "design once, build everywhere" approach.

1.4 Afternoon Theme: How can NRC's codes and standards program be enhanced?

1.4.1 NRC support to standards orgs and preparations for future reactors

Michele Sampson (previously introduced), presented on NRC's support of standards organizations and preparations for meeting future needs. NRC develops and uses consensus standards, as outlined in the NRC Policy on Codes and Standards, and actively engages in standards development under guidance provided by NRC Management Directive 6.5. NRC is actively working to streamline the approval, endorsement, and adoption of new and updated standards through both traditional and more

innovative means. NRC staff play an important role in ensuring that standards are developed and maintained and align with NRC regulations and guidance. They aid in the development of high-quality standards, and spot opportunities for new or updated standards that address evolving challenges. For example, NRC is an active participant in various working groups and collaborations aimed at advancing reactor codes, standards, licensing, and regulation including ARCSC, the International Atomic Energy Agency (IAEA), and the Nuclear Energy Agency (NEA) Committee on Nuclear Regulatory Activities (CNRA) Involvement - Working Group on New Technologies (WGNT).

1.4.2 CNSC support to standards orgs and preparations for future reactors

Hazem Mazhar, engineering design assessment division technical specialist at the Canadian Nuclear Safety Commission (CNSC) presented on how they support standards organizations and their preparation for the future. The CNSC is responsible to set safety requirements, take regulatory action based on risk, make independent, risk informed decisions, and assure parliament that licensee responsibilities are met. The licensee has the primary responsibility for safety and conducts regulatory activities in a manner that protects health, safety, security, and the environment, while respecting Canada's international obligations The CNSC are currently evaluating new designs, focusing on first of a kind small, modular reactor with novel approaches to containment and reactor shutdown. They are working through the Canadian Standards Association (CSA) to update C&S to support SMRs and identify further areas for improvement. For example, many pressure boundary requirements were established for CANDU reactors and may not be applicable to newer designs.

1.4.3 DOE NRIC's role preparing for future reactors.

Phil Schoonover, Senior Program Manager at National Reactor Innovation Center (NRIC) presented on the NRIC test beds and advanced reactor development challenges. NRIC has 2 large test beds DOME and LOTUS. The mission of both is to support the commercialization of designs. DOME has identified over 10 candidates for testing, and LOTUS will be facilitating Terra Powers MSR design. Mr. Schoonover identified several code-related constraints on advanced reactors, especially high temperature gas and molten salt designs. He stressed the importance of the limited selection of materials, especially metallics, which are not all addressed by the code or, if addressed, may need to operate above the temperatures allowed currently. Secondly, he highlighted challenges in the supply chain for metallics and non-metallics such as graphite. The constraints are related to limited operating experience and analytic data leading to higher uncertainty, and the explicit prescription on commercial grade dedication.

1.4.4 Codes and Standards Organizations activities to prepare for future reactors.

Todd Anselmi, ANS Standards Board Vice Chair presented on the work ANS is doing on developing standards for advanced reactors. First the ANS structure was presented which includes 8 consensus committees which report to a single standards board. ANS develops and revises standards including. 41 standards that have been recognized for use with advanced reactors. ANS is driving the development of standards to be risk informed and performance based, and for the community to address gaps, especially for non-water-cooled reactor designs. They are also exploring the need for standards relating to space applications, and the use of artificial intelligence, digital twins, and robotics. This could include the formation of new consensus committees.

Kate Hyam (previously introduced) presented on ASME standards development. ASME has over 5,500 volunteers and produces over 500 standards used in over 100 countries. In support of advanced reactors, they are engaged with the NRC, DOE, and National Labs on standards development and revision. Important areas getting timely attention to support advanced reactors are Qualification of

Mechanical Equipment and a more technology neutral and hazard-based Plant System Design standard. Nuclear Quality Assurance also needs significant effort to facilitate the commercial development of advanced reactors. As a consensus activity, a 2/3 majority vote is required before publication. This is a significant time constraint, and separate from any NRC endorsement process, although the NRC is an active participant during development.

Dr. Richard Wood, Nuclear Engineering Department of The University of Tennessee presented on the instrumentation and control of SMRs and advanced reactors. He noted that it is not necessary nor economic to operate an SMR like a large nuclear plant as the ratio between energy generated and personnel would be too low. With advances in instrumentation and control there is an opportunity to automate processes and reduce personnel, and relevant standards must be in place to support that. He described the activities f the two SDOs active in this area; the Institute of Electrical and Electronic Engineers (IEEE), and the International Electrotechnical Commission (IEC). They operate jointly to develop harmonized "dual logo" standards and have 5 ongoing projects in the areas of sensing and measurement, I&C system architecture, and controls and operation.

1.4.5 Reactor Vendor Perspectives

1.4.5.1 Westinghouse

Matthew Kravec, eVinci Reactor Systems Principal Engineer at Westinghouse presented on the eVinci microreactor and the perspective of Westinghouse on the current state of C&S. Westinghouse sees 4 major actions for the NRC to facilitate first and Nth of a kind project as follows: alignment of terminology and expectations for C&S produced by different organizations, cooperation with industry to address gaps for non-LWR technologies, timely endorsement of new and updated C&Ss, and guidance on how to explicitly address passive features, specifically for I&C. He also described the impacts of several necessary materials being outside the scope of existing C&S. Another unique challenge highlighted was the lack of guidance specific to long operating cycles for many advanced reactor designs.

1.4.5.2 Kairos

Brandon Haugh, director of modeling and simulation at Kairos power presented on the Kairos Power and the challenges they face relating to C&S. Mr. Hough highlighted recommended actions to support new technologies such as their fluoride salt-cooled high-temperature reactor. These included a recommendation to allow alternate QA programs to NQA-1 to allow for a robust supply chain. Further, the testing required to achieve lifetime durations for new material qualifications and the related need to maintain proprietary/competitive information is a significant challenge to the material supply chain. Finally, they encourage the NRC to explore and implement a faster endorsement process. This could include a mechanism for using new, unendorsed versions while the endorsement process is ongoing.

1.4.5.3 TerraPower

Adam Gonnering of TerraPower presented on their Natrium reactor and their perspective on C&S. They conducted a multi-discipline effort to determine what Regulatory Guides are applicable to their design and classified each as fully or partially conforming. They identified that multiple editions/revisions of some C&S are referenced in different Regulatory Guides and they typically chose to use the most recent in their licensing basis documents; supplemented by other C&S to provide additional assurance.

1.4.5.4 X-Energy

James Roll, Structural Design Lead at X-Energy presented on the Xe-100 SMR, the XENITH microreactor,

and their C&S insights. He highlighted that existing material standards for high temperature metallic and nonmetallic components have unintended constraints, and existing quality assurance standards have major cost implications but may not actually result in improved reliability. He specifically mentioned that ISO 9001 be considered as an alternative. There is a need for risk-informing QA standard requirements so they can be specified commensurate with the inherently different safety basis for advanced reactors (vs LWRs). A point was made that the qualification of graphite is severely limited due to data requirements being high and being process and supplier specific. This prevents new suppliers entering the industry as they would require new irradiation data. The existing body of historical data can't be used since the historical QA programs are difficult to assess. Finally qualifying existing civil standards is high priority and is a cross-cutting issue across all advanced reactor technologies.

1.4.6 Discussion Session on the NRC Action Plan

This session included several polling questions. The polling questions and responses are captured below. An open discussion session followed which is captured in the session videos linked below.

1.4.7 Path Forward and Closing Remarks

Closing remarks were made by Michele Sampson and Dr. Curtis Smith (previously introduced). Their comments included NRC's plans to include information gained from this meeting to generate actionable items for an action plan expected to be available in June 2024. They emphasized the importance of increasing the efficiency of developing, updating, and endorsing C&S to support new and advanced reactors.

2 APPENDIX 1 ATTENDEE ORGANIZATIONS

Aalo Atomics
Abilene Christian University
ACU NEXT Lab
Amentum
American Nuclear Society
American Society of Mechanical Engineers
ANL
ANS Safety & Radiological Analyses Consensus Committee
ARC Clean Technology Canada
Argonne National Laboratory
Arsenal Consulting, Inc.
ASME
ASME - QME
AtkinsRealis
Battelle/Pacific Northwest National Laboratory
Bechtel Corporation
Boston Government Services
BWX Technologies
CAELUS S.r.l
Canadian Nuclear Safety Commission
CANDU Owners Group
CNSC
Constellation
Construction & Trade Company
Crane Nuclear
CSA Group
Curtiss Wright
Curtiss-Wright Nuclear Division, Enertech
DOE Nuclear Energy, Idaho Operations Office
Dominion Energy
Dominion Engineering, Inc.
Duke Energy
Element Materials Technology Chicago LLC
Energy Northwest
EnergySolutions
EPM, Inc.
EPRI
EXCEL Services Corporation
Exodys
FEMA
FENMA
Fisher Nuclear Control Valves
Florida Department of Health
Fluor
FORMER NRC
Framatome Inc.
Future of Energy Initiative
Gédoynamique et Structure
GE-Hitachi
General Atomics
General Electric Vernova
Generation Atomic
Georgia Institute of Technology
Grander Services Inc
Halton MEI
Hatch LTD.
Hayward Tyler Inc.
Hill Eng Solutions, LLC
Hybrid Power Technologies LLC
Idaho National Laboratory
INPO
International Atomic Energy Agency
ISL, Inc.
ITER
Japan Atomic Energy Agency
JCNRM
Jensen Hughes
JEPIC-USA
JFoster & Associates, LLC
Kadambi Engineering Consultants
Kairos Power
KEC
Lightbridge Corp
Materials Matter

Metcalfe PLLC
Metrohm USA
MIT
Mitsubishi Heavy Industries America, Inc.

MPR Associates
NASA
National Committee of WEC
Nawah Energy Company
NB Power
NETCO - Curtiss-Wright Nuclear Division
New Brunswick Power Corporation
NNL
Nuclear Energy Consultants, Inc.
Nuclear Energy Institute (NEI)
Nuclear Regulatory Commission
Nuclear ROSE Consulting, LLC
Numark Associates
Oak Ridge National Laboratory
OECD NEA
Office of Nuclear Energy
Oklo Inc.
Orano Federal Services
Pacific Northwest National Laboratory (PNNL)
People's Power League
Pioneer Nuclear Inc.
Polytechnique Montreal
POMO18 Consult LLC
Quality Assurance
Reploy Power
Rivers Security Services
S&P Global
Sandia National Laboratories
Sargent & Lundy, LLC
Sciences Po
SGH
Shepherd Power
Simpson Gumpertz & Heger Inc.
Southwest Research Institute
State Scientific and Technical Center for Nuclear and Radiation S
NRS)
Stephens NDE Engineering Consulting
Strata-G/ORNL
Structural Integrity Associates, Inc.
Studsvik Scandpower Inc.
System Engineer
Teledyne Brown Engineering
TerraPower
Texas A&M University
The Ohio State University
The University of Tennessee
Thermal Engineering International
Trinoor
Tulane University
TVA Nuclear - New Nuclear Program
U.S. Army
U.S. Department of Energy
University of Maryland, College Park
University of Missouri Research Reactor
University of Nevada Reno
University of New Brunswick
University of Toronto
University of Wyoming
Uranium Watch
US Department of Energy
Valcor Engineering Corporation
Valiant Capital
VTT Technical Research Centre of Finland, Ltd.
Westinghouse Electric Company, LLC
White House OSTP
Xcel Energy
X-Energy, LLC
YGA Films
Zachry Nuclear Engineering

3 APPENDIX 2 SPEAKER BIOS

(in presentation order, provided by the speakers)

3.1 MICHELE SAMPSON

Ms. Sampson currently serves as Director for the Division of Engineering, in the Office of Nuclear Regulatory Research. She joined the U.S. Nuclear Regulatory Commission in 2007, and has held a number of positions including Senior Project Manager, Thermal and Containment Branch Chief, and Licensing Branch Chief in the Division of Spent Fuel Management in the Office of Nuclear Material Safety and Safeguards, Executive Technical Assistant in the Office of the Executive Director for Operations, Chief of the Reactor Security Branch, Deputy Director and Acting Director for the Division of Physical and Cyber Security Policy in the Office of Nuclear Security and Incident Response, and Deputy Director in the Division of Engineering in the Office of Nuclear Reactor Regulation. Prior to joining the NRC, Ms. Sampson worked at the Department of Transportation and at USEC's Paducah Gaseous Diffusion Plant. Ms. Sampson is a graduate of the University of Tennessee at Knoxville and Murray State University in Murray, Kentucky. Ms. Sampson is also a graduate of the NRC's SES Candidate Development Program.

3.2 DR. CURTIS SMITH

Dr. Curtis Smith is the Director of the INL Nuclear Safety and Regulatory Research Division, leading a staff of scientists and engineers supporting the demonstration of innovative nuclear energy solutions and resilient critical infrastructure. Dr. Smith has been at INL for over 33 years and has published over 300 papers, books, and reports on risk, safety, and reliability theory and applications. He holds a B.S. and M.S. in nuclear engineering from Idaho State University and a Ph.D. in nuclear engineering from MIT.

3.3 CHRISTOPHER T. HANSON

The Honorable Christopher T. Hanson was designated Chair of the U.S. Nuclear Regulatory Commission by President Joe Biden, effective January 20, 2021. He was sworn in as a Commissioner on June 8, 2020.

Chair Hanson has more than two decades of government and private-sector experience in the fields of nuclear energy. Prior to joining the NRC, he served on several roles, including Staff Member on the Senate Appropriations Committee; Senior Advisor in the Department of Energy's Office of Nuclear Energy and the Office of the Chief Financial Officer; and consultant at Booz Allen Hamilton.

Chair Hanson earned master's degrees from Yale Divinity School and Yale School of Forestry and Environmental Studies, where he focused on ethics and natural resource economics. He earned a Bachelor of Arts degree in Religious Studies from Valparaiso University in Valparaiso, Indiana.

3.4 JESS GEHIN

Dr. Jess Gehin is the associate lab director for the Nuclear Science and Technology directorate. Dr. Gehin originally joined INL in 2018 as the chief scientist for the NS&T directorate, bringing nearly 30 years of experience in reactor core physics and technologies to the lab. He also serves as the National Technical Director of the DOE Office of Nuclear Energy's Microreactor Program. His research interests include

nuclear reactor physics and reactor and fuel cycle technologies, and he has broad experience in the development and use of reactors for a range of applications including electricity production, heat production, materials production and research with specific expertise in modeling and simulation to support reactor design, operation and safety analysis.

Dr. Gehin worked at ORNL from 1992 to 2018, where he held several positions, including Director of the Consortium for Advanced Simulation of Light Water Reactors (CASL). CASL is a DOE Energy Innovation Hub located at ORNL. In that role, Dr. Gehin held leadership responsibilities for reactor technology integration, nuclear energy programs, and reactor analysis. His academic experience includes previous positions as Associate Professor at the University of Tennessee and in teaching and advising students.

Dr. Gehin earned a B.S. degree in nuclear engineering from Kansas State University and S.M. and Ph.D. degrees in nuclear engineering from the Massachusetts Institute of Technology. Dr. Gehin is a Fellow of the American Nuclear Society.

3.5 Jim Kinsey

Mr. Kinsey has over 40 years of experience in the nuclear industry, including significant commercial experience in licensing, regulatory affairs, system engineering and major project management. He has managed numerous industry licensing and regulatory affairs projects, including the NRC's certification of GE-Hitachi's ESBWR advanced reactor design.

At the Idaho National Laboratory, he is responsible for Dept. of Energy licensing strategy development and implementation in direct support of industry's near-term deployment of advanced nuclear technologies. In this role, he has led the development of a series of DOE/industry regulatory framework proposals resulting in key Commission policy changes and related updates to NRC's regulatory guidance, including acceptance of performance-based functional containment approaches, and the use of a risk-informed and performance-based approach for plant event sequence identification and assessment.

3.6 Michael Muhlheim

Dr. Muhlheim is an R&D staff member at the Oak Ridge National Laboratory. He has worked on the design, design reviews, and hazards assessments of research reactors and nuclear and industrial facilities.

3.7 Matthew Bucknor, PhD

Matthew Bucknor is a Principal Nuclear Safety/Risk Analyst in the Nuclear Science and Engineering Division at Argonne National Laboratory. He has expertise in leading and performing advanced reactor safety, security, and risk assessments for DOE and in collaboration with industry partners. Areas of technical expertise include advanced reactor safety and security analysis, nuclear facility siting, probabilistic risk assessments, component reliability evaluations, mechanistic source term evaluations, and advanced reactor modeling and simulation.

Matthew Bucknor holds a Ph.D. in Nuclear Engineering, an M.S. in Nuclear Engineering, and a B.S. in Electrical and Computer Engineering from the Ohio State University.

3.8 KATHRYN HYAM

Kate Hyam is Director of Nuclear, Clean Energy, Power, and Facilities Codes and Standards at ASME. She is responsible for ASME's portfolio of standards applicable to nuclear facilities and clean energy technology. Her previous assignment focused on the areas of Big Data, additive manufacturing, and verification and validation of computational modelling and simulation. She also has experience in the development of standards in the areas of construction safety, and thermal energy storage. Prior to her return to ASME, she was a design engineer for Bechtel Power, responsible for mechanical systems for natural gas and coal fired power plants.

3.9 HAZEM MAZHAR

Hazem is a technical specialist at the Canadian Nuclear Safety Commission (CNSC), in the Engineering Design Assessment Division. He is currently leading the physical design review of the Darlington New Nuclear Project (DNNP). Hazem is a professional mechanical engineer, in Ontario. He earned his PhD in mechanical engineering from McMaster University, in 2013. Prior to CNSC, Hazem worked as a research engineer at the Canadian Nuclear Laboratories (CNL) for 7 years, where he led several projects to support safety analysis of CANDU reactors and to improve readiness for advanced and small modular reactors. His role included being a delegated design authority for multiple research and development groups at CNL.

3.10 PHIL SCHOONOVER

With over two decades of engineering leadership in aerospace, energy, and oil and gas sectors, I have acquired extensive experience in the design, analysis, and testing of safety systems and equipment for both flight and industrial operations. Together with a degree in Aerospace Engineering from Purdue University, I am equipped with a deep understanding of various global engineering C&S.

In 2021, I joined the Idaho National Laboratory (INL), where I currently lead the development of reactor testbeds at the National Reactor Innovation Center (NRIC). My focus is on the Demonstration of Microreactor Experiments (DOME) and the Laboratory for Operations and Testing in the United States (LOTUS), both located at the INL's Materials and Fuels Complex (MFC). My role involves close collaboration with diverse third-party experimental reactor developers, which has expanded my understanding of the nuclear industry and the regulatory environment that developers must navigate.

I am particularly involved in addressing the intricate challenges faced by advanced reactor developers in their pursuit for compliance with DOE or NRC regulations to operationalize their reactors. At NRIC, our mission is to facilitate the transition from early development and research to commercialization for these developers, by providing them with access to expert guidance and national assets. This initiative not only aids in the advancement of nuclear technology but also contributes significantly to the overarching goal of energy innovation and sustainability.

3.11 Todd Anselmi

Todd supports strategic planning and long-term asset management of the Advanced Test Reactor (ATR) operating at the Idaho National Laboratory and ensuring the mission of the ATR continues for the long term.

Todd came to the ATR in 2020 with 30 years of experience in the commercial nuclear power industry and federal nuclear facilities. His C&S activities include 25 years with the American Society of Mechanical Engineers (ASME) where he is currently a member of Section XI, Division 2 that is an NRC endorsed code for the development of a reliability integrity management program for advanced reactors. In addition to ASME code activities, Todd has been a participant for seven years on several working groups for the development and revision of American Nuclear Society Standards and was recently appointed to the ANS Standards Board as its vice-chair.

3.12 Richard T. Wood

Richard Wood is a professor of Nuclear Engineering at the University of Tennessee, Knoxville. Prior to his academic appointment, he was a senior research engineer for 30 years at the Oak Ridge National Laboratory (ORNL). Dr. Wood's expertise and research experience includes digital I&C technology, nuclear power plant I&C architectures, safety system regulation, systems engineering, advanced controls, surveillance and diagnostics, cybersecurity, and simulation. He is Chair of Subcommittee 45A of the International Electrotechnical Commission (IEC) and serves on standards development committees for both the IEC and the Institute of Electrical and Electronics Engineers (IEEE). He also represents IEEE as a member of ARCSC team. Finally, until his retirement from ORNL, Dr. Wood served as the Technology Area Lead for Instrumentation, Controls, and Human Machine Interfaces under the DOE Advanced Reactor Technologies R&D program.

3.13 Matthew J. Kravec

Matthew graduated from Pennsylvania State University in 2011 with concurrent bachelor's degrees in mechanical engineering and Nuclear Engineering. He also received a master's degree in Material Science and Engineering from the University of Pittsburgh in 2015. He earned his Professional Engineer's License in the State of Pennsylvania in 2018 and is the Westinghouse representative for the ANS Research and Advanced Reactor Consensus Committee (RARCC).

Matthew is currently employed by Westinghouse Electric as the lead reactor system engineer for the eVinci™ microreactor, responsible for leading reactor performance initiatives for fuel, core design, reactor design and system analysis/integration. Matt has over 10 years of experience in design and manufacture of advanced reactors for the Naval Nuclear Laboratory, a contractor for the U.S. Navy where he was trained in in Six Sigma earning a Green Belt.

3.14 Brandon Haugh

Mr. Brandon Haugh is the Senior Director of Modeling & Simulation at Kairos Power. He is currently directing teams for the development of modeling and simulation tools for the Kairos Power Fluoride-Salt-Cooled High-Temperature Reactor (KP-FHR). Development efforts are focused on system modeling,

fuel performance, high temperature materials and source term modeling for licensing and deployment of the KP-FHR.

Previously, Mr. Haugh was Director, Innovation and Special Projects for Studsvik Scandpower Inc. with a focus on business development, licensing and deployment of LWR core design tools. Mr. Haugh also worked for NuScale Power, where he was the initial reactor physicist and helped originate the reactor analysis organization.

Mr. Haugh earned his M.S. at the Oregon State University in nuclear engineering in 2002. He is a member of the American Nuclear Society (ANS).

3.15 ADAM GONNERING

Adam Gonnering is a Principal Process Integration for the TerraPower, Natrium Sodium Fast Reactor Project. Adam has over 16 years commercial nuclear power (for both boiling water and pressurized water reactors) and radioisotope plant experience in Design, Construction and Operations. Adam has a Senior Reactor Operator Certificate from a boiling water reactor.

3.16 JAMES ROLL

James D. Roll, P.E. is the Structural Design Lead managing the Structural Mechanical Engineering group of the Reactors Division at X-energy. James has fifteen years of engineering and leadership experience in the nuclear industry, including two years leading the structural design analysis of the graphite core assembly of the Xe-100 Small Modular Reactor, a Gen-IV High Temperature Gas Reactor (HTGR). James directs the team of engineers performing detailed finite element analysis for advanced reactor core components, including for X-energy's XENITH Microreactor. With bachelor's and master's degrees in mechanical engineering from Cornell University, James is also a member of the ASME Boiler & Pressure Vessel Special Working Group for High Temperature Reactor Stakeholders.

4 APPENDIX 3 AGENDA AND PRESENTATIONS (WITH ADAMS ML LINKS)

Thursday, April 4, 2024		
Time	**Topic**	**Speakers**
Opening Theme: Purpose for meeting New and Advanced Reactors Codes and Standards: Welcome Meeting Recording Video 1 New and Advanced Reactors Codes and Standards: Chair Hanson Remarks Meeting Recording Video 2		
9:00 – 9:30 am	Welcome and Introductions	Michele Sampson, NRC, Slides: ML24089A158 Curtis Smith, INL, Slides: ML24093A027
9:30 – 10:15 am	Opening Remarks and Q&A	Christopher Hanson, NRC Chair Jess Gehin, INL Associate Lab Director, Slides: ML24096A934
Morning Theme: What codes & standards are needed to foster efficiencies (and their timeline)? New and Advanced Reactors Codes and Standards: Meeting Recording Video 3		
10:25 – 10:40 am	Summary of DOE-NE Codes and Standards	Jim Kinsey, Technical Area Lead, INL, Slides: ML24093A271
10:45 – 10:55 am	DOE Laboratory Studies on Adv Rx Needs	Mike Muhlheim, ORNL*, Slides: ML24095A141 Matthew Bucknor, ANL*, Slides: ML24092A141
10:55 – 11:20 am	Advanced Reactor Codes and Standards Collaborative (including Roadmap)	Kate Hyam, ASME, Slides: ML24092A310
11:20 – 11:45 am	Discussion	Led by Facilitator
11:45 am – 1:15 pm	Lunch Break	

Afternoon Theme: How can NRC's codes and standards program be enhanced? New and Advanced Reactors Codes and Standards: Meeting Recording Video 4 New and Advanced Reactors Codes and Standards: Meeting Recording Video 5 New and Advanced Reactors Codes and Standards: Meeting Recording Video 6 New and Advanced Reactors Codes and Standards: Meeting Recording Video 7		
1:15 – 1:30 pm	NRC support to standards orgs and preparations for future reactors.	Michele Sampson, NRC, Slides: ML24089A156
1:30 – 1:45 pm	CNSC support to standards orgs and preparations for future reactors.	Hazem Mazhar, CNSC*, Slides: ML24092A088
1:45 – 2:00 pm	DOE NRIC's role preparing for future reactors	Philip Schoonover, INL**, Slides: ML24096A167
2:00 – 2:45 pm	Codes and Standards Organizations activities to prepare for future reactors	ANS: Todd Anselmi, INL*, Slides: ML24093A002 ASME: Kate Hyam, ASME, ASME, Slides: ML24094A008 IEEE/IEC: Richard Wood, UT-Knoxville, Slides: ML24092A333
2:45 – 3:00 pm	Break	
3:00 – 4:15 pm	Reactor Vendor Perspectives	Westinghouse eVinci: Matthew Kravec, Slides: ML24093A018 Kairos Power KP-FHR: Brandon Haugh*, Slides: ML24094A042 TerraPower Natrium: Adam Gonnering*, Slides: ML24093A021 X-Energy XE-100 & XENITH: James Roll, Slides: ML24092A408
4:15 – 4:50 pm	Discussion on the NRC Action Plan	Led by Facilitator
4:50 – 5:00 pm	Path Forward and Closing Remarks	Michele Sampson, NRC Curtis Smith, INL

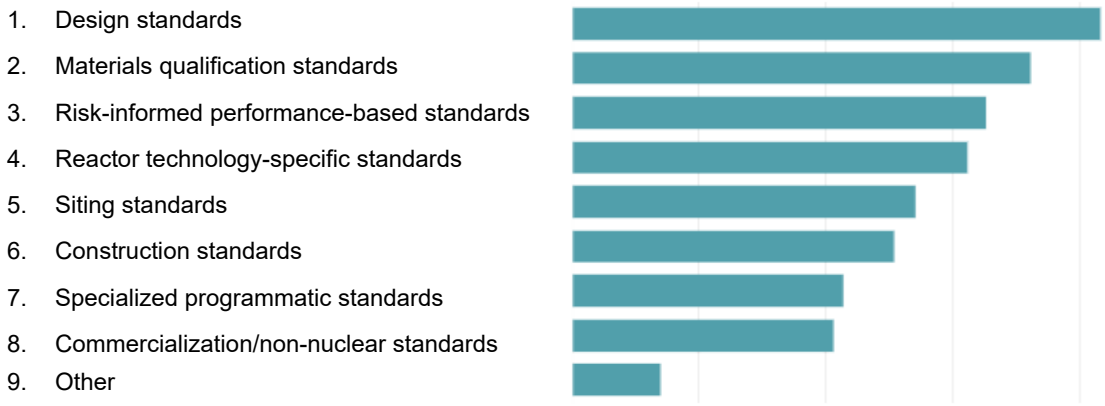
* Attending virtually via Teams

5 APPENDIX 4 POLLING/SURVEY RESULTS

Live Polling Questions and Responses

Morning Polling

Considering the next 1-to-2-year timeframe, rank the priority of these topical areas for focused codes and standards activities (#1 highest):



If other was ranked in the previous question, what other focus would you like to include?

- Human Factors Engineering
- Standards should support digital engineering. This includes clear identification of requirements within the standard. Requirements should be clear and concise following principles and guidance of systems engineering as used in DoD and aerospace. Support for cloud publishing and licensing, which provides capability for integration into user processes and procedures, reducing burden of updating them for revisions to standards. Updates on more of a "real time basis" not on a periodic bi-annual revisions. Real time updates require a major paradigm shift for regulatory review and approval of changes.
- Available well-trained workforce.
- Standard for procurement of items and services considering safety function and significance.

When you think about the nexus between codes and standards and the deployment of advanced reactors, what are the top 1 to 3 challenges or opportunities to be addressed in the next 3 to 5 years? (free-form responses)

- The regulations not evolving with the technologies and codes &standards.
- Can't write a standard in 3-5 years.
- While it is important to focus on developing C&S that address traditional engineering and nuclear engineering questions, I think a top challenge will be the industry neglecting to remember to update C&S that relate to human factors engineering.
- Regulatory acceptance of VCS, greater use of trial use and pilot application standards,

developing VCS that are truly technology agnostic.

- Materials qualification/compatibility, fuel qualification, containment/confinement
- Broader collaboration between advanced reactor developers to identify and prioritize specific needs to efficiently deploy their designs with the industry C&S developers and various regulatory agencies. Since some advanced reactor developers intend on deploying internationally first rather than stateside.
- Maritime-based standards e.g. American Bureau of shipping coordination, current LWR standards streamlining, transport of used fuel.
- Graphite qual standards, slow regulatory process culminating in CFR changes.
- Material research, resources to revise C&S, NRC review and endorsement process.
- ASME Section III gaps
- Research and resources to address AR deployment needs.
- Material, Design, and Construction topics
- Change of culture, transition from application of current methods to new methods
- From a component OEM perspective, the biggest opportunities are improving design codes and reducing over-conservatism, introducing more material properties sets for high temp design, and giving industry groups the necessary resources to accelerate standards implementation.
- High temperature materials, design codes applicable to high temperature components, including passive heat transfer devices, resolving requirements related to inspection of compact highly packaged advanced reactors during operation.
- Getting experts in new technology
- Is there opportunity to improve the standards process I.e. have reviews completed in parallel. It seems the standards processes over the last 5 to 10 years has added more reviews and requirements but shortened time for technical committee members to develop content.
- Support for personnel to attend meetings and time to participated in C&S activities, incorporation of technology, hybrid meetings, for face-to-face/on-line capabilities by standards committees.
- A major challenge is that reactor design is ahead of the release of standards. This may impact the design or make licensing more challenging. This risk is increasing the risk of design changes and increased/unpredictable costs and timeline.
- Development and implementation of technology independent C&S, connecting internationally to enable industry, developing C&S which enable industry to obtain licensing quickly without compromising safety.
- Well trained workforce.
- Qualification of traditionally non-LWR materials, e.g. graphite of varying grades and CFRC, establishing QA programs for applied C&S internationally, with issues like existing (or non-existent) local C&S and language barriers. Some specialty vendors needed for AR materials have either never used C&S like ASME or have not kept up with the rapidly evolving updates to C&S in response to AR development.
- NRC acceptance of little or no Class 1E power, NRC over prescription around the ANLWR PRA standard, NRC acceptance of non-nuclear standards for reactor buildings (assuming they are NOT containment)
- Engagement with AR developers to tell the SDO community what they need NOW, funding sources to expedite development, recognition of low safety profile in requirements for construction.
- Engineering skills to implement risk informed strategy in design and procurement decisions,

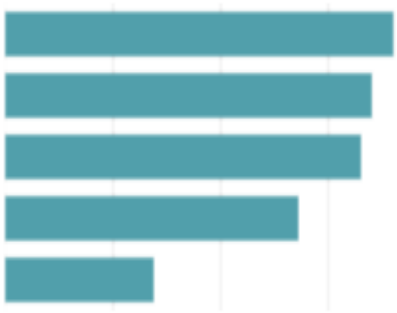
and development of smart, risk informed regulatory and construction/fabrication oversight strategies.

- Material qualification, design, and construction standards
- Elastomeric material performance in extreme high temperature and radiation environments
- Ability of NRC staff to efficiently review and endorse C&S for ARs as they are published (including code cases), industry engagement and information sharing at code committees (e.g., materials data) to enable collective industry success, and a paradigm shift in thinking of committee members and NRC staff members to acknowledge differences the in safety case of advanced reactors (e.g., passive safety systems), such that novel approaches gain acceptance.
- Design, Material, Construction
- Workforce development. Reactor developers are hiring large numbers of new employees to meet demand, but they don't have requisite knowledge of these aspects. Overly relying on the "this is the way we did it before" mentality / approach to both standards development and technology deployment.
- Open availability for advanced nuclear data and benchmarks, and C&S for specific design reactors
- The industry groups are the long-pole-in-the-tent. Seems to me, industry groups need financial help to accelerate the effort. The DOE should significantly increase emphasis on that area. The national lab's excellent efforts will go nowhere absent the deployment of the industry's codes/standards.
- Competitiveness and recognition of the paradigm shift in the safety case for advanced reactors should be a driving factor when evolving C&S. Codes are deterministic; matching and linking probabilistic system output to deterministic component construction codes should be addressed with a technology neutral approach. Research supporting C&S should have practical case studies and applications that are representative of advanced reactor designs, not simplified geometries.

Afternoon Polling

The NRC currently endorses codes and standards formally through rulemaking and through regulatory guidance. Rank by order of preference the level of formality of NRC's endorsement for the new codes and standards developed for advanced reactors (#1 highest):

1. Endorsement through rulemaking and regulatory guides
2. Endorsement through regulatory guides only (no rulemaking)
3. Endorsement through interim staff guidance
4. Endorsement through rulemaking
5. Other



If other was ranked in the previous question, what other focus would you like to include?

- Referenced in SRP
- Reg Guides in the near term, rulemaking only after experience gained with codes.
- A case-by-case basis should be applied. Rulemaking should be avoided unless safety essential. C&S should enable industry, not hinder it.
- Rulemaking and regulatory guidance
- Disagree with the endorsement of consensus codes/standards, particularly when the NRC is a part of the development process.
- Establish a new nuclear safety framework document for the specific purpose of promulgating/endorsing codes & standards with the same legal standing of regulation but inherit process characteristics that simplify revision and update.
- I have further thought about this, and the endorsement issues are (1) conformance with a Reg Guide does not relieve the Applicant with the legal obligation to comply with the law and Code of Federal Regulations, and (2) the Reg Guide is not tied to the applicant's risk-informed design, which forms a part of the applicant's submittal. From our standpoint (Hybrid Power Technologies) we would review the Reg Guide, make a link to the specific CFR issue in play, and then address that issue specifically in our submittal based on our risk-informed design, construction, and operation approach. We would only indirectly address other items in the Reg Guide that are not that significant from a risk-informed standpoint. In any case, the reviewer needs sufficient leeway to evaluate the applicant's approach and then decide if an inquiry is in order.

What additional activities by regulatory bodies, industry experts, and standards organizations can accelerate the adoption of codes and standards?

<u>Funding for codes and standards efforts (multiple comments)</u>

- Funding participation in standards development. There is only so much volunteer time from existing standards supporters.
- Dedicated resources to create and review C&S.

- Industry—financial support from companies for their engineers to participate and work on code activities (unpaid volunteer work is challenging to prioritize).
- I believe the problem fundamentally lies with funding industry codes/standards organizations. The DOE needs to step up and help. The NRC is not a good choice to provide monetary assistance to industry - obvious conflict of interest with their regulatory obligations.
- The voluntary, unfunded, participation of technical experts on the code committees is an impediment to rapid response. Can't a more formal funded method be adopted?
- Once again, the DOE needs to step in and help fund industry groups in their code/standard development efforts. The administration is clearly pushing nuclear, and DOE has billions of dollars in their budget. Actions speak louder than words.
- Specific funding to accelerate the voluntary efforts.

Workshops (multiple comments)

- Workshops and public meetings between stakeholders, including C&S, and regulatory bodies on C&S under development.
- Workshops like today's
- Workshops and public meetings between SDOs, other stakeholders and regulatory bodies on C&S under development when available for those meetings.
- Workshops and public meetings between SDOs, other stakeholders and regulatory bodies.

General comments

- More meetings, and better support from companies to send employees to meetings.
- Funding to sponsor testing of high temperature metallic and nonmetallic materials, particularly for creep and irradiation effects.
- Coordination across all SDOs to streamline and limit the number of revisions requiring regulator individual review and response.
- NRC acceptance of using parts of codes. Not something the C&S bodies prefer but may be appropriate given timelines for some ARs. Use commercial codes with select pieces of nuclear codes for added assurance.
- Think & apply out of the box application until full rule making can take place, keep listening.
- Engage and understand C&S aims.
- The current framework that has been used has worked. It has resulted in a safe operating industry. The list provided has the correct order. There is no "other" to recommend.
- Most large-scale projects use modern software for managing project requirements (including C&S). The restrictive copyright terms on most consensus codes limits their ability to be imported into these and managed digitally.
- A unified approach as through ARCSC. Too many disparate efforts.
- Prioritization initiatives that focus management attention units on those code and standard adoptions that have the biggest impact on safety and regulatory efficiency, perhaps modeled after the Common Prioritization for Rule-making analogue (if that is viewed as an effective process).
- Continue to have NRC staff participate in conferences and standard development activities. Ensure that knowledge that led to previous expectations regarding quality and rigor is preserved.
- More timely response and interaction of NRC code rep on agency issues.
- A coordinated effort to address gaps, that ensures resources are made available and duplication avoided.

- SDOs—guidance from senior volunteers to working groups with less experienced teams to better manage code actions. Regulatory body—additional availability for engagement on high priority code actions where consensus is not being achieved across multiple code cycles.
- Codes are legally enforceable and so must be adopted by regulation (or statute). This is a very lengthy process. Relying on standards endorsed in regulatory guides should be the preferred approach unless a code provides some clear benefit.
- Don't be so regimented if it doesn't meet your design guides. Approach using a more scientific backed approach. Cost vs risk needs to be part of the acceptance. Meeting safety and risk without evaluating against social benefit does not work for the good of the public.
- Increased communication and understanding of NRC scope (only safety related? Or inclusive of trends that would indicate poor plant performance? All of safety culture at plant/site/remote monitoring location)? 2. Development of international cooperation, much like the airline industry. 3. Ensure we are focusing resources on highest areas of return (e.g. fuel qualification and functional containment, not a drain valve). 4. Ensure we do not incrementally increase cost by adding requirements for each successive plant; this happened in the 1970s (e.g. cost did not decrease as more plants were built)
- USNRC should use, as much as possible, industry expert ad-hoc committees to prepare or revise regulatory guides for advanced reactor designs.
- There was an effort for comparing international nuclear standards for pressure boundary about 10-15 years ago. I can't remember the group that was working on this, but I believe a CNSC staff member lead the group. It covered US, Canadian, British, Japanese, Russian and others pressure boundary standards. At the CSA N285A committee we received updates on this project when it was active.

6 OPEN QUESTION AND ANSWER SESSIONS

At several points in the public meeting the participants were able to ask questions. Questions were asked in person, via Teams, and in writing during each Q&A period. Some were submitted anonymously. The questions gave speakers an opportunity to address things that were not covered in the presentations and allow them to reinforce points made earlier. This summary is not meant to be a transcript of the sessions. The Q&A sessions are included in the linked video files from the meeting.

Adapting and Modernizing Codes and Standards:

- NRC should enhance our focus on doing things differently while maintaining a safety mindset. Find the balance for endorsement between rulemaking and guidance to enhance flexibility.
- C&S should be developed and updated to meet the technical and schedule needs of advanced reactors. Implement updates on a "real time basis" to reduce time lags. Consider allowing use of new C&S on a case-by-case trial or pilot basis.
- C&S should be modernized to support technology advancements in areas such as digital, human factors, containment/confinement, fuel qualification, passive systems, qualification of graphite of varying grades, and new high temperature materials and use cases.
- Consider expanded use of non-nuclear standards alongside nuclear standards. Recognizes a difference in approaches for first of a kind vs Nth of a kind.
- Reliance on volunteers adds time to the process. Consider DOE or other financial and personnel support for industry personnel to participate in standards development process, rather than continuing to rely on volunteers. Leveraging DOE labs and NRC staff is part of the answer.
- Continue to follow a unified approach through ARCSC to prioritize efforts, avoid duplication, and focus efforts where there is the greatest impact on safety and regulatory efficiency.

Implementing Risk-Informed and Performance-Based Approaches:

- Incorporate risk-informed and performance-based approaches to be more technology inclusive and ensure safety without being overly conservative.
- Allow use of historical advanced nuclear data and benchmarks that were not under an Appendix B QA program. Waiting for material qualification as currently required could take decades, with graphite being the most often referenced case.

Enhancing Collaboration and Training:

- Encourage early collaboration and among reactor developers, SDOs, NRC, and DOE labs.
- Training and knowledge management is critical to retaining and recruiting a qualified workforce.
- Increase international collaboration, including an international quality assurance program. The current focus on US deployment may hinder the expansion of US designs internationally.

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