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ACTI Final Design Review Report

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NRIC National Reactor Innovation Center

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REVISION LOG

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ACRONYMS

ACTI	Advanced Construction Technology Initiative
DOE	U.S. Department of Energy
DPSC	diaphragm plate steel composite
EPRI	Electric Power Research Institute
ETI	Energy Technologies Institute
GEH	GE Hitachi
INL	Idaho National Laboratory
NDE	nondestructive examination
NRIC	National Reactor Innovation Center

ACTI Final Design Review Report

1. DESCRIPTION

This document summarizes the final design review held for the National Reactor Innovation Center (NRIC) Advanced Construction Technology Initiative (ACTI) project with GE Hitachi (GEH). The purpose of this document is to provide an overview of the project and a summary of the design review meeting, including the agenda, attendees, deliverables reviewed, and topics discussed, as presented on June 18, 2024. The final design for this project is necessary to inform the proposal that GEH will submit to NRIC in a bid to move into the Phase 2 demonstration portion of this project.

2. BACKGROUND

Various nuclear energy economic studies have identified the major role of construction costs and schedule risks in driving up nuclear power plant costs.[1]

The NRIC ACTI Program supports a transformation in nuclear energy construction, management, and deployment costs, enabling nuclear energy to make important contributions to the energy systems of the future. This transformation will increase the confidence of investors, energy system planners, policymakers, and ultimately consumers in the capability of nuclear energy to meet future needs; thus, it represents a critical element of advanced nuclear energy system demonstration. Development and demonstration projects will consider regulatory requirements for commercial nuclear implementation and will incorporate strategies to develop regulator experience and review of the technology.

There are many activities that have, or could have, significant cost and productivity impacts on the design, permits, construction, and operation of a nuclear facility. The primary NRIC mission is to identify these areas and develop approaches and technologies that will have a major impact.

In 2021, NRIC awarded a cost-shared, multiyear project to GEH and other key stakeholders on the first project of the ACTI Program. The goal of this cost-shared public-private partnership is to help demonstrate several technologies that, when combined, could reduce the construction costs of building new reactors by more than 10% and significantly lower the scheduling risks and uncertainties associated with them. Included in this work are three key technologies—vertical shaft construction, fabricated steel and concrete modular wall systems, and real-time monitoring with digital twins.

[1] (e.g., The Future of Nuclear Energy in a Carbon-Constrained World, Massachusetts Institute of Technology [MIT], 2018; The ETI Nuclear Cost Drivers Project: Summary Report, Energy Technologies Institute [ETI], 2018; Advanced Nuclear Technology: Economic-Based Research and Development Roadmap for Nuclear Power Plant Construction, Electric Power Research Institute [EPRI], 2019).

- Vertical shaft construction leverages best practices from the tunneling industry and others to reduce the amount of excavation and the need for engineered backfill after the structure is constructed. This could potentially save $50 million in project costs for a typical nuclear plant that requires one million cubic yards of excavation and significantly reduce its construction schedule. Vertical shaft construction is particularly applicable to advanced nuclear reactors because many reactor plants call for below-ground installation to achieve their passive safety and security attributes.
- Several companies are looking at modular steel-concrete composites as a possible option to build the major structural components of their nuclear facilities, including containments. These modular wall systems have several advantages over traditional steel-composite techniques and could significantly reduce the amount of labor required onsite. Steel casings can be rapidly produced in factories concurrent with site excavation and be then shipped to the site for faster installation. This allows developers to significantly compress schedules by initiating wall construction in parallel with site excavation. In addition, these systems can dramatically improve construction quality as wall frames are built in a controlled environment; and they result in a significant decrease in required site work.
- Advanced inspection techniques will be used to provide an "as-built" three dimensional (3D) model of the structure. The team will then use embedded sensors, 3D structural and geotechnical models, and software services that interact with the physical structure to create a virtual representation known as a digital twin. By combining the digital twin with seismic and stress-strain sensors, the group can actively monitor the structure during and after construction to better understand the building's structural integrity. This can help solve or anticipate construction issues before they happen and allow for active monitoring of the facility throughout its lifetime.

The GEH ACTI Project is broken up into two phases. Phase 1 included a detailed, site-specific design of a demonstration reactor containment building, utilizing the proposed technologies. To support the design, this first phase also included the fabricating and testing of steel-concrete composite specimens to validate the calculations, models, and assumptions used for designing the containment structure using steel-concrete composites. Also included in this first phase was developing an implementation plan for the proposed Phase 2 demonstration as well as identifying nondestructive examination (NDE) techniques that can be deployed on a concrete-composite structure during construction. At the completion of Phase 1, GEH will propose the demonstration structure design, project cost, and projected construction schedule to NRIC to potentially receive additional funding to move into Phase 2. The second phase of this project (if awarded) would be to construct a demonstration reactor building structure.

GEH began the ACTI Project utilizing a steel-concrete composite walling system called SteelBricks. However, as the project progressed, GEH identified several SteelBricks-related construction issues projected to cause cost and schedule overruns during the demonstration (Phase 2) portion of the project. A significant weld volume was required for the full penetration welds to join each of the individual SteelBricks together. To address the construction limitations of SteelBricks and challenges with the full penetration welds in a SteelBricks system, a decision was made by an integrated focused team of project stakeholders to use a similar walling system design called diaphragm plate steel composite (DPSC) for the reactor building walling system. The DPSC design greatly reduces the weld volume and helps solve the projected cost and schedule overruns for the demonstration portion of the project.

The DPSC system is composed of two continuous plates connected using diaphragm plates. Like the SteelBricks system, the DPSC diaphragm plate is welded to the face plate using fillet welds. The fillet weld is designed to develop the capacity of the plates, similar to the full penetration weld in the SteelBricks system; however, the inspection and welding process (using automated robotic arms) is much easier to execute than the full penetration weld. The inspection of the fillet weld in the DPSC diaphragm plate and the face plate is classified as a Category H weld and only requires visual inspection. The visual inspection can be accomplished by attaching a camera to the robotic welding arm, as opposed to extensive NDE for SteelBricks welds.

A DPSC module system, like SteelBricks, consists of multiple components arranged and welded together to form a module. Each component consists of an individual steel element. The DPSC modules are spliced together to form structural walls, floors, or mat foundation sections. Figure 1 depicts a DPSC module. The DPSC system has a similar configuration to the SteelBricks system but without full penetration welds used to connect the individual bricks. This system addresses the limitations of the SteelBricks system and has the following advantages:

- Major reduction in weld volume and NDE
- Strength and stiffness similar or equal to SteelBricks
- Does not require bending, forming, and post-forming heat treatment
- Simplified fit up
- More cost effective
- Some industry experience using this method for straight walls in AP1000.

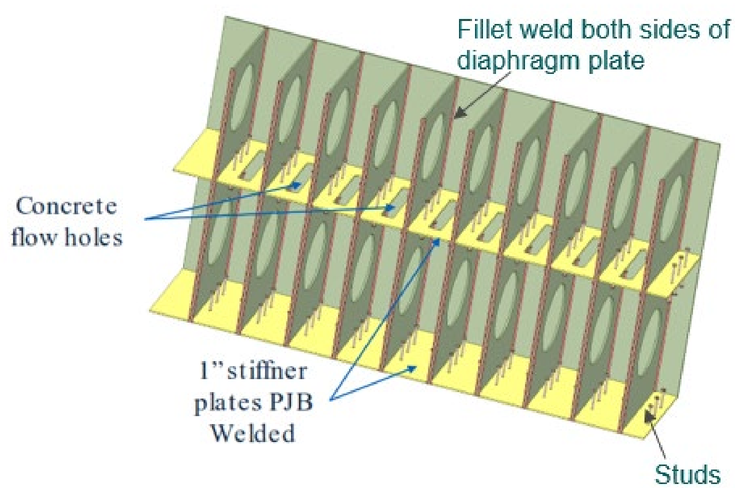

Figure 1. DPSC diagram.

GEH is currently in the process of fabricating DPSC test specimens to send to Purdue University for structural load testing to validate the DPSC performance against finite-element models and confirm calculations used for analysis and design. This testing will assess and improve the constructability and feasibility of the DPSC system, and the welds used when applying it to actual construction projects. The testing will also develop relevant experimental results for accelerating the regulatory review of reactor building containment designs using the DPSC system. A total of nine DPSC prototype specimens will be tested. The purpose of the testing is to subject the DPSC specimens to various loading scenarios that will represent accidental pressure and loading conditions, accidental thermal conditions, thermal cycling, and seismic conditions. A test set-up example is shown below in Figure 2.

Figure 2 Purdue testing rig.

GEH is working to provide a cost proposal to NRIC for building and demonstrating a reactor building structure using DPSC technology. For the Phase 2 demonstration, due to funding constraints, GEH has proposed a minimum viable structure that will demonstrate the key construction techniques, critical connections, concrete application, and other various aspects of using DPSC for a cylindrical reactor containment building. Figure 3 shows a digital representation of the proposed minimum viable reactor building structure using a DPSC system with a base mat, containment building wall, outer reactor building wall, critical base mat-to-wall connections, second level mezzanine, and inner passageway walls.

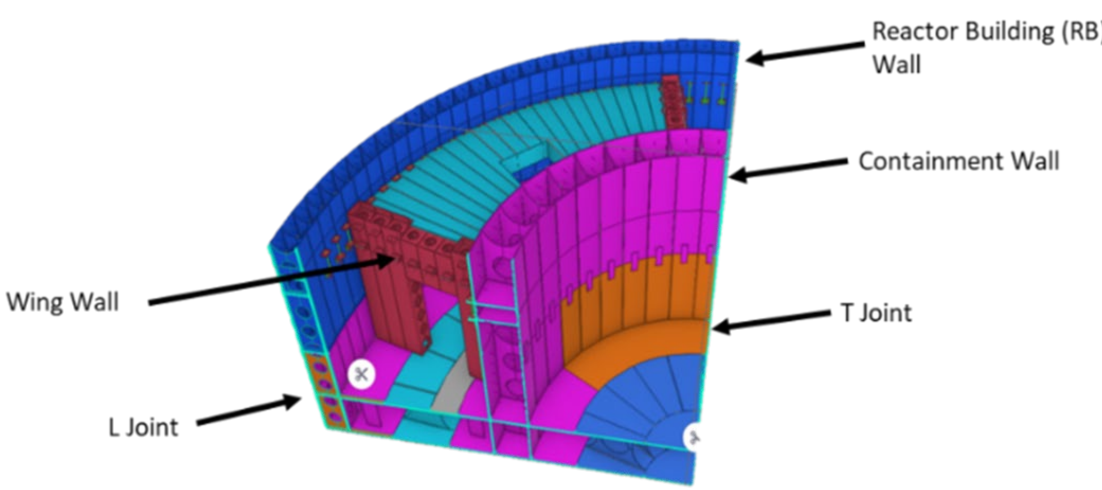

Figure 3. Digital representation of DPSC system demonstration structure.

The NRIC ACTI Project is important to GEH because the primary purpose is to demonstrate advanced construction, deployment technologies, processes, and approaches that will reduce risks associated with nuclear energy construction costs and schedule if implemented on nuclear energy projects. Phase 1 results have already created more confidence for GEH customers in the constructability of this design. Phase 2 will further reduce risk with DPSC as the preferred technology. Furthermore, the ACTI Project helps develop the supply chain and train the nuclear energy workforce to develop the techniques and methods to construct concrete- and steel-composite structures. Many lessons have already been learned by the SteelBricks manufacturers, and many more lessons will be learned while fabricating the DPSC test specimens and demonstration structure.

This ACTI Project with GEH benefits the entire nuclear industry because it can be used by numerous U.S.-based small modular reactor and advanced reactor companies. It will help develop and build a mature supply chain for nuclear component and structure fabrication and develop a knowledgeable workforce with building, welding, and fabrication techniques. This project will capture lessons learned and benefit the nuclear industry in the following ways:

- Establish and improve supply chain capabilities for mass deployment to the nuclear industry
- Demonstrate a reduction in construction time and improved quality for DPSC fabrication using automated welding techniques
- Demonstrate the fabrication of DPSC submodules and field erection of the critical joint and section types
- Develop construction and fabrication workforce capability for DPSC modules
- Demonstrate nondestructive testing methods during DPSC fabrication and construction
- Enable more accurate estimation of timelines for new plant construction.

Results of this work at the completion of Phase 2 should sufficiently demonstrate the viability, expected cost savings, regulatory implications, and interface conditions of the construction and deployment technologies, processes, or approaches. The intent of the work is to demonstrate that the systems and technologies can be subsequently used in nuclear energy projects to reduce cost and schedule risk.

3. FINAL DESIGN REVIEW MEETING SUMMARY

3.1 Objectives

The GEH ACTI project final design review occurred on June 18th, 2024. This design review covered the design of a reactor building structure using the DPSC technology. GEH had previously held a 60% and 90% design review for this project. The primary purpose of this review was to evaluate whether previous review comments have been addressed and whether the design drawings and specifications showed the finished product in sufficient detail to be constructed. The review will determine if the design is mature enough to move into the construction phase.

3.2 Applicable Documentation

The applicable documentation that was presented during the final design review is shown in Table 1

Table 1 Final design review master document list.

Document Number	Document Title
007N5115	Demonstration of NDE of Concrete in Mockups and Prototypes
007N5348	Implementation Plan for the ACTI Digital Twin
007N5114	Test Plan
007N5113	Construction Execution Plan
007N3451	Nuclear Regulators and Construction Standards
007N2881	Decommissioning Plan
P411151-0BSA-S5001	NRIC Building Structural Drawings
NA (presentation)	Purdure – NRIC ACT Phase 1 Final Design Review Meeting
NA (presentation)	EPRI – NRIC ACT Phase 1 Final Design Review Meeting (NDE)
NA (presentation)	EPRI – Digital Twin 2024 NRIC ACT Phase 1 Completion
NA (presentation)	B&V – NRIC ACT Phase 1 Final Design Review Meeting
NA (presentation)	GEH – NRIC ACT Phase 1 Final Design Review Meeting

3.3 Key Findings and Observations

The design review encompassed the work to date of the Demonstration Structure 60° pie slice utilizing the DPSC design. The presentation from Purdue University reviewed the test sample design requirements to meet ANSI N690. Personnel from Purdue also explain the test apparatus and sample setup in detail with the expected results. EPRI reviewed the NDE plan for the installed samples at the demonstration facility and the physical DPSC digital twin program, which details the monitoring and data collection plans. The team reviewed the documentation listed in Section 3.1 and drilled into the data to examine the basis behind conclusions. The reports were reviewed in a draft form to allow the inclusion of comments and section revisions that might come about during the review. The design review team concluded that the design and supporting data provides the necessary engineering to support construction of the demonstration facility at the Clinch River site if Battelle Energy Alliance, LLC chooses to move forward with Phase 2.

3.4 Action Items

There were no action items identified during the review.

3.5 Recommendations

There were no recommendations identified during the review.

4. CONCLUSION

After all presentations, the design and review teams were polled to determine if the design as presented would be approved by the teams. The review chair and review team agreed without comment that the design review met all necessary requirements and objectives.

5. PARTICIPATION AND AGENDA

Table 2 is a list of GEH ACTI final design review meeting attendees.

Table 2 Final design review attendee list.

Attendee	Organization	Title
Amit Varma	Purdue	Professor
Brad Tomer	NRIC	Acting Director
Bruce Greer	EPRI	Principle Technical Leader
Chandu Bolisetti	INL	Civil Engineer
Cybil Miller	GEH	Civil Design
Danny Kabir	Black & Veatch	Engineer
Dennis Rodriquez	GEH	Chief Engineer
Diana Hansen	GEH	Senior Commercial Proposal Manager
Efe Kurt	INL	Civil Engineer
Eric Loewen	GEH	Chief Engineering Manager
Fred Sock	NRC	NRC Consultant
Hailie Neaves	GEH	Senior Sourcing Manager
Jacob Pulfer	Black & Veatch	Civil Engineer
Jake Ballard	GEH	Civil Engineer
Jeff Hawkins	UNCC	Professor
Jennifer Smith	TVA	Manager
Joe Ondish	GEH	Project Manager
Jun Matsumoto	GEH	HGNE Liaison
Jungil Seo	Purdue	Assistant Professor
Kristen Marcera	GEH	Senior Project Management Specialist
Kyle Sena	GEH	Project Director
Levi Smith	Black & Veatch	Civil Engineer
Luke Voss	NRIC	Technical Program Manager
Maria Pease	GEH	Records Administrator
Maria Pressel	GEH	Project Management Specialist
Mark Gake	Black & Veatch	Engineer
Mike McDowell	TVA	Clinch River Project Manager
Paul Grenon	Black & Veatch	Engineer
Paul Gyswyt	Black & Veatch	Engineering Manager
Ray Alexander	TVA	Civil Engineering
Robert Cox	UNCC	Professor
Sal Villalobos	EPRI	Senior Technical Leader
Savannah Fitzwater	DOE	Program Manager
Sharon Chikota	GEH	Senior Civil Engineer

Attendee	Organization	Title
Valentine Braxton	GEH	Lead Sourcing Specialist
William Wood	TVA	Engineering

The agenda for the GEH ACTI final design review meeting is shown below in Table 3.

Table 3 Final design review agenda.

Time (ET)	Topic	Presenter
9:00	Introduction, Safety Start and Agenda Review	Kyle Sena (GEH) Luke Voss (BEA)
9:10	Design Review Goals	Kyle Sena (GEH)
9:20	Prototype (Phase 1) Test Plan Status Update	Amit Varma (Purdue) Jungil Seo (Purdue)
9:35	NRIC Demonstration Project Design	Steve Thomas (Black & Veatch) Paul Gyswyt (Black & Veatch)
9:45	Construction Plan (Construction Sequence and 3D Model)	Steve Thomas (Black & Veatch) Jason Lane (Black & Veatch)
9:55	Phase 2 Demonstration Test Plan	Steve Thomas (Black & Veatch) David Calhoun(Black & Veatch)
10:05	Decommissioning Plan	Steve Thomas (Black & Veatch)
10:15	List of Expected Permit, Impact Assessments, Reviews, and Approvals	Steve Thomas (Black & Veatch)
10:30	Break	
10:40	Technical Specification for Construction and Inspections	Steve Thomas (Black & Veatch)
10:50	Nuclear Regulators and Construction Standards Report	Steve Thomas (Black & Veatch)
11:00	Mini Digital Twin and Digital Twin Plan	Bruce Greer (EPRI) Robert Cox (UNCC)
11:10	NDE Techniques and Processes	Sal Villalobos (EPRI)
11:20	Q&A	All
11:30	Review of Action Items & DR Conclusion	Kyle Sena (GEH) Tech Writer (GEH)