

NuScale Testing Programs



Dr. José N. Reyes, Jr.

Dr. Kent Welter

Dr. Eric Young

February 29 - March 1, 2012

Testing & Demonstration



© NuScale Power, LLC 2012

Outline

- Presentation Objectives
- Overview of Test Programs
- Details of Thermal Hydraulic Test Programs
 - Critical Heat Flux
 - Helical Coil Steam Generator
 - Integral System

Objectives of the Presentation

- Provide a brief overview of the NuScale testing programs being used to obtain data needed to support design and analysis efforts.
- Interact early with the U.S. Nuclear Regulatory Commission (NRC) to resolve any potential technical or regulatory issues.
- Elicit feedback on planned thermal hydraulic (TH) test programs with respect to adequacy of test matrices to support a high-quality Design Certification Application.
- Identify opportunities for NRC witnessing of specific tests that may be of mutual value

Types of NuScale Test Programs

Structures, Systems, and Components

- Steam Generator (SG)
- High Pressure Containment
- Module Assembly Equipment
- Control Rod Drive Mechanisms
- Fuel Assemblies
- ECCS Valves
- SG Inspection Equipment
- Reactor Upper Plenum Internals



Separate Effects Testing

- Hydraulic
 - Mixing and distribution
 - Pressure drop
 - Lifting force
 - Flow induced vibration
- Functional, Physical, and Structural
 - Remote operation (e.g., latching)
 - Mechanical movements (e.g., step size)
 - Destructive crush testing
- Thermal
 - Heat Flux
 - Condensation
 - Diabatic flow regimes

Integral Effects Testing

Thermal hydraulic performance of passive safety systems

Fabrication & Constructability

Evaluation of fabrication methods and ability of vendors to construct special geometries

Overview of NuScale Test Programs

[[

]]^{3(a)-(b)}

Overview of NuScale Test Programs

[[

]]^{3(a)-(b)}

Fuel Critical Heat Flux Test Program

Critical Heat Flux Testing Outline

- Provide test program objectives
- Describe the prototype core design
- Describe the CHF facility and fuel specimen design
- Detail the test matrix and schedule
- Obtain feedback from the NRC on the adequacy of the testing program with respect to CHF correlation development

Program Objectives

- Obtain CHF data to extend the database for development of a CHF correlation applicable to the conditions of the NuScale design.
- Obtain bundle subchannel exit temperatures in order to determine mixing coefficients.
- Obtain single- and two-phase pressure drop characteristics of the assembly for a range of bundle powers and hydraulic conditions.

NuScale Core Design

- Approximately Half-Height
- 37 assemblies/16 control rod clusters
- 17x17 Lattice
- Low Power Density (45-65 kW/L)
- Axial Peaking Factor ≤ 1.5
- Natural Circulation Flow (low mass flux)



NuScale Fuel Design

[[

]]^{3(a)-(b)}

Critical Heat Flux Test Bundle Parameters

[[

]]^{3(a)-(b)}

Critical Heat Flux Test Bundle Instrumentation

[[

]]^{3(a)-(b)}

Critical Heat Flux Test Bundle Instrumentation

[[

]]^{3(a)-(b)}

Critical Heat Flux Test Bundle Parameters

[[

]]^{3(a)-(b)}

Geometry and Range of Test Conditions

[[

]]^{3(a)-(b)}

Critical Heat Flux Test Matrix

[[

]]^{3(a)-(b)}

Critical Heat Flux Test Matrix

[[

]]^{3(a)-(b)}

Critical Heat Flux Test Schedule

[[

]]^{3(a)-(b)}

Critical Heat Flux Summary

- Critical heat flux test program is in progress.
- Testing is for prototypic geometry and flow conditions.
- Data to be used for correlation extension to NuScale reactor conditions.
- Applicable components of program are compliant with the requirements of 10 CFR 50 Appendix B and NQA-1.
- Facility is available for NRC directed tests through STERN, and observation of the NuScale test matrix.

Helical Coil Steam Generator Separate Effects Test (SET) Program

Outline

- Provide test program objectives.
- Describe the preliminary SG design.
- Describe the large-scale SG testing program.
 - facility designs
 - instrumentation
 - testing matrix
 - schedule
- Obtain feedback from the NRC on the adequacy of the testing program, with respect to characterization of the thermal hydraulic performance of the SG.

Steam Generator SET Program Objectives

- Obtain large-scale thermal hydraulic data important to design and operation of the NuScale helical coil steam generator.
- Data to be used for validation of safety analysis and design codes.

Preliminary Helical Coil Steam Generator

[[

]]3(a)-(b)

Helical Coil Steam Generator Test Programs at SLET

[[

]]3(a)-(b)

SIET - HCSG Electric Direct Heated Testing

[[

]]3(a)-(b)

SIET - HCSG Electric Direct Heated Test Loop

[[

]]3(a)-(b)

HCSG Electric Direct Heated Test Loop Thermocouples

[[

]]^{3(a)-(b)}

SIET - HCSG Electric Direct Heated Test Section



Reproduced from SIET with permission

[[

[[

]]^{3(a)-(b)}

]]^{3(a)-(b)}

HCSG Electric Direct Heated Test Loop Instrumentation

[[

]]^{3(a)-(b)}

SIET - HCSG Electric Direct Heated Test Matrix

[[

]]^{3(a)-(b)}

SIET - HCSG Fluid Heated Testing

[[

]]3(a)-(b)

SIET GEST Facility Test Loop

[[

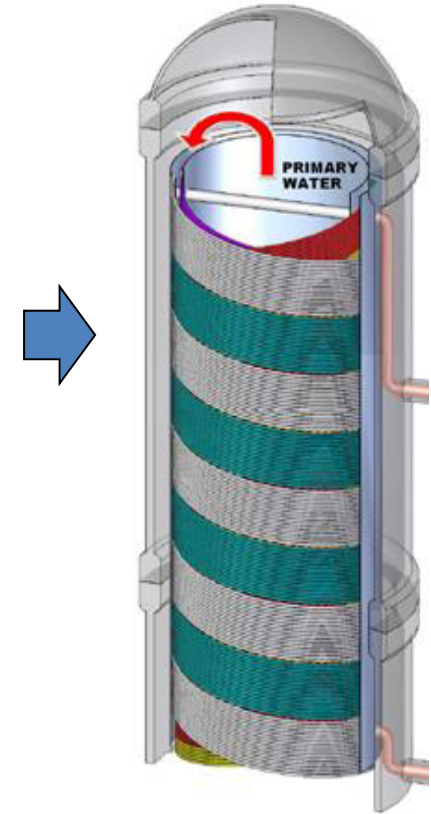
]]^{3(a)-(b)}

SIET – HCSG GEST Facility

[[



]]3(a)-(b)



Person

Reproduced from SIET with permission

SIET - GEST Facility Tube Geometry

[[

]]^{3(a)-(b)}

GEST Facility Tube Headers

[[

]]3(a)-(b)

Tube Thermocouple Locations

[[

]]^{3(a)-(b)}

NuScale Steam Generator SET Instrumentation

[[

]]^{3(a)-(b)}

SIET - HCSG GEST Test Parameters

[[

]]^{3(a)-(b)}

SIET- Testing Schedule

[[

]]^{3(a)-(b)}

SIET Summary

- Thermal fluid test program for the helical coil steam generator is in progress.
- Testing is for large-scale geometry and near prototypic flow conditions.
- Data to be used design and safety code validation .
- Two separate facilities are being constructed to allow detailed investigation of the operation and performance of the helical coil steam generator.
- Applicable components of program are compliant with the requirements of 10 CFR 50 Appendix B and NQA-1.
- Facility is available for NRC directed tests through SIET, and observation of the NuScale test matrix.

NuScale Integral Effects Test Program

Objectives

- Relate the Test Facility configuration to the prototype.
- Describe the NuScale integral effects test facility design and capabilities.
- Describe how the phenomena identification and ranking table (PIRT) process informs design of the facility and development of test matrix.
- Describe the test matrix and schedule.
- Obtain feedback from the NRC on the adequacy of the testing program with respect to loss-of-coolant accident (LOCA) methods development.

Natural Circulation Flow Integral Effects

[[

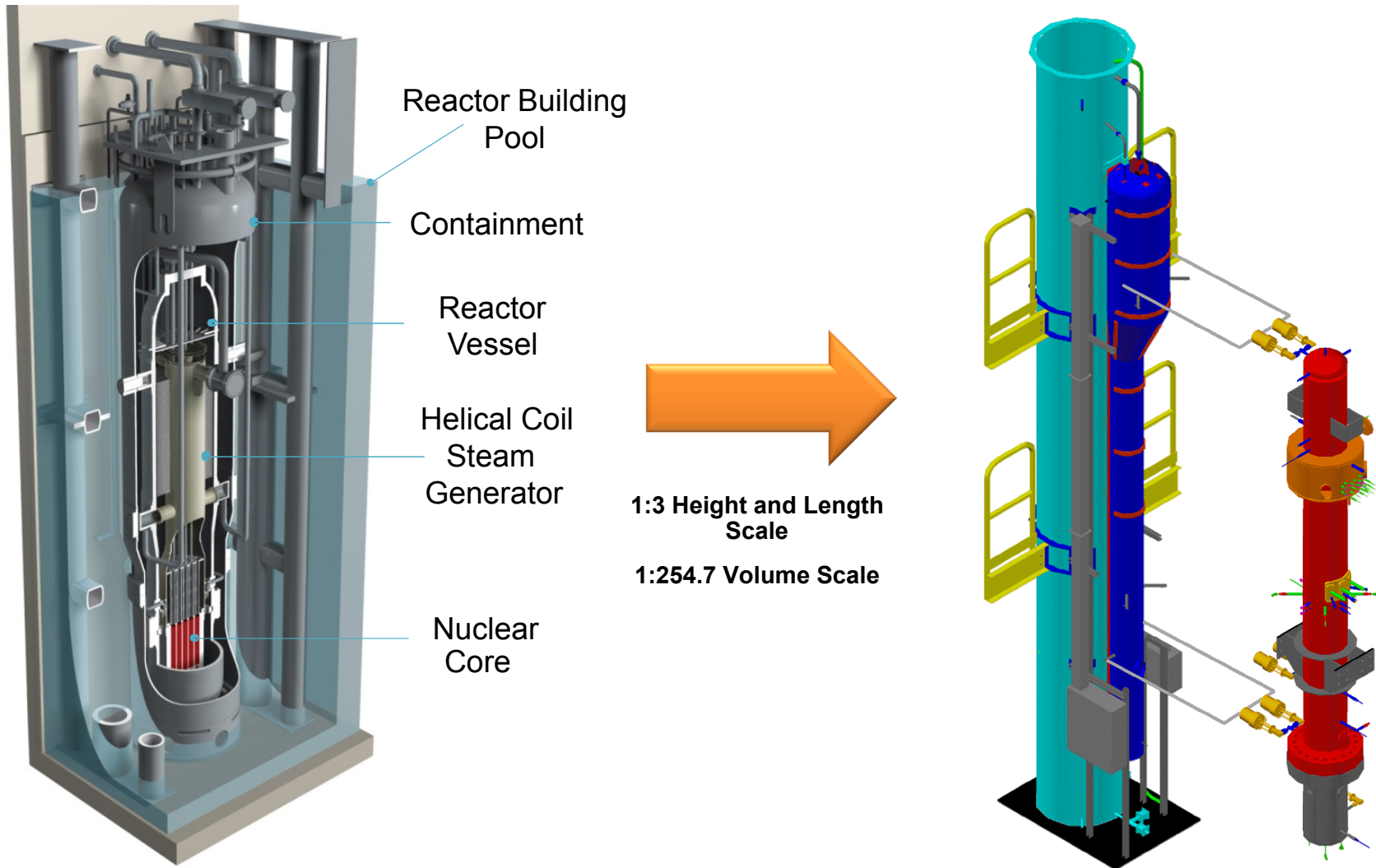
]]^{3(b)}

PIRT-Informed Facility Features

[[

]]^{3(a)-(b)}

Prototype and Test Facility Relationship



NuScale Integral Effects Test Facility



- 1:3 Height and Length scale
- 1:254.7 Volume scale
- Prototypic Pressures & Temperatures
- Integral test facility
 - Reactor vessel
 - Containment vessel
 - Reactor building pool
 - Electrically heated core
 - Core shroud with riser
 - Pressurizer
 - ECCS
 - Helical coil steam generator
 - Decay heat removal system

NuScale Integral Effects Test Facility

[[

]]^{3(a)-(b)}

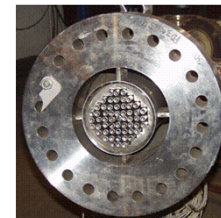
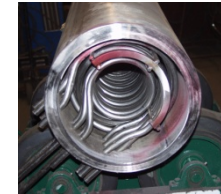
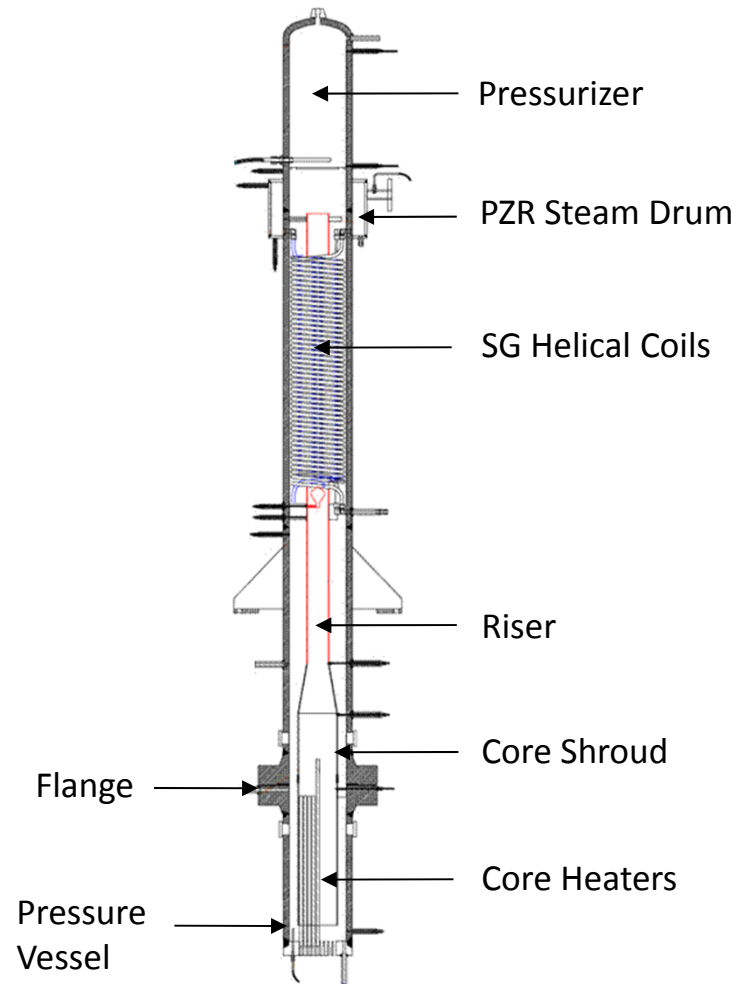
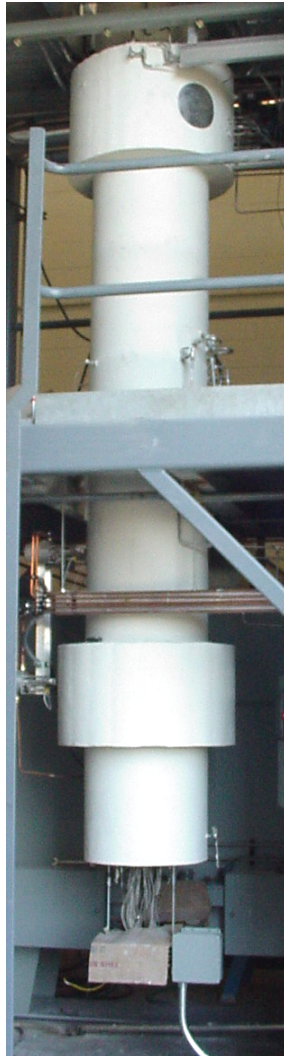
Containment and Cooling Pool

[[



]]3(a)-(b)

Reactor Pressure Vessel



Core Internal Structure

[[

]]^{3(a)-(b)}

Core Shroud

[[

]]^{3(a)-(b)}

Helical Coil Steam Generator Layout

[[

]]^{3(a)-(b)}

NuScale Integral Systems Test Instrumentation

[[

]]3(a)-(b)

NuScale Integral Systems Test Instrumentation

[[

]]^{3(a)-(b)}

Test Matrix

[[

]]^{3(a)-(b)}

Test Matrix

[[

]]^{3(a)-(b)}

Test Matrix

[[

]]^{3(a)-(b)}

Schedule

[[

]]^{3(a)-(b)}

Integral Effects Test Summary

- NuScale IET Phase II program is in progress.
- Facility design and modifications will provide scaled prototypic integral test data for codes and methods development.
- Facility will be available for NRC directed tests through Oregon State University, as requested.
- 10 CFR 50 Appendix B and NQA-1 compliant program is being implemented.

Summary and Conclusions

- Considerable effort has been spent developing test program requirements
 - Gap analyses
 - PIRTs (LOCA, non-LOCA, Severe Accident)
 - Pre-test calculations
 - Literature surveys
- Test programs focus on those components and integral effects unique to the NuScale design.
- The NuScale test program is broad in nature to ensure appropriate coverage of important phenomena and system performance.
- Program schedule facilitates early interactions with the NRC and integration with design and methods development activities.
- Experimental programs are being conducted by world-class testing organizations with high-quality programs.