# ENCLOSURE 3

"Westinghouse Small Modular Reactor Nuclear Fuel Technical Discussion"

presentation for the closed session

(Non-Proprietary)

# Westinghouse Small Modular Reactor Nuclear Fuel Technical Discussion (Non-proprietary)

## Closed Meeting Discussion

Presented to:

Nuclear Regulatory Commission

July 2013

Westinghouse

This document is classified Westinghouse non-Proprietary

# Agenda

- Introductions
- High Level Fuel Design Rationale & Design Basis Description
- Mechanical Design of Fuel and Control Rods
- CRDM Design and Testing Overview
- Core Design / Fuel Management

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- Questions and Wrap Up

# High Level Fuel Design Rationale & Design Basis Description

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# Fuel Design Philosophy

**Objective of fuel design program is to minimize licensing risks:**

- Base SMR fuel design on currently operating designs with significant operating experience
- Use proven materials
- Use currently developed fuel assembly and core components as much as possible
- Rely on currently used design processes and procedures
- Draw upon lessons learned from recent **AP1000®** PWR fuel development program

# Fuel Design Process

**Following Typical Design Process for Fuel Assembly Design:**

- Collect SMR Reactor Specific Information that Impacts the fuel
- Initial Fuel Concept
  - RFA Technology chosen for the SMR fuel design
- Project Planning, including risk assessment
- Concept Selection Process
  - Multiple Disciplines: mechanical design, thermal & hydraulic design, nuclear design, manufacturing, supply chain, product management
- Technical Reviews
- Hydraulic Testing
  - Fretting wear is major PWR fuel failure mechanism – scoping test to investigate for SMR fuel concept

# Fuel Design Basis

## Design Manuals define Design Basis:

- For SMR Fuel Assembly Concept
  - Determine important design criteria that need to be addressed for the SMR concept
  - Evaluate these criteria and document per procedures
  - This provides basis for fuel assembly design that will be defined in the DCD
- Technical Reviews
  - As part of the design process, technical reviews by peers are being performed to ensure that the fuel design for SMR meets the design criteria

# Mechanical Design of Fuel and Control Rods

# Correlations and Design Tools

- Correlations

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- Design Tools
  - The same design tools used for the **AP1000** PWR fuel mechanical design will be used for the SMR fuel
  - As shown in following slides, the SMR fuel and the **AP1000** PWR fuel are both based on the proven 17x17 Robust Fuel Assembly (RFA) design

# Mechanical Design Overview

# SMR Fuel Assembly Components

- Standard RFA Components
  - Top Nozzle
  - Top Grid
  - Mid-Grid
  - Protective Grid
  - Bottom Grid
  - Bottom Nozzle

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# Pellet / Fuel Rod / Thimble Design

- Pellet

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- Fuel Rod

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- Thimble Design
  - Typical thick-walled design used in RFA fuel which was developed for IRI resistance

# SMR Fuel Assembly Design

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# GSI-191 Considerations

- No new components are being introduced into the SMR fuel assembly design
- There is no fuel impact on GSI-191 considerations

# DNB Correlation

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# RCCA / Gray Rod Design

- RCCA
  - **AP1000** PWR NG RCCA with short rodlets
- GRCA

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# Prototypes of SMR Fuel Assembly Design

- Two Prototype SMR Fuel Assemblies were built in June 2013

# Purposes of Prototypes

1. Hydraulic scoping test of SMR fuel assembly design
    - Testing will take place at CFFF in Product Development Test Lab
    - Fretting wear test in VIPER test loop

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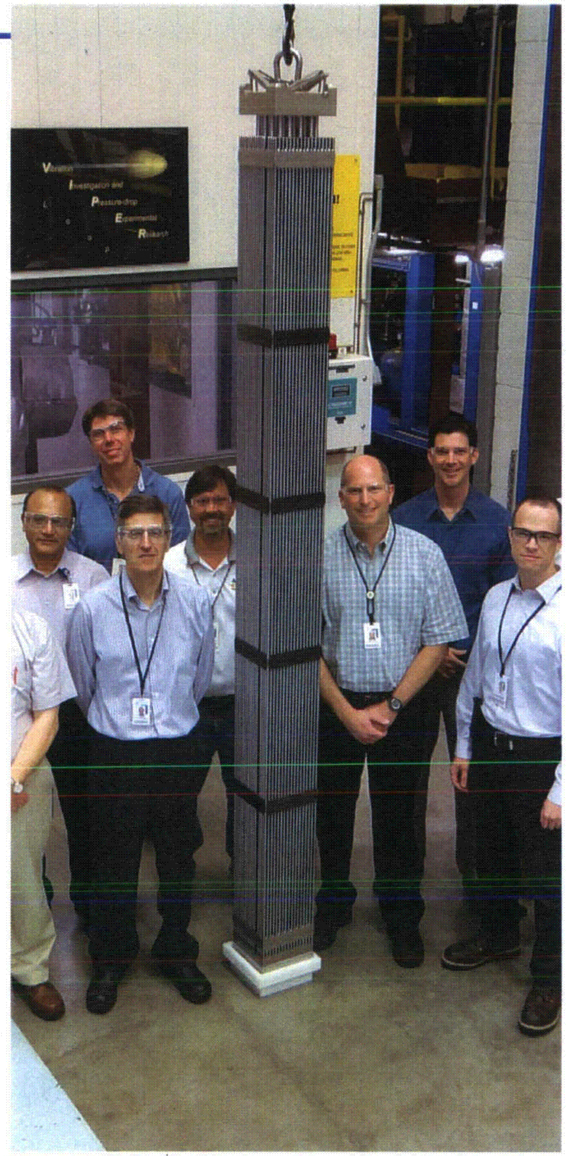
    - Results of testing to support mechanical fuel design

2. Evaluate manufacturing capability for SMR fuel and identify areas for improvement



# Purpose of VIPER Test

- Ensure SMR Fuel Assembly has good fretting-wear resistance
  - It is shorter than current fuel designs where good in-core fretting performance has been achieved

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  - Test results from SMR test will be compared to test data for other fuel types that have excellent in-core performance

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# End-of-Life Effects on Grid Strength

- The End-of-Life effects on grid strength will be addressed for the SMR fuel assembly seismic/LOCA analysis
  - The **AP1000** PWR grid impact test results will be used
  - The same EOL seismic/LOCA analysis method used in the supplement report for **AP1000** PWR core reference report will be applied

# CRDM Design Basis and Testing

# SMR Internal Electric CRDM

- The Westinghouse SMR includes a Control Rod Drive Mechanism (CRDM) assembly that is inside of the reactor vessel.

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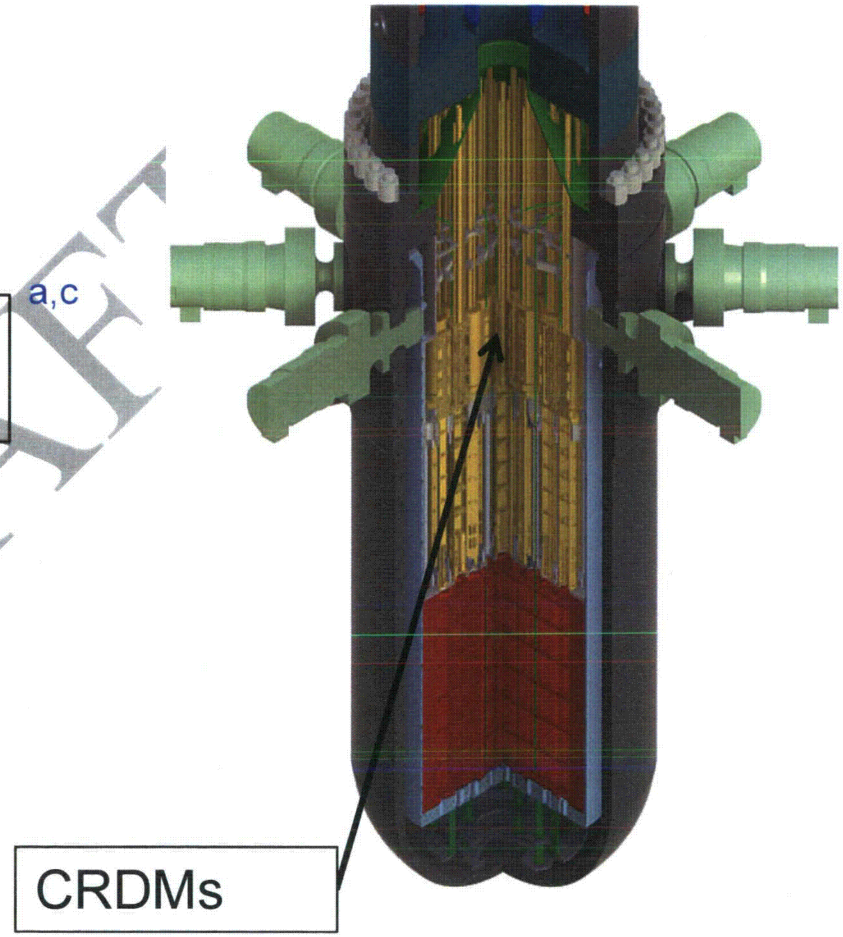

# SMR CRDM Design

- The SMR CRDM is essentially a standard **AP1000** PWR style CRDM mounted internally within the reactor vessel.

- The CRDM system includes:
  - Latch Housing / Coil Stack Assembly with integral lift and latch coils
  - **AP1000** PWR style latch assembly
  - **AP1000** PWR style drive rod with integral upper magnet
  - Rod Travel Housing
  - Dual Reed Switch Rod Position Indication (RPI) Housings
  - Interconnecting Electrical Conduits

# SMR CRDM Design (continued)

- The Latch Housing / Coil Stack Assembly
  - Contains the lift, stationary, and movable latch coils which are designed to be operated using a standard **AP1000** PWR Digital Rod Control System

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  - Is designed and fabricated to ASME B&PV Section III, Subsection NB for operation within a 650 °F, 2250 psig reactor environment for 60 years

# SMR CRDM Design (continued)

- The **AP1000** PWR style latch assembly

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- The **AP1000** PWR style drive rod assembly
  - Is similar to the drive rod used in the **AP1000** PWR plant, except a,c

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# SMR CRDM Design (continued)

- The Reed Switch Rod Position Indication (RPI) Housing
  - Is attached to the side of the Rod Travel Housing

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  - Is designed and fabricated to ASME B&PV Section III, Subsection NB for operation within a 650 °F, 2250 psig reactor environment for 60 years

# SMR CRDM Design (continued)

- The Interconnecting Electrical Conduits
  - Contain the interconnecting electrical wires
  - Connect to the Reactor Vessel Penetration Assemblies
  - Connect the Coil Assemblies to the external Rod Control System
  - Connect the Reed Switch RPIs to the external Rod Position Indication System

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  - Are designed and fabricated to ASME B&PV Section III, Subsection NB for operation within a 650 °F, 2250 psig reactor environment for 60 years

# SMR CRDM Materials

- All materials exposed to reactor coolant will meet ASME B&PV Code ASME Section III and II requirements
- Expected life will be 60 years for all materials at 650 °F

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# SMR CRDM Operation

- CRDM operation will be the same as **AP1000** PWR, specifically

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# SMR CRDM Coil Testing

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- All candidate materials for the final coil design are in various stages of investigation and manufacturing technique trials.

# SMR CRDM Coil Performance

- Current CRDM coils operate at up to 392 °F (200 °C).

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# SMR CRDM Reed Switch RPI Testing

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# SMR CRDM Reed Switch RPI Testing

- The Reed Switch RPI is the preferred method for the SMR
- The basic design has been in use for over 40 years in Combustion Engineering (CE) plants in the USA and Korean Standard plants in South Korea.

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# Core Design / Fuel Management

# Core Design Tools and Methods

## SMR core design analyses will use currently licensed methods:

- NEXUS / PARAGON for generation of fuel, control rod and reflector cross-sections

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- ANC9 for nodal solution:

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# Core Design Tools and Methods

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# Core Design Tools and Methods

**SMR core analysis will account for thermal conductivity degradation (TCD):**

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# Core Design Follows Current Limits

## Core Design Limits

- Based on currently-licensed core design limits:
  - Maximum fuel enrichment of 5% weight percent U235

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  - MTC ≤ 0 during normal operation

# Core Design Current Limits

## Core Design Limits

- Core design limits developed for input to safety analyses: a,c

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# Core Design T/H Boundary Conditions

## Core Design T/H Parameters

- 800 MWt core power

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# Core Design Considerations

## Core Design Parameters

- Reactor pressure vessel (RPV) diameter constrained to standard rail shipping envelope
  - Core radial size constrained by RPV size

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- Cycle length target of 24 months
  - Driven by customer feedbacks
  - Experience with 24 month operating cycles and impacts on plant operations
  - Factors into core power density and active core height

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# Representative 24-Month Equilibrium Cycle Core Design

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# Representative 24-Month Equilibrium Cycle Core Design

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# Representative Cycle 1 Core Design

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# Preliminary Control Rod Configuration

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# Preliminary Control Rod Configuration

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# Core Operating Strategy

## SMR to use Mechanical Shim (MSHIM™) operating strategy developed for AP1000 PWR

- Two independent sets of control banks:
  - M banks for $T_{avg}$ control; AO bank for axial flux difference control
- Advanced rod control system to automate rod motion
- Minimize required operator actions by reducing frequency of soluble boron changes required
- Simplifies baseload operation

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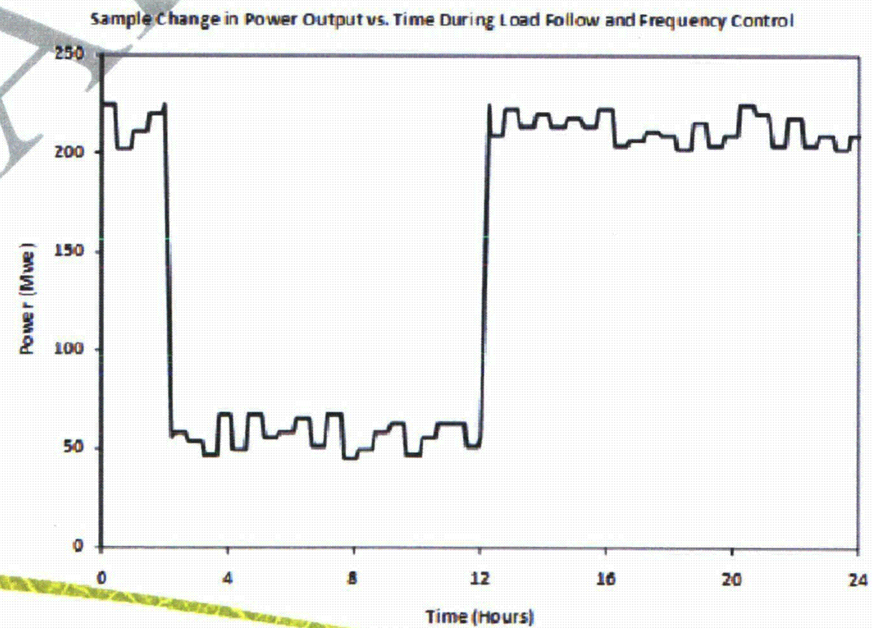

# Core Design Summary

- **Core sized to provide 2-year fuel cycle capability**

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- **MSHIM operating strategy to be implemented**
  - Draws from **AP1000** PWR design experience, including use of gray rods to support baseload and load-follow operations

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# Wrap Up

- The purpose of today's presentation was to provide a general overview of Westinghouse's Small Modular Reactor fuel and core design.



Thank You

Questions ?