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NRC Meeting:
Fuel Qualification and Testing

May 10th, 2023

Meeting Agenda

- Introductions
- Purpose and Outcomes
- Background
- Applicability Assessment
- Interface Requirements
- Timeline

Introductions

- NRC Staff
- Holtec Staff
- Framatome Staff

Purpose and Outcome

PURPOSE: To provide a high-level overview of the fuel qualification and testing program

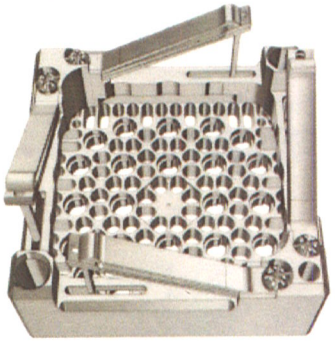
OUTCOME: To obtain feedback from the NRC staff on the high-level overview and identify specific topics that the NRC would like to discuss further in future meetings.

Background

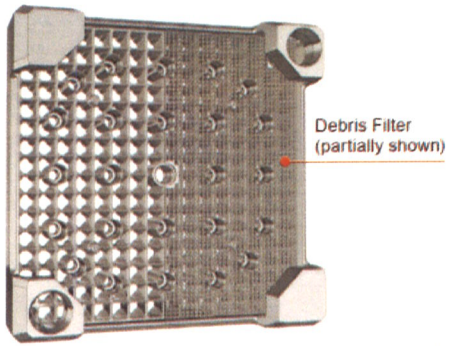
- SMR-160 will incorporate Framatome's 17x17 GAIA fuel assembly and HARMONI rod cluster control assembly (RCCA)
- GAIA fuel is currently operating in various quantities in the US at three different Westinghouse three and four loop PWRs
- HARMONI 17x17 RCCAs have been supplied to more than 10 Westinghouse PWRs over the last 25 years
- SMR-160 will leverage Framatome's proven analysis methods, engineering experience and expertise, test facilities, and licensing experience to support the fuel qualification and testing program

GAIA 17x17
for Holtec SMR-160

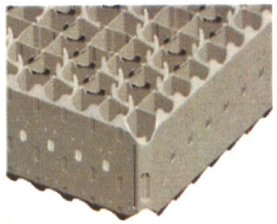
Reconstitutable Top Nozzle



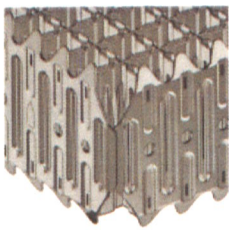
GRIP™ Bottom Nozzle



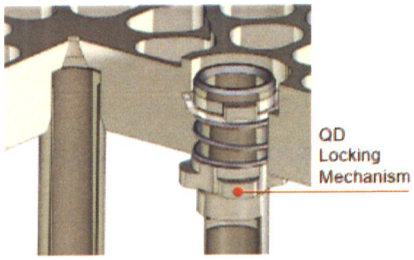
GAIA Mixing Grid



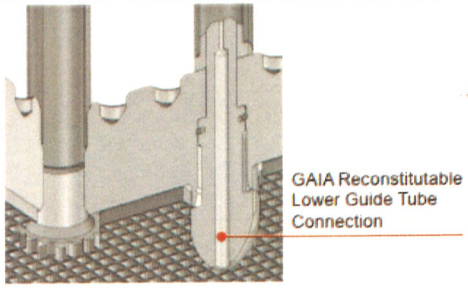
HMP™ Grid



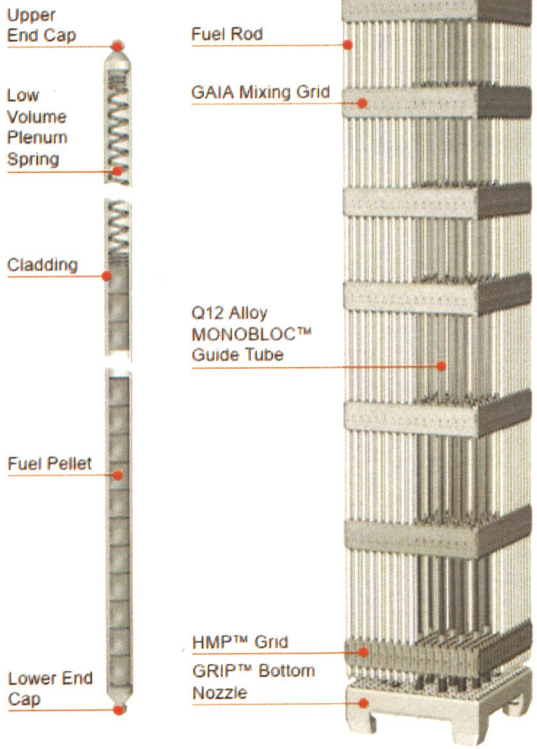
Quick Disconnect (QD) Upper Connection



Reconstitutable Lower Guide Tube Connection

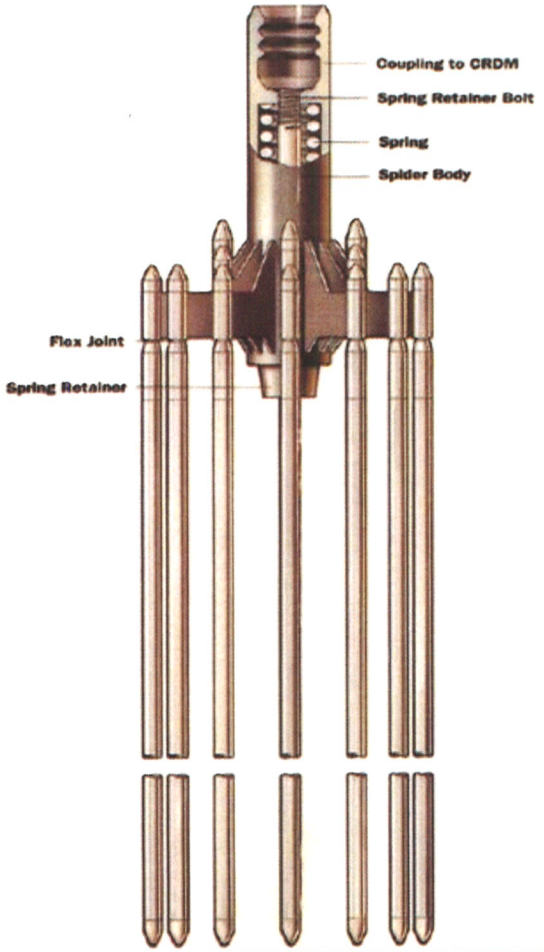


Fuel Rod



framatome

HARMONI RCCA



- Framatome has supplied over 7,700 HARMONI RCCAs operating in 97 reactors around the world, including the united states

GAIA Fuel Assembly Design Features

- M5® Fuel Rods
  - ✓ High resistance to corrosion and hydrogen uptake
  - ✓ High density pellets
- M5® GAIA Spacer Grids
  - ✓ Fretting resistance consistent with Framatome's HTP™ design
- Two Inconel 718 HMP™ spacer grids at top and lowermost grid positions. Top HMP™ grid has a reduced fuel rod grip force to reduce fuel rod bow.
- All three intermediate GAIA mixing grids (IGM) are removed for the SMR-160 application to reduce pressure drop and increase core flow rate
- Q12™ MONOBLOC™ Guide Tubes and Instrument Tube
  - ✓ Increased cross-sectional area to improve lateral stiffness
  - ✓ Q12™ material based on M5®, with improved creep properties
- GRIP debris resistant bottom nozzle
- W17x17 top nozzle with hold-down springs
- ¼-turn quick disconnect top nozzle connection
- Welded cage
- Nominal active fuel length of 144 inches

HARMONI RCCA Design Features

- Twenty-four control rods with stainless steel clad
- One-piece stainless steel spider
- Standard 17x17 rod configuration and position
- Flex joint formed by the combination of the pin, nut, upper end plug, and spider boss
- Inner rod stack support feature and lower end plug to mitigate life limiting phenomena
- Absorber is silver-indium-cadmium (AIC) bars (80% Ag, 15% In, 5% Cd) with a large diametral gap / reduced diameter in lower tip region
- Nominal absorber length is 142 inches

General Work Scopes

- The fuel qualification and testing program consists of several key areas
  - Core Neutronics
  - Materials
  - Mechanics
  - Thermal-Mechanics
  - Core Thermal-Hydraulics
  - Safety Analysis (SRP Chapter 15)
  - Testing

Applicability Assessment

- Framatome performed initial applicability assessment of their NRC approved codes and methods against the SMR-160 operating conditions

MECHANICAL
ANP-10342P-A, "GAIA Fuel Assembly Mechanical Design"
ANP-10337P-A Rev. 0, "PWR Fuel Assembly Structural Response to Externally Applied Dynamic Excitations" ANP-10337P-A, Rev. 0, Supplement 1P-A Rev. 0, "Deformable Spacer Grid Element"
ANP-10334P-A, "Q12 Structural Material Topical Report"
THERMAL-MECHANICAL
BAW-10231PA-01, COPERNIC Fuel Rod Design Computer Code BAW-10183P-A, Rev. 0, "Fuel Rod Gas Pressure Criterion (FRGPC)"
BAW-10084P-A, Rev. 3, CROV "Program to Determine In-Reactor Performance of BWFC Fuel Cladding Creep Collapse"
BAW-10227P-A, Rev. 1, "Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel"
THERMAL-HYDRAULICS
ANP-10341P-A, "The ORFEO-GAIA and ORFEO-NMGRID Critical Heat Flux Correlations"
XN-75-32(P)(A), "Supplements 1-4, Computational Procedure for Evaluating Fuel Rod Bow"
BAW-10227P, Rev. 2, "Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel"
ANP-10311P-A, Revision 1 "COBRA-FLX: A Core Thermal-Hydraulic Analysis Code"
XN-NF-82-06(P)(A), Revision 1, "Supplement 2, 4, and 5, Qualification of Exxon Nuclear Fuel for Extended Burnup". Supplement 5 p.5 (DNB Propagation)

Applicability Assessment

- Framatome concluded SMR-160 is mostly within the applicably ranges and limitations of their topical reports based on SMR-160 data at this time
- Applicability assessments identified the following items to be addressed:
  - Fuel assembly damping ratios for analysis of seismic and LOCA events are not applicable due to lower flow rates. New ratios have been calculated.
  - ORFEO-GAIA and ORFEO-NMGRID CHF correlations do not cover entire SMR-160 operating range
  - COBRA-FLX
    - Thermal hydraulic conditions need to be verified by SMR-160 safety analysis calculations.
    - Low flow benchmarks were identified in VIPRE and should be included for COBRA-FLX

Interface Requirements

- Framatome and Holtec collaborated on interface requirements of the GAIA fuel assembly with SMR-160 design
- Goal was to minimize changes to GAIA fuel assembly
  - Top nozzle will be modified to accommodate top loaded in-core detectors
- No changes to critical design features of SMR-160 were required
  - Minor changes to SMR-160 upper and lower core plates were made to accommodate GAIA fuel assembly

Mechanical Analysis

- Stress and fatigue of all fuel structural components under normal operation and AOOs
- Axial growth analysis of fuel assembly and fuel rods
- Lateral growth analysis of spacer grids
- Flow Induced Vibration (FIV) assessment
- Seismic and LOCA (faulted) analysis
- Fuel assembly and fuel rod bow analysis
- Fuel assembly lift and drop analysis

Thermal-Mechanical Analysis

- Rod internal pressure
- Clad corrosion
- Clad creep collapse
- Transient clad strain
- Clad fatigue
- Clad stress
- Fuel centerline melt

Thermal Hydraulic Analysis

- Form loss coefficient (FLC) development
  - IGM grids were evaluated and determined to not be required, so they were removed to reduce RCS pressure drop and increase core flow rate
- Control component cooling evaluations

Test Program

- Flow Lift and Pressure Drop Coefficient
  - Analyses or testing will be utilized to validate these items in the SMR-160 operating range
- CHF Testing – KATHY Facility in Karlstein
  - Required due to low flow and inlet temperature of SMR-160
  - Framatome performed two-phase CFD calculations to guide CHF test plan
  - 4 CHF tests are planned:
    - Unit cell with uniform axial power shape
    - Unit cell with cosine power shape
    - Guide tube cell with uniform axial power shape
    - Guide tube cell with cosine power shape

Timeline

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