Southern Nuclear Operating Company

ND-12-0356

Enclosure 3c.

Vogtle Electric Generating Plant (VEGP) Unit 3&4

Transmittal of
March 28, 2012 SNC Presentation to the NRC on
AP1000 Overview of First-Plant-Only and First-Three-Plants-Only Test
Comprehensive Vibration Assessment Program (CVAP)
Instrumentation and Analysis Plans
(Non-Proprietary)

AP1000® First Plant and First Three Plant Tests

Comprehensive Vibration Assessment Program (CVAP)

Instrumentation and Analysis Plans

March 28, 2012

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Agenda

- Purpose
- Background and previous submittals
- Description of changes and implications
- Current approach and methodology for complying with RG 1.20, Rev. 2
- Near Term Submittals
- Closing Questions, Comments

Purpose

- Summarize the technical aspects of the AP1000 CVAP program
- Obtain NRC comments in preparation for the submittal of two reports in April:
  - Vibration Analysis Plan for AP1000 CVAP
  - AP1000 CVAP Measurement, Test and Inspection Plan

Background and Previous Submittals

- The AP1000 DCD describes CVAP in section 3.9.2
- The details of the CVAP Pre-Hot Functional Test (Pre-HFT) report are provided in two referenced technical reports
  - WCAP-15949-P, Rev. 2 (APP-MI01-GER-001, Rev. 2)
  - WCAP-16687, Rev. 1 (APP-GW-GLR-001, Rev. 0)

WCAP-15949-P,Rev.2

- Describes Analysis
  - Comparison with and scaling from previous CVAPs and tests
  - Modal results based upon system model
  - Analysis results and margins
- Measurement Plan
  - Table of sensors
- Test conditions
- Table and Figure for Inspection

WCAP-16687-P, Rev 1

- Expected and Allowable Sensor Responses
  - For Hot Functional Test (HFT) conditions
    - HFT pressure and temperature
    - 4 RCPs, 100% speed
    - No core or core simulator (with justification)
  - Table of sensors
  - Table and figure for inspection

Pre-HFT Report Conclusions

- RVI evaluations demonstrate acceptable margins to endurance limits
- Expected and allowable sensor responses provided for one test condition
- Measurement Plan and Inspection Plan defined
- Report methods and results were based upon the RVI design and operating conditions at that time

Description of Changes and Implications

- Design change APP-GW-GEE-411 changed the in-core instrumentation (ICI) system from the "Upper Mounted Instrument Assembly" design to the "Instrument Grid Assembly" (IGA) design
  - Allowed ICIs to be stored in the upper internals (shielded) during outages
  - Allowed reduction in the number of RV closure head penetrations for ICIs from 42 to 8

Instrument Grid Assembly

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Impact of IGA on CVAP

- IGA consists of multiple tubes and supports in the RV Upper Head
- The AP1000 utilizes cooling nozzles to provide flow from the down-comer to the upper head.
- The increased potential for flow induced vibration effects has prompted the need for:
  - More detailed predictive methods and
  - Incorporating the hydraulic resistance of the core to achieve prototypic velocities in the upper head

Impact of IGA on CVAP…

- Predictions are based on analyses and utilize detailed assembly models
- HFT will use flow restrictors to simulate the hydraulic performance of the fuel and provide prototypic upper head velocities
- Number of sensor locations on the IGA is 31, compared with 5 on UMIA
- Specify pre-HFT and post-HFT inspection locations for the IGA

Other Significant Updates for CVAP

- Sensor predictions will be provided for multiple test conditions (RCS pressure & temperature, RCP pump speed, pump operating configurations)
- Predictive analyses will address uncertainties.
- Total number of sensors increased from 51 to 97

Current Approach and Methodology for Compliance with RG 1.20

US Regulatory Requirements

- NRC Requirements
  - General Design Criteria (GDC) 1 and 4 in Appendix A to 10CFR50
  - 10CFR50.34 (documentation requirements)
  - Requirements can be met by following guidance provided in RG 1.20, Rev. 2
- DCD Rev. 19
  - Commits to following RG 1.20, Rev. 2

RG 1.20, Rev. 2

- Objective
  - Verify the structural integrity of reactor internals for flow induced vibrations prior to commercial operation
- Major Elements of CVAP
  - Predictive analysis
  - Test and Measurement
  - Inspections
  - Documentation
    - Predictive analysis report (Pre-HFT report)
    - Preliminary test report
    - Final (Reconciliation) report

RG 1.20 Plant Design Categories

- "Prototype"
  - Unique or first of a kind design
  - Has to go through analysis, test, measurement and inspection
    - Sanmen 1 will be "Prototype" prior to CVAP test
- "Valid Prototype"
  - A "Prototype" plant that has successfully gone through CVAP
    - Sanmen 1 will be classified as "Valid Prototype" after the successful CVAP
- "Non-Prototype Category 1"
  - Subsequent plants similar in design to "Valid Prototype"
    - Requires analysis and either measurement or inspection

Predictive Analysis

- Objective is to consider all flow induced forcing functions, predict response of reactor internal structures and demonstrate that they meet the acceptance criteria
- Forcing Functions
  - Vortex shedding
  - Turbulence induced
  - Pump induced
  - Vessel motion
- Velocity field either by CFD or simplified methods
- Turbulence induced forcing function using standard correlations

Predictive Analysis Contd.

- Structural Response
  - Finite element models for major assemblies
  - Modal analysis
  - Forced response analysis
- Acceptance Criteria
  - Alternating stress intensity at limiting location is limited to fatigue curve value at 10^{11} cycles in the ASME Boiler and Pressure Vessel Code , Section III, Appendix I-9.0
- Simulation models – FEM or CFD validated and benchmarked
  - Grid sensitivity studies
  - Modal and damping test
  - Scale model test for CFD

Predictive Analysis Contd.

- Testing
  - IGA
    - Mock up test to measure fundamental frequencies and damping
  - IGA Hydraulic Test
    - Quarter scale, quarter symmetry
    - Most of the major structural components modeled
  - Core Barrel
    - Full scale modal test if possible
  - Data from the legacy scale model tests, CVAPs, HFTs

Predictive Analysis Contd.

- Biases and Uncertainties
  - Biases and uncertainties will be assessed for each major step of the analytical and test process
  - They will be combined mathematically to derive a overall uncertainty for the predictions
  - Comparison with the CVAP test measurements will provide the final "end to end" uncertainty

Measurements

- Different types of sensors utilized
  - 31 accelerometers (7 external),
  - 53 strain gages,
  - 5 dynamic pressure transducers (2 on IGA and 3 on core barrel),
  - 8 Linear Variable Displacement Transducers (LVDTs) - 4 on upper support/IGA and 4 on Core Shroud radial keys
- Sensor location criteria
  - DCD Commitment
  - Critical to safety
  - New component
  - High stress areas
  - Analytical model validation
  - Based on previous experience

Measurement Contd.

- Sensor Specifications
  - Static Pressure: 2250 psig design, 3300psig maximum
  - Operating Temperature: 557°F design, 68°F to 600°F maximum
  - Surrounding Medium: Water with HFT required Primary Chemistry
- Sensor Sensitivity and Measuring Range
  - All sensors will have enough sensitivity and measurement range to adequately capture all meaningful sensor data.
- Sensor Reliability
  - In order to assure high reliability, sensors that have been used in similar tests are selected. They will be tested and calibrated prior to use
- Sensor Redundancy
  - Additional sensors are carefully selected to still be able to get meaningful data even in the event of sensor failure

Sensor Mounting

- Mounting hardware requirements:
  - Designed to withstand the HFT test conditions
  - Installation and removal will be performed by qualified installers

Mounting Hardware Considerations

- Mount sensors as close to the locations of interest as possible
- Measurement quality not adversely affected by sensor attachment method
- Prevent cable failure and limit cable vibration
- Prevent loose parts
- No damage to RVI

Permanent Modifications for CVAP

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Test Conditions

- Cover expected range of pump RPM, coolant temperatures, and flow rates from the initial zero flow condition to hot standby temperature, pressure and flow conditions
- Transients involving various pump speeds and pump operating configurations

Inspections

- CVAP requires detailed visual inspections of reactor internals pre and post test to ensure no damage has occurred
- Visual examination is performed:
  - On critical surfaces to see if there are any cracks
  - On welds to see evidence of cracks
  - On interface surfaces to see evidence of wear or distress
  - On fittings to see if they are tight

Documentation

- CVAP documentation per RG 1.20, Rev. 2
  - Predictive analysis report to be submitted prior to the test
    - This report provides best estimate structural response predictions and acceptance criteria
    - Also, provides measurement, test and inspection plans
  - Preliminary test report at the conclusion of CVAP test
    - Includes measurement results, inspection results
    - If all acceptance criteria are met, plant is allowed to load fuel
  - Final reconciliation report
    - This report reconciles any and all significant differences between analytical predictions and measurements
    - This provides an end to end estimate of uncertainty for the program

Near Term Deliverables

WCAP-17534 "Vibration Analysis Plan for AP1000 CVAP"

WCAP-17584 "AP1000 CVAP Measurement, Test and Inspection Plan"

WCAP-17534
Vibration Analysis Plan for AP1000 CVAP

- The Analysis Plan provides:
  - Methodology for predicting dynamic response of internal structures due to all flow induced loads for normal operating and transient conditions
  - Methodology for determining the expected and acceptable response of sensors to demonstrate the structural integrity of reactor internals
- Consistent with RG 1.20, Rev. 2 requirements

WCAP-17534 Vibration Analysis Plan Contd.

- Details for:
  - Assessing various forcing functions for all internals
    - Turbulent buffeting, pump induced pulsations, vortex shedding, vessel motion
  - Computational Fluid Dynamics (CFD) models benchmarked by scale model test used to obtain velocity fields for Upper Head
  - Correlations and models used for Lower and Upper Internals regions
  - Finite element structural models for modal analysis and forced response analysis

WCAP-17534 Vibration Analysis Plan Contd.

- Methodology for determining expected structural response of internals using detailed ANSYS assembly models.
- Methodology for uncertainty analysis to evaluate the overall uncertainty in the predictions for comparison with CVAP measurements

WCAP-17584 AP1000 CVAP Measurement, Test and Inspection (MTI) Plan

- Provides criteria for selecting components for measurement and inspections
- Provides typical sensor types and locations based upon existing analyses and experience
- Provides transducer specifications to ensure accurate and reliable measurements
- Provides requirements for the Data Acquisition System (DAQ)

WCAP-17584 Measurement, Test and Inspection (MTI) Plan Contd.

- Provides criteria for type of pre- and post-CVAP test inspections and locations
- Provides proposed CVAP test conditions

March 27, 2012

Proposed Licensing Process For CVAP Analysis, Test Performance Reports, and Removal of License Condition

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CVAP Submittal Summary

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Closing Questions, Comments?