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San Onofre Nuclear Generating Station

Unit 2

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COMPREHENSIVE VIBRATION ASSESSMENT PROGRAM

FINAL REPORT

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## ATTACHMENTS:

1. "Precritical Vibration Monitoring Program Standard Procedure for Visual Inspection of Reactor Vessel Internals for 3410 Type Plants", Specification No. 00000-RCE-413, Revision 00, dated 6/12/80.
2. "Precritical Vibration Monitoring Program Project Procedure for Visual Inspection of Reactor Vessel Internals for Southern California Edison Company San Onofre Nuclear Generating Station Units 2 and 3", Specification No. 1370-RCE-413, Revision 00, dated August 13, 1980.

San Onofre Nuclear Generating Station  
Unit 2  
Comprehensive Vibration Assessment Program

1. INTRODUCTION

The Comprehensive Vibration Assessment Program (CVAP; formerly referred to as the Precritical Vibration Monitoring Program, PVMP) reported herein satisfies the NRC Regulatory Guide 1.20, Revision 1 (Reference 1), requirements for verifying the structural integrity of the reactor internals for flow induced vibrations prior to commercial operation. The CVAP provided confirmation, based upon prototype PVMP programs, an analytical program and an inspection program, that the hydraulic excitations and structural responses of the San Onofre Nuclear Generating Station Unit 2 (SONGS 2) reactor internals are within design estimates and are acceptable for all normal steady state and transient modes of reactor coolant pump operation.

As stated in Reference 2, Section 3.9.2.4, the Maine Yankee and Fort Calhoun reactors are designated jointly as the Valid Prototype for the SONGS CVAP, with SONGS 2 and 3 designated as Non-Prototype Category 1 reactors. Reference 3 (Question 112.7) and Reference 4 (Section 3.9.2.3) state that the NRC staff has conditionally accepted the prototype designation; with the acceptance contingent upon the results of NRC's review of the Arkansas Nuclear One - Unit 2 (ANO-2) augmented internals inspection, reported in Reference 5.

Reference 1 requires that an analysis program and a measurement or inspection program be performed for the CVAP for Non-Prototype Category 1 reactors. The analysis program for the SONGS 2 and 3 CVAP was reported in Reference 2, Section 3.9.2.6. A visual inspection program with photographic documentation was performed for SONGS 2 in lieu of a measurement program.

This report summarizes the results of the SONGS 2 CVAP and provides an evaluation of those results.

## 2. SUMMARY AND CONCLUSIONS

The SONGS 2 CVAP was successfully completed in accordance with the requirements of NRC Regulatory Guide 1.20, Revision 1 (Reference 1).

The vibration analysis program, performed in accordance with regulatory position C.3.1.1 of Reference 1, provided sufficient evidence to support the classification of SONGS 2 as Non-Prototype, Category 1, with the Valid Prototype designated jointly as Maine Yankee and Fort Calhoun. In support of the NRC's acceptance of the Valid Prototype designation, the results from the Arkansas Nuclear One - Unit 2 PVMP were provided in Reference 5; no corrective action was required and no indications were observed that would necessitate reactor internals modifications on SONGS 2 and 3.

The SONGS 2 vibration inspection program, performed in accordance with the guidelines of regulatory position C.3.1.3 and C.2.3 of Reference 1, included inspections of the SONGS 2 reactor internals both prior to and following pre-core hot functional testing. The pre-core hot functional testing included all steady-state and transient modes of reactor coolant pump operation. Neither real nor dummy fuel assemblies were in position for the testing. It was shown by analysis that the absence of fuel assemblies would yield conservative results for the CVAP of reactor internals. The critical reactor internals component with the lowest natural frequency is the Core Support Barrel (CSB). Based upon the minimum significant response frequency of the CSB, the critical reactor internals components were subjected to greater than  $10^7$  cycles of vibration during the pre-core hot functional testing.

The inspection program was performed without deviation from the specified operating conditions. No unanticipated observations or inspection anomalies were encountered. The inspections of the SONGS 2 reactor internals revealed no defects, evidence of unacceptable motion, or excessive or undue wear. The interior of the reactor vessel was visually inspected after the pre-core hot functional testing and found to be absent of any loose parts or foreign material.

In summary, the SONGS 2 CVAP inspection program was entirely consistent with the PVMP of the Maine Yankee and Fort Calhoun reactors (and with that of ANO-2) and with the SONGS 2 CVAP analysis program.

Evaluation of the results of the SONGS 2 CVAP concludes that a significant margin of safety for the structural integrity of the SONGS 2 reactor internals will be maintained during all normal steady-state and transient conditions of reactor coolant pump operation.

### 3. VIBRATION ANALYSIS PROGRAM

The Maine Yankee and Fort Calhoun reactors together constitute a Valid Prototype for the purpose of the SONGS 2 and 3 CVAP. The San Onofre Units' reactor internals configuration have substantially the same arrangement, design, size and operating conditions as the Valid Prototype. Nominal differences in arrangement, design, size and operating conditions have been shown by test or analysis to have no significant effect on the vibratory response and excitation of those reactor internals important to safety; for these reasons, the SONGS 2 and 3 reactors are designated Non-Prototype, Category 1, for the CVAP.

As mentioned in Reference 2, Section 3.9.2.4, theoretical prediction analyses were performed for Maine Yankee (Reference 8) and Fort Calhoun (Reference 9) to estimate the amplitude, time, and spatial dependency of the steady state and transient hydraulic and structural responses to be encountered during pre-critical testing. The PVMP for Maine Yankee and Fort Calhoun were completed successfully and reported in References 10 and 11, respectively. Comparisons of the measured and predicted responses for Maine Yankee and Fort Calhoun demonstrate that the theoretical prediction methods used provided accurate estimates of the steady-state response of the core support barrel system, when reasonable best estimate values for the magnitude of the inlet pressure fluctuations are used. It was concluded from these programs that flow induced vibrations of the Maine Yankee and Fort Calhoun reactor internals are well within design allowables and are acceptable for all normal steady-state, and transient flow modes of reactor coolant pump operation.



Reference 2, Table 3.9-7, presents a summary of the significant hydraulic and structural design parameters for the SONGS 2/3, Maine Yankee and Fort Calhoun reactor designs. The effects of these structural and hydraulic parameters on the flow-induced vibratory response of the reactor internals are presented in Reference 2, Section 3.9.2.6, where it is shown that the nominal differences have no significant effects on the stress levels. In general, the analysis of the San Onofre Units demonstrates that:

- A. The predicted structural response of the San Onofre reactor internals are well within design allowables and are acceptable for all normal steady-state, and transient flow modes of primary coolant pump operation.
- B. The prototype precritical vibration monitoring programs for Maine Yankee and Fort Calhoun adequately account for the specific design features of the San Onofre Units which are shared by the Valid Prototype reactor designs.

#### 4. VISUAL INSPECTION PROGRAM

The SONGS 2 CVAP inspection program was performed per the procedure of References 6 and 7 (Attachments 1 and 2), which meet the intent of regulatory positions C.3.1.3 and C.2.3 of Reference 1. The inspection program included photographic documentation of the condition of the SONGS 2 reactor internals, both prior to and after pre-core hot functional testing.

The inspection was conducted in two phases. The first phase (baseline inspection) was completed on September 7, 1980. The second phase (post-hot functional, pre-core, inspection) was completed on April 20, 1981.

Reference 1 requires that the reactor internals critical components be subjected to at least  $10^7$  cycles of vibration prior to the CVAP final inspection, based upon the component's computed minimum significant response frequency. The SONGS 2 Core Support Barrel (CSB) was calculated to have the lowest natural frequency of the critical reactor internals components. During pre-core hot functional testing, the SONGS 2 reactor internals were subjected to 11.5 days of cold flow (below 360°F) and 43.3 days of hot flow (above 360°F). Based

upon the minimum significant response frequency of the CSB, the internals' critical components were subjected to greater than  $10^7$  cycles of vibration. Neither real nor dummy fuel assemblies were included in the hot functional testing. The lack of fuel serves to provide greater flow velocities and forces on reactor internals components, and therefore yields conservative results for the CVAP.

The detailed inspection report, prepared in accordance with References 6 and 7, includes photographic documentation and descriptions of conditions observed during both phases, in addition to commentary on changes from the baseline inspection. The inspections were performed and quality assured by qualified inspectors. The inspection procedures provide the tabulation of all reactor internals components and local areas inspected, which includes:

- A. All major load-bearing elements of the reactor internals relied upon to retain the core support structure in position.
- B. The lateral, vertical, and torsional restraints provided within the vessel.
- C. Those locking and bolting components whose failure could adversely affect the structural integrity of the reactor internals.
- D. Those surfaces that are known to be or may become contact surfaces during operation.
- E. Those critical locations on the reactor internal components as identified by the vibration analysis.
- F. The interior of the reactor vessel for evidence of loose parts or foreign matter.

The analysis program (Reference 2, Section 3.9.2.6) identified the core support barrel upper flange region to have the maximum stress intensity. This region



was included in the SONGS 2 inspections to verify the results of the vibration analysis, that the maximum stress intensities are below allowable stress criteria.

A comparison of the baseline surface conditions with those of the post-hot functional inspection indicated that no abnormal flow-induced vibration had occurred and that no reduction in the structural integrity of the internals components, closure head or reactor vessel had occurred. There were indications of normal amounts of relative thermal growth between the stainless steel internals and the carbon steel vessel. At areas where contact occurred between core support barrel (CSB) snubbers, guide lugs, and alignment keys, little or no wear was indicated, but close fits were evident by discoloration and some surface burnishing. Contact between the reactor vessel, upper guide structure flange, CSB flange, and closure head appeared uniform with no wear. All structural threaded fasteners and lockbars appeared secure and showed no indications of loading. The girth welds on the CSB all appeared sound as did the core shroud welds.

Due to lack of any indication of abnormal movement and calculational results based on post-hot functional dimensions, it is concluded that the internals were provided with adequate lateral and axial support. In general, all internals components were found to be in very good condition, their contact areas all appeared normal and as expected following hot functional testing and compared favorably with the prototype inspections.

#### REFERENCES:

1. "Comprehensive Vibration Assessment Program for Reactor Vessel Internals During Preoperational and Initial Startup Testing", NRC Regulatory Guide 1.20, Revision 1, dated June 1975.
2. "Final Safety Analysis Report, San Onofre Nuclear Generating Station Units 2 and 3", Docket Nos. 50-361 and 50-362.
3. "Responses to NRC Questions, San Onofre Nuclear Generating Station Units 2 and 3", Docket Nos. 50-361 and 50-362, (Supplement to Reference 2).
4. "Safety Evaluation Report by the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Related to the Operation of San Onofre Nuclear Generating Station Units 2 and 3", Docket Nos. 50-361 and 50-362, NUREG-0712.
5. "ANO-2 Precritical Vibration Monitoring Program Visual Inspection of the Reactor Internals with Photographic Documentation", Arkansas Power and Light, CEN-91 (A), Combustion Engineering, Inc., April 1978.
6. "Precritical Vibration Monitoring Program Standard Procedure for Visual Inspection of Reactor Vessel Internals for 3410 Type Plants", Specification No. 00000-RCE-413, Revision 00, dated 6/12/80 (Attachment 1 herein).
7. "Precritical Vibration Monitoring Program Project Procedure for Visual Inspection of Reactor Vessel Internals for Southern California Edison Company San Onofre Nuclear Generating Station Units 2 and 3", Specification No. 1370-RCE-413, Revision 00, dated August 13, 1980 (Attachment 2 herein).
8. "Analysis of Flow-Induced Vibrations: Maine Yankee Precritical Vibration Monitoring Program Predictions", Combustion Engineering, Inc., CENPD-55, May 30, 1972.
9. "Analysis of Flow-Induced Vibrations: Fort Calhoun Precritical Vibration Monitoring Program", Combustion Engineering, Inc., CENPD-85, January 1973.
10. "Maine Yankee Precritical Vibration Monitoring Program, Final Report", Combustion Engineering, Inc., CENPD-93, February 1973.
11. "Omaha Precritical Vibration Monitoring Program, Final Report", Combustion Engineering, Inc., CEN-7(0), May 1974.