Department of Energy
Washington, D.C. 20545

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MAY 17 1982

Mr. Paul S. Check, Director
CRBR Program Office
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Check:

RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION - MECHANICAL ENGINEERING

Reference: Letter, P. S. Check to J. R. Longenecker, "CRBRP Request for Additional Information," dated March 11, 1982

This letter formally responds to your request for additional information contained in the referenced letter.

Enclosed are responses to Questions CS 210.11, CS 210.13, and CS 210.14 in the area of mechanical engineering. These responses will also be incorporated into the PSAR Amendment 69, scheduled for May 28.

Sincerely,

John R. Longenecker

John R. Longenecker, Manager
Licensing & Environmental
Coordination
Office of Nuclear Energy

Enclosure

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Question CS210.11

Describe the piping startup vibration testing program, especially for the sodium loops. Since primary system pumps have experienced excessive vibrations in the FFTF tests, describe the vibration testing program and acceptance criteria for the CRBRP primary pumps.

Response:

PSAR Section 3.9.1.1 provides an outline of the preoperational vibrational and dynamic effects testing program to be conducted during startup functional testing for safety related ASME Code Class 1, 2 and 3 piping and supports. The planned preoperational testing and plant acceptance test program will provide added assurance of the operability of the piping systems before plant startup.

Preoperational thermal expansion and vibration acceptance test programs will be carried out to:

(1) verify that the pipe behaves as predicted in the design stress reports,

(2) verify that pipe thermal motions are not adversely affected by interferences or binding of support hardware,

(3) provide all the measurements for future comparison during the inservice inspection program,

(5) verify that both mechanical and flow induced vibration amplitudes are of sufficiently low level so that pipe and pipe support integrity will not be compromised over the plant design lifetime.

The vibration testing program and acceptance criteria for the CRBRP primary pumps are described in PSAR Section 5.3.2.1.2.

The pump stress analysis is being performed using verified and documented computer programs as well as standard hand calculations. Where possible, the design of the pumps is such as to keep the membrane stresses in the elastic range; where this is not possible, inelastic analysis techniques are being used. The pump unit and all its parts are being designed such that no damage or malfunction will result from internally or externally generated operational vibrations, including shaft rotating frequencies, impeller vane wake passing frequencies, flow induced pressure oscillations, or vibrations and shock loads anticipated during shipping and installation. Vibration of the pump components and the pump's response to seismic excitation are being determined by analysis. Amplitude and frequency limits imposed are being limited to accumulated fatigue damage and consider proper function of the pump parts. RDT Pump Standards require that the first rotor bending natural frequency must be at least 25 percent higher than the maximum pump shaft speed. This requirements is being augmented with amplitude restrictions; the pump generated vibrations measured at the discharge and suction nozzles shall not exceed .010 in. peak amplitude within the continuous operating ranges of the pump.

Pump Operability

The PHTS pump manufacturer is required to assure operability under accident conditions and during seismic events in accordance with Reference 12, PSAR Section 1.6.

Prototype pump testing includes acceptance testing in water at the pump suppliers' facility and performance testing in sodium at the Sodium Pump Test Facility. The prototype pump was tested in water at 130% of full flow design conditions to verify hydraulic and mechanical performance. Sodium performance testing is being done at full rated flow, at expected operating head and temperature. Testing in sodium includes mapping of head and flow or both maximum and minimum plant loop impedences. Testing of the pump's performance when subjected to fluid borne temperture transients includes the plant predicted upset and emergency transients up to capability of the facility. Operability of the pump during and after the emergency and faulted plant conditions is being verified by analysis, since comprehensive accident and seismic qualification testing is not possible due to test facility limitations.

A dynamic analytical model which includes foundation mass and stiffness, piping mass and stiffness, drive motors, pump tank and all internal pump parts including sodium masses has been constructed for these analyses.

This model is used to calculate displacements and loads during normal operation and during the specified seismic events. For the prototype pump the model was modified to change the foundation from that the CRBRP to the water test pump mounting stand. Using the modified model predictions of pump dynamic performance were made and correlated with measurements taken during water test thereby verifying the adequacy of the model.

Each plant pump will be assembled and water tested by the pump supplier before final cleaning and shipment to the site. This test will confirm that each pump assembly is properly balanced and that it will operate within acceptable vibration limits. Similiarly each shaft seal cartridge assembly is operated prior to shipment to insure its proper operation.

Question CS210.13

Many components for the CRBRP plant were manufactured several years ago and have been in storage since then. Have the components been stored in such a fashion so that the stress analysis and fatigue analysis have not been compromised? If any analysis are affected, what procedures have been or are being taken to ensure that the appropriate analysis will be revised.

Response:

Yes, each stored component has an assigned storage level plus any additional requirements deemed prudent by the designer. Considerations are; material type, cleanliness requirements, corrosion resistance, intended service (temperature, pressure, flow, process fluid, etc.), storage maintenance (purge, dessicant, rotation, lubrication, etc.), and storage maintenance verification criteria.

The storage conditions are maintained such that there are no adverse effects on physical and chemical properties of the components. These conditions are monitored and periodically checked to verify compliance with requirements.

The procedures used for storage, including housekeeping of storage facilities are as described in Section 17.1 and Appendices A and F.

Question CS210.14

The SRP states that Loading Combination Methodology shall be consistent with NUREG-0484. Section 3.9.3 of the PSAR does not reference the transients of Appendix B of the PSAR, nor does it explicitly address the methods used for loading combinations.

Response:

The CRBRP PSAR was prepared in accord with the LMFBR Edition of Standard Format and Content (SFAC) of Safety Analysis Reports for Nuclear Power Plants of February 1974, which was based on the LWR Edition of SFAC at the time.

The information on "ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures" is provided in Section 3.9.1.6 (Analytical Methods for ASME Code Class 1 Components); 3.9.2 (ASME Code Class 2 and 3 Components); and 4.2.2.4.1.1 (Analysis of Core Support Structure) of the CRBRP PSAR.

The transients of Appendix B of the PSAR are referenced in the PSAR sections that describe and analysis of the systems and components. These include Sections 5.2.1.1 (for Reactor Vessel System), 5.3.1.1 (for PHTS), 5.4.1.1 (for IHTS), 5.5.1.1 (for SGS), and 4.2.2.1.1 (for Core Support Structure). In conjunction with this response, PSAR pages of Sections 3.9.1.6, 3.9.2.1 and 4.2.2.4.1.1 are updated for additional clarity in this regard.

Loading combinations required for consideration in the design and analysis of these components are described in Section 3.9.1.5. NUREG-0484 specifically deals with stress combinations due to plant accident loads and loads caused by natural phenomena, such as earthquakes. In the design of the CRBRP Code components, the more conservative ABS methodology is in general used when combining the stresses due to plant transient or accident loads and the OBE or SSE loads. The SRSS methodology is used where appropriate such as the derivation of seismic loads per se as described in Section 3.7.2.1.2 and Attachment A to Appendix 3.7-A of the PSAR. Therefore, the design of the Code components in the CRBRP is consistent with NUREG-0484.

Where appropriate, the mathematical model of a large system may be subdivided into two or more subsystems. The uncoupling of the mathematical models can be justified if the mass and stiffness of the supporting and supported subsystems are such that they do not appreciably affect the dynamic response of each other, or if the mathematical models can be suitably modified to account for the interaction effects at the interfaces. The justifications for mathematical models uncoupling will be documented with the design analysis. Decoupling criteria are given in Appendix 3.7-A.

The seismic forcing functions will be in the form of response spectra and/or motion time histories at the support point of the system or subsystem being analyzed. Other forcing functions will be provided later.

Dynamic analyses will be made using a modal analysis, plus either response spectrum analysis, or integration of the uncoupled modal equations, or by direct integration of the coupled differential equations of motion. In addition, other dynamic analysis methods exist (such as Laplace and Fourier transforms, and power spectral density analysis) and may be used, but the Westinghouse computer program and machine capability conveniently perform the above analyses on a production basis.

See Section 3.7 for a detailed description of the seismic analysis methods. Briefly, a dynamic analysis consists of mathematical modeling of a structure or component, determining the equations of motion of the system, and solving the equations of motion for the forcing functions considering the system boundary conditions.

In general, a computer program will be used for performing the dynamic analyses. Exceptions may exist where a limited amount of complexity and/or number of degrees of freedom exists, and a hand solution can be made. The mathematical model, boundary conditions, and forcing functions are input to the program and deflections, stresses, etc., are output from the program.

Loadings involving operating loads in conjunction with Seismic Loads for ASME III Code components are combined in the manner described in Appendix 3.7-A.

In the design of the ASME-III Code components, the absolute or linear summation (ABS) method is in general used when combining the stresses due to plant transients or accident loads and the loads caused by natural phenomena such as OBE or SSE. The square root of the sum of the squares (SRSS) method is used where appropriate such as in the calculation or combination of the seismic loads as described in Section 3.7.2.1.2 and Attachment A to Appendix 3.7-A of this PSAR

3.9.1.6 Analytical Methods for ASME Code Class 1 Components

The design transients for these components are described in Appendix 3 of this PSAR. The analytical methods and stress limits will be discussed in the FSAR. The evaluation of ASME Code Class 1 components will comly with the requirements of 1974-Edition ASME Boiler and Pressure Vessel Code Section III, Subsection NB, supplemented by the following:

(1) Low Temperature Components (below 800°F):

RDT Standard E15-2NB-T, October 1975.

Regulatory Guide 1.48, "Design Limits and Load Combinations for Seismic Category I Fluid System Components."

(2) Elevated Temperature Components (above 800°F):

(a) Interpretations of the ASME Boiler and Pressure Vessel Code Case 1592, "Class 1 Components in Elevated Temperature Service Section III".**

(b) RDT Standard F9-4T, "Requirements for Design of Nuclear System Components at elevated Temperatures" Jan. 1976.

(c) RDT Standard E15-2NB-T, October 1975.

(d) Regulatory Guide 1.48.

The inelastic and limit analysis methods having the stress and deformation (limits) established by the ASME Code, Section III, and Code Case 1592 (elevated temperature design) for normal, upset and emergency conditions may be used with the dynamic analysis. For these cases, the limits are sufficiently low to assure that the dynamic elastic system analysis is not invalidated.

For the case of elevated temperature components designed in accordance with Code Case 1592, conservative deformation (or strain) limits have been formulated to help ensure the applicability of the other rules of the Code Case; i.e. the strain limits in Code Case 1592 are set conservatively low such that they effectively ensure that small deformation theory is applicable for most structural analyses of elevated temperature components. The small deformation assumptions, which have been the cornerstone for analyses of structures at low temperatures, are retained by the majority of current computer structural models being used for elevated temperature analysis.

**There are no deviations at present. All supplemental criteria will be fully identified and justified in the FSAR.

The elevated temperature Code Case places the following limits on the maximum accumulated inelastic strain for parent material (Section T-1310 of Case 1592):

1. Strains averaged through the thickness, 1%

2. Strains at the surface due to an equivalent linear distribution of strain through the thickness, 2%

These limits are consistant with the NRC Standard Review Plan, Section 3.9.1, which states that small deformation methods of analysis typically tend to have acceptable effective strain limits in the range of 0.5 to 1.5 percent.

For components designed in accordance with the low temperature rules of Section III of the ASME Code, the 3 S_m limit on primary-plus-secondary stress ensure the applicability of small deformation theory: i.e., the 3 S_m limit ensures shakedown and precludes ratchetting.

For faulted conditions, the plastic and limit analysis stress and deformation limits are specified in Appendix F of the ASME Code, Section III. These limits are established in terms of an equivalent adopted elastic limit which can be used with a dynamic elastic system analysis. Particular cases of concern will be checked by use of simulated inelastic internals properties in teh elastic system analysis.

At the component level, use of plastic or inelastic stress analysis or application of inelastic stress and deformation limits may be used with the elastically calculated dynamic external loads provided that shakedown occurs (as opposed to continuing deformation) or deformations do not exceed specified limits. Otherwise, readjustment to the elastic system analysis will be required.

Complete system inelastic methods of flexibility analysis combined with inelastic stress techniques may be used if there is justification.

Active components will be qualified for operability on a component by component basis in accordance with Reference 12, PSAR Section 1.6.

3.9.2 ASME Code Class 2 and 3 Components

3.9.2.1 Component Operating Conditions and Design Loading Combinations

Design pressure, temperature, and other loading conditions that provide the design basis for fluid system Code Class 2 and 3 components are described in Appendix B of this PSAR and referenced in the sections that describe the system functional requirements.

References to Section 3.9

1) BNWL-575, "Applications of Geometric Models for the FFTF Hydraulic Core Mockup," D.S. Trent, November 1967.

2) Franklin Institute Research Laboratories Report, F-B2437, "Study of the Feasibility of Modeling Vibration," George P. Wachtell, November 22, 1965.

3) Report, ANL-CT-75-37, "An Evaluation of Flow Induced Vibration Prediction Techniques for In-Reactor Components," dated May 1975.

4) Report, ANL-CT-76-31, "Comparison of Analytical Predictions With HCM Results for FFTF Reactor Flow Induced Vibrations and Summary of Prediction Methods," dated April 1976.

Since the time-dependent failure modes were shown to be insignificant for the CSS by satisfying the conditions of Test No. 4, Code Case 1592 and RDT F9-4, the alternate structural limits of the code case were employed in the CSS evaluation.

Geometry

The core support structure (CSS) concept considered in this analysis is shown in Figure 4.2-50. The CSS consists of a perforated support plate, core barrel, and lower inlet module liners. Portions of the support core and reactor vessel, are included in the analytical model, and all of these components are referred to the "core support structure" in this analysis.

Thermal Analysis

Two thermal models were developed to calculate transient temperatures in the CSS. A 30 degree sector model (TAP-A computer code) was used to calculate temperatures in the perforated support plate and an axisymmetric model (ANSYS finite element code) was used to determine temperatures in other CSS components. The element geometry of the thermal models is identical with the corresponding stress models shown in Figures 4.2-52 and 4.2-54.

The sector and axisymmetric models were used to analyze the CSS-6N ($N-4_a$, as described in Appendix B of this PSAR), CSS-2U(U-2e), CSS-4U(U-18) and CSS1E(F-4a) design transients for the CSS. It was shown that these four transients conservatively umbrella all of the plant duty cycle events.

Reactor inlet plenum mixing analyses were performed to determine the transient sodium boundary temperatures for the CCS. Convective heat transfer coefficients were calculated for the CSS surfaces exposed to flowing sodium. Interfact conditions with the lower inlet modules (LIMs) were determined with detailed local modals.