WASHINGTON NUCLEAR PLANT 2

DESIGN REVERIFICATION PROGRAM

RHR ADDENDUM

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WNP-2 Design Reverification Program
Final Assessment Report

Volume III - Final Assessment Report - RHR Addendum

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

This report presents the results of the two review activities that were incomplete when the WNP-2 Design Reverification Program Final Assessment Report, reference 1, was transmitted to the NRC. The two activities, defined in sections 3.3.5 and 3.5.6.4 of reference 2, are the RHR piping and support reviews and effect of amplification of floor responses respectively.

The results of each of these activities were discussed with NRC staff members during a meeting held in Bethesda on November 29, 1983. This report does not change any of the results or conclusions presented at that meeting.

1.2 SUMMARY OF RESULTS

The 0.5 man years required to complete the RHR Piping and Support reviews included the examination of approximately 100 documents. Six potential finding reports (PFRs) were issued as a result of this review. All PFRs were considered valid and classified as observations by the Findings Review Committee.

Three of the PFRs concerned design and three resulted from construction activities. All PFRs were transmitted to the responsible Project Organization and the deficiencies have been corrected. Table 1.1 revises a similar table in reference 2 and summarizes the distribution of PFRs for the overall design reverification program. Including the 6 additional PFRs in the program trend analysis yields no changes from the conclusions discussed in reference 2.

TABLE 1-1

DISTRIBUTION OF FINDINGS BY SYSTEM

System	Number of Documents Reviewed	Findings	Observations	Invalid PFRs
Requirement Reverification	266	0	5	5
HPCS Design Review	1,056	8	46	18
RHR Design Review	760	5	28	4
RFW Design Review	834	3	13	7
System Interaction Reviews	675	10	13	6
TOTALS	3,591	26	105	40

The 26 findings are listed and categorized by type of error or deficiency in Table 1-2 of reference 2.

Evaluation of the effect of seismic floor amplification on attached piping and equipment required approximately 600 man hours of engineering and review. An evaluation of the concrete and structural steel floors in the reactor building was performed to determine a bounding case for further evaluation. The first mode fundamental frequencies for concrete floors were found above 18 Hz which is in the ZPA range of the response spectra. Therefore, concrete floors were eliminated from further review. The bounding structural steel floor identified at 441 feet elevation was calculated to have a first mode frequency of 9 Hz. The effect of amplification on piping and equipment was evaluated utilizing three increasingly complex models. It was found that although the responses at various floor locations would experience both increasing and decreasing maximum loads, the overall maximum stresses in the pipe and reactions in the pipe hangers are predominantly lower. In those isolated areas where increased reactions were calculated, it was shown that the original design allowables would not be exceeded.

1.3 CONCLUSIONS

The following conclusions were drawn with respect to the reviews described in this report.

1. The generic problems identified during the HPCS piping and support reviews were not apparent in the RHR piping design. The corrective actions initiated by Burns and Roe following the HPCS reviews were effective in eliminating the generic problems.

2. The RHR piping and support design and construction are acceptable and comply with necessary design criteria.

3. Based on floor amplification reviews it is shown that the conservatism utilized in the original seismic design, i.e., lumped mass model response spectra, envelopes the potential effect of seismically induced structural steel or concrete floor amplification on the design of floor mounted piping and equipment.

In summary, as presented in reference 2, it is concluded that the overall WNP-2 design process was conservative and produced a safe plant conforming to FSAR and regulatory requirements.

2.0. RESIDUAL HEAT REMOVAL SYSTEM (RHR) PIPING AND SUPPORTS DESIGN REVERIFICATION RESULTS

2.1 SUMMARY

A representative sample of the RHR System Loop B piping and supports was selected for review as part of a program described in reference 2 to verify the adequacy of WNP-2 design. The sample, discussed in reference 2, section 3.3.5, includes one large bore pipe stress anchor group and four large bore pipe hangers which were designed by Burns and Roe (B&R), and one small bore pipe stress anchor group and an associated small bore support which were designed by Gilbert Commonwealth (G/C). The purpose of this section is to provide the results of the review.

The reverification of the RHR piping and supports, as with the HPCS piping and supports, was based on a comprehensive design review approach utilizing detailed checklists and alternate calculations. Special attention was given to those areas of concern identified during the HPCS piping and support reviews performed in June and July 1983, to assure the generic problems identified had been corrected in the RHR calculations. The reverification included review of two piping stress calculations and five pipe support calculations. In addition to the detailed design reviews, alternate calculations were performed for three of the five pipe supports.

The piping stress calculations reviewed address 650 feet of RHR piping and associated pipe supports.

Table 2.1 identifies the areas reviewed and the PFRs issued in each area and their classification. Six PFRs were issued, all were classified as observations. All areas of design reviewed are considered acceptable.

TABLE 2.1

SUMMARY OF REVIEW AREAS AND PFRs ISSUED

Review Area	Number of Review Questions	Number of Documents Reviewed	PFR'S ISSUED		Recommended Classification		
			Number	Designation	Not Valid	Observation	Finding
2.2.1 Piping Design Review							
A. RHR System (M200-107,112,115,119,127,136)		32					
Isometric Check	4		0				
Modeling Check	9		0				
Deadweight Analysis	2		0				
Thermal Analysis	4		0				
Seismic Analysis	19		0				
Anchor Movements	6		0				
Load Combinations	16		1	RHR-36		X	
Pipe Stress Check	7		0				
Support Loads	8		0				
B. RHR-2289-1&2		26					
Design Data Transmittal Transmittal	7		0				
Isometric Check	4		0				
Modeling Check	7		0				
Deadweight	1		0				
Thermal	4		0				
Seismic	3		0				
Anchor Movements	4		0				
Load Combinations	7		0				
Pipe Stress Check	7		0				
Support Loads	24		0				

TABLE 2.1 (continued)

Review Area	Number of Review Questions	Number of Documents Reviewed	PFR'S ISSUED		Recommended Classification		
			Number	Designation	Not Valid	Observation	Finding
2.2.2 Pipe Supports							
A. RHR-436		9					
Code/Design Guide Check	3		0				
Procedural Control	4		0				
Design Check							
Loads	9		1	RHR-32		X	
Welding	1		0				
Materials/Geometry	5		0				
Base Plates	4		0				
Allowable Stresses	5		0				
Movements	1		0				
Member Stresses	5		0				
Alternate Calculation	4		0				
B. RHR-902N		4					
Code/Design Guide Check	4		0				
Procedural Control	3		0				
Design Check							
Loads	9		0				
Welding	1		0				
Materials/Geometry	5		1	RHR-40		X	
Base Plates	4		0				
Allowable Stesses	5		0				
Movements	1		0				
Member Stresses	5		0				

TABLE 2.1 (continued)

	Review Area	Number of Review Questions	Number of Documents Reviewed	PFR'S ISSUED Number	PFR'S ISSUED Designation	Recommended Classification Not Valid	Recommended Classification Observation	Recommended Classification Finding
C.	RHR-915N		5					
	Code/Design Guide Check	3		0				
	Procedural Control	3		0				
	Design Check							
	Loads	4		0				
	Welding	1		0				
	Materials/Geometry	4		0				
	Base Plates	3		0				
	Allowable Stesses	4		0				
	Movements	2		0				
	Member Stresses	3		0				
D.	RHR-184		8					
	Code/Design Guide Check	3		0				
	Procedural Control	3		0				
	Design Check							
	Loads	5		0				
	Welding	1		0				
	Materials/Geometry	5		0				
	Base Plates	1		0				
	Allowable Stesses	5		0				
	Movements	1		0				
	Member Stresses	5		0				

TABLE 2.1 (continued)

Review Area	Number of Review Questions	Number of Documents Reviewed	PFR'S ISSUED Number	PFR'S ISSUED Designation	Recommended Classification Not Valid	Recommended Classification Observation	Recommended Classification Finding
E. RHR-2289-11 A&C		9					
Code/Design Guide Check	3		0				
Procedural Control	4		0				
Design Check							
Loads	4		0				
Welding	2		0				
Materials/Geometry	3		0				
Base Plates	1		0				
Allowable Stresses	5		0				
Movements	1		0				
Member Stresses	4		0				
Alternate Calculation	17		0				
2.3 As Built Inspection							
2.3.1 Piping Iso							
M200-107,112,115, 119,127,136	102		0				
RHR-2289-1	17		1	RHR-37		X	
RHR-2289-2	17		0				
2.3.2 Pipe Supports							
RHR-436	9		0				
RHR-902N	9		0				
RHR-184	9		1	RHR-39		X	
RHR-915N	9		1	RHR-38		X	
RHR-2289-11	9		0				
Totals	502	93	6			6	

2.2 PIPING AND SUPPORT DESIGN REVIEW

The design of the RHR System piping and supports within the reverification scope is governed by Section III of the ASME Boiler and Pressure Vessel Code and ANSI B31.1, Power Piping Code. Two piping calculations, one large bore which included ASME Section III Class 2 and 3 piping and one small bore which included ASME Section III Class 2 and ANSI B31.1 piping, were chosen for review. The Class 2 and 3 large bore piping was designed by B&R and the small bore piping was designed by Gilbert Commonwealth. The sample includes the major pipe sizes and code classifications, a range of pipe support types and required interfaces between the design organizations, B&R, Gilbert Commonwealth, and construction contractors. Selection was made to assure coverage of the methodology, inter-organizational interfaces and compliance by each organization with the design requirements. As with the HPCS piping and supports, the RHR reverification was based on a comprehensive design review approach utilizing detailed checklists and preparation of alternate calculations. The checklists were developed based on the Supply System's experience with ASME peer reviews. The following critical areas of design control, analysis and field inspection were addressed:

Piping Design Review

- o Design data transmittal
- o Isometric check
- o Modeling check
- o Deadweight analysis
- o Thermal analysis
- o Seismic analysis
- o Anchor movements
- o Load combinations
- o Pipe stress check
- o Support loads
- o Field inspection.

Pipe Support Design Review

- o Code/design guide check
- o Procedure/control check
- o Design check
  - Loads
  - Welding
  - Materials/Geometry
  - Base Plates/Anchor Bolts
  - Allowable Stresses
  - Member Stresses
- o Field Inspection.

The review included 650 feet of piping and associated supports and anchors. In addition to the detailed design reviews, alternate calculations were performed for three of the five pipe supports reviewed.

2.2.1 PIPING DESIGN REVIEW

A. RHR Large Bore Piping - (M200 - Sh. 107, 112, 115, 119, 127, 136)
ASME Class 2 and 3 B&R Calculation 8.14.127B
Burns and Roe Design Scope

Reverification was accomplished by means of a design review of B&R calculation 8.14.127B, Rev. 9, "Stress Analysis of Isometrics: M200-Sh. 107, 112, 115, 119, 127, 136", which is a final as-built calculation. The documentation package consisted of four volumes of hand calculations and computer runs which provide documentation of the stress analysis of Anchor Group 36 piping. This piping network consists of a large volume of Loop "B" RHR piping, including portions of the RHR heat exchanger supply line, the RHR drain line, the reactor head spray line, and the RHR heat exchanger bypass line and connects to three nozzles of the RHR "B" heat exchanger, the fuel pool cooling (FPC) system, the reactor core isolation cooling (RCIC) system, and the standby service water (SW) system. Thirty-two documents were reviewed during the course of this reverification activity.

The B&R stress analysis was performed using the ADLPIPE computer program which uses linear elastic structural and spring elements. The model consisted of twelve valves, 108 supports, three equipment connections, approximately twenty small bore pipe connections and a variety of 6, 8, 10, 14, 18 and 20 inch diameter piping.

All aspects of the mathematical model of the piping system used in the computer runs were verified to be in agreement with the isometric drawings. Specifically, the following items were checked:

- Piping geometry
- Support types (rigid, snubber, springs)
- Support locations and orientation
- Valve weights, orientations, inertial properties, and locations
- Locations of branch pipe connections
- Pipe and fitting sizes, materials, weights including water and insulation
- Stress intensification factors for fittings
- Support stiffness.

In particular, the locations of valves, supports, flanges and branch pipe connections were checked and found to be correct. A few minor dimensional inconsistencies were found, but they were insignificant in terms of the stress analysis.

Each individual load evaluation was reviewed to assure that the loadings were correctly defined and that the resulting pipe loads and deflections were reasonable and within acceptable limits. The load cases reviewed were pressure, deadweight, several thermal expansion cases, thermal expansion range, and separate OBE and SSE seismic response spectra cases. There were no required hydrodynamic load cases. Thirteen ADLPIPE load evaluation and load combination cases were reviewed in detail. These cases range from static runs to response spectra analyses.

To show compliance with ASME Code requirements, the individual load cases were combined together into normal, upset, emergency and faulted condition combinations, as defined by Table 6 of the B&R Engineering Criteria Document (ECD), Section I. The loads producing primary stresses are pressure, deadweight and seismic OBE and SSE. Stresses caused by thermal expansion, as well as anchor motions due to thermal and seismic events, are considered to be secondary stresses and are included in secondary stress equations 10 and 11 of the Code.

Stresses were also checked for compliance with B&R functional capability requirements, as defined in Tech. Memo 1240, Rev. 2. Pipe break and welded attachment stress calculations were performed at the WNP-2 site and were included in the pipe support calculations.

Summary tables containing loads, deflections or accelerations, as applicable for each support, valve or branch location, were also reviewed for accuracy and completeness. The summary tables are compiled for transmittal to the appropriate equipment design organization.

One PFR was issued to note findings in the calculation of valve seismic accelerations.

PFR-RHR-36, classified as an observation, reported that seismic accelerations on valves RHR-V-14B and RHR-V-104 calculated by B&R did not utilize the as-built valve stem orientation. These two valves are oriented such that their operators lie in the horizontal plane, as opposed to the vertical plane, like the other valves in this system. The accelerations were calculated and reported to the Supply System Equipment Qualification Group (EQ) utilizing the Global 'X', 'Y', 'Z' coordinate system. Further investigation revealed that when the accelerations are reported to the EQ group responsible for seismic qualification, the accelerations are transformed from the Global system into correct local orientation for use in seismic qualification. This conversion is performed in accordance with Technical Directorate Procedure TDP 3.32 and the data sheet for transformation of the coordinate system. This approach is

an acceptable process for establishing seismic qualification. It could be argued, based on these considerations, that the PFR should be classified as invalid; however, since the calculation does exist with an assumption that is not the same as the as-built configuration, the PFR was reported to the project as an observation.

In conclusion, it can be stated that all aspects of the ASME piping design analysis process have been adequately addressed in the stress calculation. The analyses meet the requirements of the ASME Code and the B&R Engineering Criteria Document.

B. <u>RHR Small Bore Piping (RHR-2289-1 and 2)</u>
ASME Class 2 and B.31.1
Gilbert Commonwealth Design Scope

This 3/4" diameter pipe serves as a drain line for the RHR "B" heat exchanger at nozzle N6 and the 18" diameter piping shown on M200-112. It consists of two stress isometrics, RHR-2289-1 (ASME CL2) and RHR-2289-2 (ANSI B31.1.) The drain piping was mathematically modeled by Gilbert Commonwealth (G/C) and analyzed on Version 4.3 of the TPIPE analysis program. Twenty-six documents were reviewed during the course of this reverification activity.

The mathematical model correctly reflects the as-built geometry of the pipe line and all material and section properties were verified to be correct. Stress intensification factors were correctly applied at all piping node points.

The pipe line was analyzed for deadweight, thermal, static seismic, and anchor movements due to seismic and thermal end conditions. All analyses were correctly executed and end movement design data at the large bore pipe attachment point were correctly obtained from the large bore stress calculations. Subsequent to the small bore piping design review, the large bore piping was reanalyzed resulting in larger thermal movements at the piping interface. Review has shown that the as-built piping design remains acceptable.

The various loading conditions (e.g., deadweight, thermal, seismic, etc.) are combined into the usual load combinations with one exception. Gilbert Commonwealth combines stress due to seismic anchor displacement (SAD) with the primary stress Equation 9 or with the secondary stresses in Equations 10 and 11. The SAD stress is compared to the thermal plus thermal anchor displacement stress. To obtain the secondary stresses for equation 10 and 11, the largest stress from the comparison is added to the SAD stress. This is a very conservative method of combining stresses. Although Equation 10 stresses are conservatively high for this line, all required equation allowables are satisfied.

The loads at the heat exchanger nozzle were reviewed to assure they were within the allowable values. No deficiencies were noted.

In conclusion, no PFRs were issued in the review of the RHR small bore piping analysis. All aspects of the ASME and ANSI piping design analysis process have been adequately addressed.

2.2.2 PIPE SUPPORTS DESIGN REVIEW

A. RHR-436 Rigid Vertical Support for M200-112

Reverification of the design for RHR-436 was accomplished by in-depth review of the B&R calculation. In addition, an alternate calculation was completed to cross check the B&R trunnion analysis. Eight documents were reviewed in the process of reverifying the RHR-436 design.

The hanger calculation was checked for the following items:

- Correct code classification
- Correct procedural control of the calculation
- Application of correct member loads
- Member and weld stresses
- Base plate flexibility analysis
- Use of correct allowable stresses.

The review of this hanger originally started in April of 1983. At that time, a discrepancy was noted in the summation of worst case loads at one of the member connections.

PFR-RHR-32, classified as an observation, was issued to document the error in the calculation of the maximum vertical load on the member connection. Analysis showed that the support design was conservative and adequate for the increased load. The hanger has been redesigned based on the as-built stress calculation. The revised hanger calculation corrected the previous error and no errors were noted in the revised calculations.

To check the stress induced in the piping due to the trunnion load an alternate calculation was performed. The original BRI trunnion calculation used an approach based on Welding Research Council Bulletin 107 to determine stress. The 107 bulletin approach was checked using the methodology currently under development by ASME. Calculated stresses for the two methods differed by only 4.5%; therefore, no additional PFRs were written.

In conclusion, Hanger RHR-436 is adequately designed to perform its intended function.

B. RHR-902N Snubber for M200-150

An in-depth review was chosen for reverification of RHR-902N. The B&R hanger calculation was compared to design criteria/conditions as specified in the governing design documents. Four documents were used to complete the review. Loads used for the hanger design were verified to be in agreement with loads from the piping stress calculation.

The component standard parts (snubber, rear bracket, and clamp) were checked using the manufacturer's load condition data sheets. All component standard parts were adequately sized for the design loads and movements.

The remaining hanger parts (base plates, anchor bolts, and structural members) were checked for acceptable design margin. Stresses in members and welds were compared to allowables and the hanger base plate was checked against the design guide standard.

PFR-RHR-40, classified as an observation, was issued as a result of checking the section properties used for determination of shear and bending stresses in an M4X13 beam. The analyst had mistakenly used section moduli from a W4X13 beam. Correction of the error will cause member stresses to increase slightly, less than 2000 psi, but will remain within allowable limits. B&R has corrected the calculation error. No further action is required.

Reverification established that hanger RHR-902N was adequately designed to perform its intended function.

C. RHR-915N Snubber for M200-150

An in depth review was chosen for reverification of hanger RHR-915N. The hanger is a simple design utilizing a standard clamp, snubber and adapter to transfer the pipe load to a base plate which is bolted to the wall.

The hanger loads were checked against the piping stress analysis load summary sheet to assure correct data transmittal between the BRI pipe stress group and the pipe support group. All loads used in the hanger design were determined to be correct.

The component standard parts used in the hanger were checked against the manufacturer's load condition data sheets. In addition, the weld connecting the base plate to the snubber bracket was verified to have an acceptable safety margin and the base plate met the design guide criteria for stiffness.

To complete the reverification, five documents were reviewed and compared with the B&R hanger calculation. No design deficiencies were noted in the hanger design.

D. <u>RHR-184 Rigid Support for M200-150</u>

Reverification of the Burns and Roe design for RHR-184 was accomplished by means of an alternate calculation. The calculation for member forces, moments and stresses was completed on a verified Westinghouse structural analysis computer program called PIPSAN.

The design loads used in the hanger design were compared to the latest hanger loads in the pipe stress calculation. It was noted that the loads from the pipe stress calculation were much lower than those used in the hanger design. No PFR was issued to note this difference because of conservatism. The higher loads resulted from an earlier piping analysis and were simply retained by the pipe support design group since they bounded the final loads.

The hanger structure was modeled based on the as-built drawing, and analyzed for normal, upset, and faulted conditions. Initial results indicated that the hanger design was not adequate. Field inspection revealed that the as-built drawing did not clearly specify the sizes of two of the supporting members. PFR-RHR-39 documents the as-built drawing problem and will be discussed further in the as-built portion of this report. When the correct material sizes were put into the model all calculated stresses were below the allowable limits.

Independent hand calculations were performed to verify weld strengths and base plate stiffnesses.

The alternate calculation demonstrated that RHR-184 has adequate strength for its design loads and that the design safety margin is greater than indicated due to a reduction in pipe calculation design loads.

To complete the above reverification eight documents were reviewed.

No PFRs were written on the review of RHR-184 and it was concluded that the hanger was adequately designed.

E. RHR-2289-11 Small Bore Pipe Support for RHR-2289-1

Reverification of the Gilbert Commonwealth small bore pipe support RHR-2289-11 was accomplished by means of an alternate calculation and a review of portions of the hanger calculation. Support loads were checked against those induced by the piping. A model of the hanger was then input into a structural analysis program (GTSTRUDL) for calculation of member forces and moments. One load case which conservatively added the loads on the support using absolute sums was analyzed.

To complete the reverification, nine documents were reviewed to assure inclusion of the appropriate design criteria.

Stresses and loads for all members, welds, U-bolts, and base plates were verified to be within the allowables. Therefore the design was acceptable and no PFRs were issued.

2.3 PIPING AND SUPPORT ON-SITE INSPECTIONS

Each piping run or support chosen for design reverification was inspected to determine if the 'as-built' configuration matched the assumptions or details of the design calculation and drawings.

2.3.1 PIPING INSPECTIONS

As-built inspection of piping systems included verification of the following pertinent information:

- Pipe diameters, lengths, and locations of branch lines or specialty items
- Valve locations, types, orientations

- Support locations, direction of restraint, clearances
- Verification of boundary conditions, anchors, nozzles, penetrations
- Possible interferences caused by surrounding walls, equipment, piping.

Inspections were conducted for the following piping runs:

1) M200-107, 112, 115, 119, 127, 136

   Only piping defined as Anchor Group 36, calculation 8.14.127B, was checked, including some piping on M200-136 that was included in the analysis model for its effect on the AG 36 piping. All as-built checks were satisfactory, and no PFRs were issued. The as-built drawings are adequately reflected in the design calculation package.

2) RHR-2289-1 and 2

   PFR-RHR-37, classified as an observation, was issued to document a potential interference between the piping and a brace on pipe support RHR-2289-11. This PFR was noted during the piping as-built walkdown. Analysis shows that for this small bore line, the thermal movement will eliminate any interferences. Project Engineering was notified of the potential generic consideration. The generic aspects will be addressed when Power Ascension Test 8.2.17, Piping Systems Expansion and Vibration Tests, is performed. These tests will meet the requirements of ASME Section XI, Winter 1978 Addendum and NRC letter GI2-81-62. High energy small bore piping with a safety significance is included in the testing. No further action is required.

   All other as-built checks for RHR-2289-1 and 2 were satisfactory.

2.3.2 SUPPORT INSPECTIONS

As-built inspection of pipe and component supports included the following checks as applicable to the individual supports:

- o Verification of members, welds, anchor bolts, base plates for sizes, types and quantities
- o Check of support clearances and direction of action
- o Critical dimensions check
- o Verification of correct standard component sizes and types for springs, snubbers, clamps, struts, etc.

As-builts of the large bore component supports RHR-436, RHR-902N and small bore support RHR-2289-11AC were verified to be satisfactory.

Except for the identified PFRs, the as-builts of the following supports were found to be satisfactory.

RHR-184: PFR-RHR-39, classified as an observation, was issued to document an incorrect deletion of material from the bill of materials shown on the hanger as-built drawing. Project Engineering was requested to correct the as-built error. The error has been corrected and no further action is required.

RHR-915N: PFR-RHR-38, classified as an observation, was issued to document an error in an overall dimension shown on the as-built drawing for the hanger. Project Engineering was requested to correct the error. The error has been corrected and no further action is required.

3.0 STRUCTURAL MEMBERS - AMPLIFICATION OF FLOOR RESPONSE DESIGN REVERIFICATION RESULTS

3.1 SUMMARY

Section 3.5.6.4 of the WNP-2 Design Reverification Program Final Assessment Report (reference 2) indicated that the Supply System would complete a review of the B&R calculations which evaluated the effect of seismic floor amplification on floor mounted piping and equipment. This section describes the analyses that were performed and provides a summary of the results.

To satisfactorily resolve this issue, B&R was requested to extend their analysis to include concrete and other structural steel floors in order to identify the most flexible floor located in the reactor building. Therefore, this discussion addresses the steel floor at reactor building elevation 444 feet as described in the Final Assessment Report, an entire concrete floor at elevation 471 feet, and other steel floors including a floor at elevation 512 feet, 9-1/2 inches in primary containment.

The results of the study and our review are as follows:

1. Concrete floors in the plant have first mode fundamental frequencies above 18 Hz. Therefore, attached piping and equipment will receive accelerations in the ZPA range of the response spectra.

2. The steel floor at reactor building elevation 444 feet represents the bounding case for consideration as originally projected.

3. A comparison of the coupled floor/pipe analysis to a decoupled piping analysis, at 444 feet, demonstrated that although the piping responses at various locations experience variations both upwards and downwards, the key parameters, i.e., maximum stress in the pipe and pipe support loads, are lower than the original design values.

Based on the above results, we conclude that the original WNP-2 design provides sufficient conservatism to envelope the effect of seismic amplification caused by the flexible floors.

3.2 AMPLIFICATION OF FLOOR RESPONSES

WNP-2 Final Assessment Report, Volume I, section 3.5.6.4, discussed the results of an evaluation of the potential effect of seismic floor amplification on the design of the floors and attached piping and equipment in the reactor building. The review concluded that amplification due to floor flexibility was not a concern in the design adequacy of the floors themselves. A B&R analysis of the floor amplification effect on floor mounted piping and equipment arrived at the same conclusion but had not undergone a confirmatory review by the Supply System.

During the confirmatory review, B&R was requested to extend their analysis to include concrete and other structural steel floors located in the reactor building to arrive at a bounding example for detailed analysis. To do this, the fundamental natural frequency of all major steel floors and of an entire concrete floor (elevation 471 feet) in the reactor building were calculated. The lowest vertical natural frequency for any region of the concrete floor is 18.2Hz. The vertical natural frequency for the steel floor at elevation 444 feet is approximately 9Hz. The lowest vertical natural frequency for the steel floors other than elevation 444 feet, is 10Hz at elevation 512 feet, 9-1/2 inches in the drywell. Thus the steel floor at elevation 444 feet is a representative and critical floor.

To determine the floor amplification effect for piping attached to the steel floor at elevation 444 feet, three models of increasing complexity were developed. These models are as follows:

a. Pipe model with rigid supports
b. Coupled pipe/flexible floor model
c. Coupled pipe/flexible floor/reactor building model.

Model a, which reproduces the conditions of the original design, was analyzed by the response spectrum method. In this analysis all pipe supports were assumed fully rigid. The original FSAR seismic floor response spectra, based on a lumped mass model, enveloped for elevations 443 feet through 500 feet were used as input motion (one vertical and two orthogonal horizontal spectra). A 0.5% damping factor was used for the piping analysis.

Model b, accounts for the dynamic coupling between the floor and the attached piping. The RHR pipe was modeled as in (a), except for those supports connecting the pipe to the floor which are modeled to represent their actual mass and flexibility. Other attachments to the floor, such as pipes and tray supports, are included as added floor masses. The floor framing was modeled as a grid, with due regard to essential characteristics such as beam flexibility and masses, bracing and supports. The floor grating was included as added mass only (zero stiffness was conservatively postulated). This coupled model was subjected to a response spectrum analysis, using three components of the earthquake motion. The applicable floor response spectra were obtained from a finite element (FLUSH) soil-structure interaction analysis of the reactor building. This spectra reflects the current practice of earthquake design (Standard Review Plan Sections 3.7.1 and 3.7.2 and Regulatory Guide 1.60 and 1.61). A 1% damping factor was used for both the 18" diameter RHR pipe and the bolted steel floor.

Model c, was used to quantify the conservatism inherent in the model (b) analysis. It was obtained from the coupled pipe/floor model, extended so as to include the supporting concrete structure. Seismic responses are obtained from a time history analysis, for the vertical component of earthquake motion only. This choice was motivated by the results for model (b), which show that

the vertical seismic component is largely dominant as far as coupling effects are concerned. The input motion for model (c) was derived from a soil-structure interaction analysis of the basic FLUSH model of the reactor building and applied to the refined model (c) at foundation level.

A comparison between results of the models (b) and (c) analyses revealed the conservatism inherent in model (b) analysis. Stresses at critical locations throughout the pipe are uniformly lower for model (c) by a factor which varies between 0.50 and 0.75. Based on this finding, the results obtained with model (b) were conservatively scaled by a factor of 0.75 to obtain estimated design values for the coupled pipe/floor system, subjected to three directional seismic input. A comparison of this set of results with the original design values (a) shows that although pipe stresses have increased or decreased depending on locations, the overall maximum stress in the pipe and reactions in the pipe hangers are predominantly lower. To quantify the variability of the pipe stresses due to pipe/floor coupling effects, a variation factor was defined as the ratio of the stress variations to the the allowable stress. It was found that the variation factor of the maximum pipe stress is -2.3% (decrease), whereas at no location is the variation factor of relative (local) maxima higher than 6.8%. Similarly, a variation factor of pipe support reactions was determined as the ratio of the variation of a given reaction to its design value (which includes effects of loads other than seismic). This factor ranges from a 2% increase to a 35% decrease.

During review of the B&R calculations, several conservatisms were noted which could be used to lower the coupled floor/pipe response even further. These include:

1. Use of higher damping factors as allowed by Regulatory Guide 1.61 (2% for piping over 12 in. and 4% for the bolted steel floor)

2. Inclusion of stiffness of the other attached piping, trays and steel grating

3. Completion of the actual time history analysis for model b rather than using a scaling factor to estimate response would show reduced stresses.

The results for the RHR piping studied provide a basis for assessment of other piping and equipment attached to the structural steel floors. Assessment of floor supported equipment in addition to the piping, included an HVAC fan coil unit and selected electrical cable trays. For this equipment it was shown that there is sufficient conservatism in the original design to account for the increased response caused by conservatively calculated floor amplifications.

No potential findings reports were issued as a result of this area of review.

4.0 REFERENCES

(1) Letter, G. C. Sorensen to H. R. Denton, "WNP-2 Design Reverification Program", dated September 27, 1983.

(2) Washington Nuclear Plant 2 Design Reverification Program Final Assessment Report, Volume I, September 1983.

(3) Washington Nuclear Plant 2 Design Reverification Program Appendices to Final Assessment Report, Volume II, September 1983.

5.0 APPENDICES TO RHR ADDENDUM

APPENDIX 1

WNP-2 REQUIREMENTS AND DESIGN REVERIFICATION

FINAL ASSESSMENT REPORT

RHR ADDENDUM

List of Potential Finding Reports

APPENDIX 1

LIST OF POTENTIAL FINDING REPORTS

PFR No.	Classification** F	O	NV	Review Area*	Description
RHR-32		X		2.1.2.A	Incorrect load used in calculation of support reactions.
RHR-36		X		2.1.2.A	Valve accelerations were calculated based on incorrect orientation.
RHR-37		X		2.3.1	Horizontal support brace may cause restraint due to pipe/insulation interference.
RHR-38		X		2.3.2	Overall dimension for RHR-915N is incorrect on as-built drawing.
RHR-39		X		2.3.2	Correct material size shown as deleted on Bill of Material on As-built for RHR-184.
RHR-40		X		2.2.2.B	Incorrect section properties were used in a beam analysis for RHR-902N.

** F - Finding
O - Observation
NV - Not Valid

*Corresponds to Report Section Number

APPENDIX 2

WNP-2 REQUIREMENTS AND DESIGN REVERIFICATION

FUEL ASSESSMENT REPORT

RHR ADDENDUM

List of Documents Reviewed

A. Specifications/Codes/Guides

B&R Engineering Criteria Document, Sections E and I, Appendices A and 2, Rev. 5

ASME B&PV Code, Section III, 1971 Edition, including Addenda through Winter, 1973. Subsections NB, NC, ND, NF

B&R Piping Design Guide, Rev. 3

WNP-2 FSAR

Gilbert Commonwealth Engineering Handbook

AISC Steel Construction Manual

ASME Code Case N318

Welding Research Council Bulletin 107 and 256

ANSI B31.1 Power Piping Code, 1973 Ed W73 Addenda

Contract 208 Specification, "Small diameter piping and pipe support criteria

B. Calculations

B&R Calculation 8.14.127B, Rev. 9, for Stress Isometric M-200 - sheets 107, 112, 115, 119, 127, 136

TPIPE Computer Analysis, BC2RB2A, run 1, 7/29/83

G/C Calculation No. RHR-2289-1, Rev. 1

G/C Calculation No. RHR-2289-2, Rev. 1

G/C Calculation No. RHR-2289-11 A&11C

BRI Calculation 8.15.2341 for RHR-436

BRI Calculation 8.15.213 for RHR-184

BRI Calculation 8.15.251 for RHR-902N

BRI Calculation 8.15.360 for RHR-915N

BRI Calculation 6.19.138, Flexibility of Steel and Concrete Floors

Supply System Calculation CE-02-83-06, Estimation of Natural Frequency at EL 444 ft

C. Technical Memoranda

T.M. 1226, Rev. 3, "Piping System Evaluation for Hydrodynamic Loads"

T.M. 1240, Rev. 2, "Functional Capability Criteria for WNP-2 Piping"

Tech. Memo #1257, Rev. 2 (Seismic and Hydrodynamic Response Spectra)

Project Engineering Directive 208-H-0689, 7/15/83

Project Engineering Directive 208-H-0745, 7/28/83

BRI Project Engineering Directive, PED-C0208-0689

BRI Technical Memorandum #1226, Rev. 2

BRI Technical Memorandum #1257, Rev. 0

BRI Technical Memorandum #1240, Rev. 1

D. Manuals

"Weldolet Stress Intensification Factors", Bonney Forge, 1976

"NAVCO Piping Datalog", Edition No. 10, 1974, National Valve and Manufacturing Company, Pittsburgh, PA

ADLPIPE User Manual, Rev. J, 11/18/82, Issued by CDC

ADLPIPE Input Preparation Manual, May, 1981 Revision

ADLPIPE Reference #16, "Lumped Mass Location", March, 1975

TPIPE Users Manual, Version G/C 4.3

GT StRUDL Users Manual Vols. 1,2,3

E. Drawings

B&R Stress Isometrics

a. M200-Sh. 107, Rev. 7
b. M200-Sh. 107A, Rev. 1
c. M200-Sh. 112, Rev. 6
d. M200-Sh. 112A, Rev. 1
e. M200-Sh. 115, Rev. 10
f. M200-Sh. 115B, Rev. 2
g. M200-Sh. 119, Rev. 11
h. M200-Sh. 119A, Rev. 2
i. M200-Sh. 127, Rev. 9

j. M200-Sh. 127A, Rev. 1
k. M200-Sh. 136, Rev. 7
l. M200-Sh. 136A, Rev. 1

B&R Flow Diagrams

a. M501, Rev. 23
b. M519, Rev. 33
c. M521-Sh. 1, Rev. 41
d. M521-Sh. 2, Rev. 41
e. M524-Sh. 2, Rev. 39
f. M526, Rev. 43

G.E. 761E428, Rev. 2, RHR Heat Exchanger

G.E. 731E966, Rev. 6, RHR Process Diagram

G.E. 731E966AD, Sh.-1 & 2, Rev. 2, RHR Process Data

Pipe Isometric, G/C Drawing RHR-2289-1, Rev. 4

Pipe Isometric, G/C Drawing RHR-2289-2, Rev. 5

Pipe Isometric, BR1 Drawing M200-112, Rev. 5

Valve Drawing, Borg-Warner No. 76590, Rev. 1

Flow Diagram, BRI Drawing M521-2, Rev. 40

Heat Exchanger Drawing GE762E482, Rev. 3

Hanger Drawing RHR-436

Hanger Drawing RHR-915N

Hanger Drawing RHR-184

Hanger Drawing RHR-902N

Valve Drawings

a. Anchor/Darling, 2646-3, Rev. B
b. Anchor/Darling, 2648-3, Rev. A
c. Anchor/Darling, 3471-3, Rev. 0
d. Velan, P2-2767-N-2, Rev. N
e. Velan, P2-3313-N-40, Rev. E
f. Velan, P2-3313-N-42, Rev. F
g. Velan, P2-3313-N-31, Rev. D
h. Fisher Controls, 53A2406, Rev. B
i. Fisher Controls, 53A2723, Rev. B
j. Fisher Controls, 53A2722, Rev. B

F. Memoranda

B&R Memo from Braverman/O'Donnell to R. Snaith, 2/10/81 (Seismic Anchor Motions)

B&R Memo from Braverman/O'Donnell to Verderber, 1/18/83 (Seismic Anchor Motions)

B&R Memo from C. Chung to Verderber/Hess 8/17/83, revised RHR system temperatures

GCBR-F-82-020, "Stress Justification Factors", 2/8/82

BRWP-F-82-047, "Piping Stress Analysis of Nuclear Piping", 2/20/82

G/C Memo TPIPE-098, 3/10/83 for TPIPE Version G/C 4.3