ATTACHMENT B

FLORIDA POWER CORPORATION
CRYSTAL RIVER UNIT 3
DOCKET NUMBER 50-302/LICENSE NUMBER DPR-72

GENERIC OPERABILITY EVALUATION
FOR
LARGE BORE SAFETY RELATED PIPING
AT CRYSTAL RIVER-3

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CR-3 Large Bore Safety Related Piping
Operability Evaluation

1.0 Description and Purpose

The purpose of this Operability Evaluation is to evaluate the safety significance of 1) the individual and collective technical issues identified by the Wais Report (reference 1) and subsequent PC's (references 2, 4 and 5) as it affects the qualification of large bore safety related piping, and 2) the lack of documentation demonstrating qualification of large bore ($2^1/_2$" and over) safety related piping and supports at Crystal River -3. This scope of this evaluation includes all large bore, safety related piping and supports analyzed by Gilbert Commonwealth (now Parsons) and its subcontractors. The RCS primary piping was supplied and analyzed by B&W and has adequate analyses and documentation.

2.0 Safety Classification

By definition, this evaluation discusses all large bore, safety related piping supplied and analyzed by Gilbert Commonwealth (now Parsons) and its subcontractors with the exception of the RCS Primary Loop which was supplied and analyzed by B&W (now Framatome).

3.0 Licensing Basis

There are multiple sections throughout the FSAR that address the requirements regarding the analysis and qualification of large bore safety related piping and supports. These generic sections are:

1) Section 1.3.2.12, *Piping*. This section identifies USAS (ANSI) B31.1.0-1967 as the piping code of record for CR-3.

2) Section 5.2.4.1.2, *Dynamic Solution*. This section discusses the damping values to be used in the analysis of Class 1 structures. Vital piping systems are identified as using a damping of 0.5%.

3) Section 5.4.4, *Other Class I Structures and Systems*. This section provides the generic piping design criteria for lines not identified in Chapter 4 as a part of the primary loop. This section identifies USAS (ANSI) B31.1.0-1967 and those portions of Code Case N7 as the design code for the subject piping.

4) Section 5.4.5, *Methods of Analysis*. This section contains some select generic criteria associated with piping analysis methods.

Other portions of the FSAR discuss piping analysis and qualification for particular systems but, in general, are enveloped by the above FSAR sections.

4.0 Description of Identified Concern

Multiple concerns were identified in the Wais Report and subsequent PC's. The particular Wais Report concerns discussed here are limited to those significant items identified in section

4 of the report. Several of the concerns in section 4 were judged to be either insignificant or not operability concerns and are not included. The following is a list of the concerns considered significant and a brief description of each.

4.1 Uplift on Rod Hangers - Rod Hangers are designed to carry the weight of the pipe and its contents and are design for downward only load. There can, however, be instances where the combined thermal and seismic in the upward direction is greater than the weight load thereby causing uplift. For long, slender rods the support becomes ineffective in this situation.

4.2 Evaluation of Welded Attachments/ Axial Trunion Supports on Elbows - There are very few evaluations available to evaluate the local effects of welded attachments, such as lugs or trunions. Because the attachment is welded to the pipe, it may cause local deformations or flattening of the pipe.

4.3 Temperature Cut-Off - The temperature below which a thermal stress analysis was not required was defined as 150°F. Several cases were identified with design/operating temperatures greater than 150°F (but less than 200°F).

4.4 Anchor Design - Different types of non-standard anchor designs were observed in the review of support sketches and during the walkdown. No support design analysis was found to document local pipe wall stresses or the ability of the anchor to perform its intended design function.

4.5 Uncinched U-Bolts acting as Two-Way restraints - CR-3 has many U-bolts analyzed as 2-way restraints; however, no evaluation of the horizontal functional capability of these restraints was observed.

4.6 Dual Snubbers - Support sketches and walkdowns indicated restraint design with two snubbers acting together in the same restraint. Because of the potential for different "lock-up" rates, it is unlikely that the two snubbers would react identically to a shock load.

4.7 Consistency of Damping Values Used in Seismic Analysis - The approved damping value for response spectra analysis for piping at CR-3 is 0.5%. Although the Wais report did not specifically identify any examples where anything other than 0.5% damping was used, there may be some select analyses that may be discovered to have use a higher damping.

4.8 Strut/Snubber Angularity - The review of pipe support drawings and the walkdown showed supports installed at varying degrees of angularity to the pipe. The restraining action is therefore not perpendicular or parallel to the axis of the pipe as may have been analyzed.

4.9 Active Spring Hangers in Seismic Analysis - One of the observations in the Wais Report is that spring hangers in seismic analysis are considered active in the piping analysis.

4.10 Modeling of Valves/ Valve Accelerations - The modeling of valves was a bulleted item in the Wais Report but no discussion was provided. Due to the lack of details of the specifics of this discrepancy, it is assumed that it deals with the accurate modeling of valves in the piping model (i.e. weight and center of gravity) and subsequent determination of valve accelerations for seismic qualification.

4.11 Consideration of Seismic Anchor Motions (SAMS) - The concern here is that pipe stresses due to the seismic motion of buildings, both within one building and between buildings, was not considered in the design of CR-3 piping systems.

4.12 Inadequate Truncation of Seismic Class I/III boundaries - FSAR section 5.4.5.2, *Seismic Analysis of Equipment and Vital Piping Systems*, states "Class I piping analysis includes all significant piping between anchor points, regardless of class change. Therefore, stress effects of class I and III piping contribute to the stress levels in the class I portion of the system and are reflected in the analysis output". During the design and licensing of CR-3 what constituted an adequate seismic overlap was unclear and little guidance was provided in industry or regulatory documents. For seismic piping (class 1) which has continuation piping which is non-seismic (class III) protection of the seismic pressure boundary does not always appear adequate by todays standards.

4.13 No Equipment Specific Response Spectra - FSAR section 5.4.5.2, *Seismic Analysis of Equipment and Vital Piping Systems*, states "When Class I piping is anchored to a piece of rigid equipment (25 cps or higher), floor response curve is used as input. When the piping is anchored to a piece of flexible equipment, either the equipment will be lumped as a part of the model, or new floor response curve applicable at the anchor point to the equipment will be developed". For flexible equipment, no examples can be found where equipment specific response spectra were developed when an analysis ended at an equipment nozzle and was modeled as a rigid anchor.

4.14 Lack of Original Support Calculations - There are no original support calculations at CR-3. It is difficult to verify the ability of the support to meet its design basis requirements without them. For supports with welded attachments to pipe, there is no documentation of the local stress on the pipe.

5.0 Impact of Analysis and Reliability Considerations

Each of the items identified in section 4.0 will be compared against the licensing commitments shown in section 3.0.

5.1 Uplift on Rod Hangers - There is no specific commitment discussed in any of the licensing basis documents reviewed specific to rod hanger uplift.

5.2 Evaluation of Welded Attachments/ Axial Trunion Supports on Elbows - There is no specific commitment discussed in any of the licensing basis documents reviewed specific to evaluation of welded attachments.

5.3 Temperature Cut-Off - There are no commitments discussed in any of the licensing basis documents reviewed specific to temperature cut-off for thermal analysis.

5.4 Anchor Design - There is no specific commitment discussed in any of the licensing basis documents reviewed specific to Anchor design. Flexible anchors modeled as rigid in a piping analysis can potentially yield erroneous support loads.

5.5 Uncinched U-Bolts acting as Two-Way restraints - There is no specific commitment discussed in any of the licensing basis documents reviewed specific to U-Bolts and the ability to act as a two-way restraint.

5.6 Dual Snubbers - There is no specific commitment discussed in any of the licensing basis documents reviewed specific to Dual Snubbers. The evaluation of dual snubbers locking at different rates was not a design or licensing commitment at CR-3.

5.7 Consistency of Damping Values Used in Seismic Analysis - SAR Section 5.2.4.1.2 identifies a damping value of 0.5% to be used for vital piping systems. Should piping systems be discovered that used a higher damping, it would not be in compliance with the FSAR.

5.8 Strut/Snubber Angularity - There is no specific commitment discussed in any of the licensing basis documents reviewed specific to snubber or strut angularity. However, struts or snubbers oriented significantly differently than the analyzed configuration will produce stress results and adjacent support loads.

5.9 Modeling of Spring Hangers in Seismic Analysis - There is no specific commitment discussed in any of the licensing basis documents reviewed specific to modeling of spring hangers in a seismic analysis.

5.10 Modeling of Valves/ Valve Accelerations - There is no specific commitment discussed in any of the licensing basis documents reviewed specific to modeling of valves.

5.11 Consideration of Seismic Anchor Motions (SAMS) - There is no specific commitment discussed in any of the licensing basis documents reviewed specific to consideration of SAMs'.

5.12 Inadequate Truncation of Seismic Class I/III boundaries - As discussed in section 4.6, FSAR section 5.4.5.2 requires that the non-seismic pipings influence on the seismic piping be evaluated. Since this cannot be determined to be true in all cases, we are currently not in compliance with this portion of the FSAR.

5.13 No Equipment Specific Response Spectra - As discussed in section 4.7, FSAR section 5.4.5.2 states that either equipment specific response spectra is used when the piping is anchored to a piece of flexible equipment or the equipment will be lumped as a part of the model. Since there are examples where neither was done, we are currently not in compliance with this portion of the FSAR.

5.14 Lack of Original Support Calculations - There is no commitment discussed in any of the licensing basis documents reviewed specific to having support calculations on file. However, the lack of calculations represent conditions contrary to 10CFR50, Appendix B which discuss document control activities and requirements for retention of Quality Assurance records.

Additionally, inclusion of several of items listed in sections 5.1 to 5.13 into the piping analysis has the potential to cause the code allowables of ANSI B31.1 to be exceeded for pipe stress which are identified in section 5.4.4 of the FSAR.

6.0 Operability Evaluation / Justification for Continued Operation

Operability, in the case of piping and supports, is the ability to demonstrate there will be no loss of pressure boundary integrity and no degradation in the ability to deliver rated flow. Operability evaluations of discrepancies discovered in the past have not revealed any systems that could not perform their intended design and/or safety function. Attachment A documents some of these past operability evaluations. The acceptance criteria for these determinations was the pipe stresses not exceeding the materials yield strength (Sy). This acceptance criteria is well below the ASME Section III Appendix F criteria which is mentioned in the NRC Inspection Manual Part 9900: Technical Guidance as an acceptable method for determination of operability.

Due to the lack of current specific operability concerns, this operability discussion will focus on the generic attributes associated with each issue and, generically, why they are not operability concerns (only code compliance concerns). This discussion will be based on CR-3 specific experience as we have dealt with the various issues over the years (attachment A), as well as industry experience. At the conclusion there will be a discussion of the cumulative effects.

6.1 Uplift on Rod Hangers - Rod supports are acceptable for the support of dynamic loads and computer analysis results are a sufficiently reliable indication of whether or not tension can be maintained in a rod. The normal design process allows for the utilization of a rod hanger in dynamic conditions if 1) net downward load from sustained loadings, i.e. dead weight and thermal, is greater than the analyzed seismic uplift load thereby providing an indication that uplift (compression on the rod) will not occur or 2) in the event that uplift may occur, the rod hanger can accommodate the compressive load (will not buckle).

As discussed in Reference 3, seismic analysis at CR-3 currently is very conservative in both the definition of SSE equivalent zero period ground acceleration and the definition of design basis floor spectra and allowable piping stresses. This not only results in failure probabilities which are several orders of magnitude less than currently required by ASME and NRC piping design criteria but also generates seismic support loads that are very conservative. These conservatisms include the magnitude of the upward seismic load generating uplift. Removing these conservatism's would likely eliminate the uplift from most rods.

It should be noted, there are currently no known rods at CR-3 that have uplift concerns. Past evaluations of rod hanger uplift at CR-3 have either demonstrated that the rod can take the compressive load in the upward direction without buckling, or removal of the rod from the dynamic analysis results in acceptable stress levels and support loads in the adjacent supports. Some previous evaluations of uplifting rods have been conducted in the past with favorable results (see attachment A).

Even though earthquake experience data is not a part of the design basis for piping systems at CR3, it does provide a clear indication that single acting supports such as rod hangers are effective in the mitigation of seismic effects (see discussion in reference 3). This also establishes a basis for concluding that this issue has no significant consequences to the operability of the affected piping systems.

6.2 Evaluation of Welded Attachments/ Axial Trunion Supports on Elbows - Typically, the designers and design engineers sized lugs and other integral attachments based on experience and performed no deterministic stress analysis. The resulting stresses are considered by the Code to be secondary in nature and result in localized deformations, i.e. flattening and/or local yielding, but are not considered to affect the pressure boundary integrity or the fluid transport capability, therefore they are judged not to represent a design basis issue.

Behavior of B31.1 piping in power plants in California which have been subjected to strong motion ZPGA above 0.2g validate this assumption. No pipe lug or attachment failures due to earthquake effects (on over 2 million feet of pipe inspected) of at least twice the MHE design basis for CR-3 have been recorded (ref NUREG/CR-6239). This is not to say that lugs don't occasionally fail in the pipe walls due to high cycle thermal loads. However, such failures are quite rare, even in the vast majority of cases where such localized stresses were not explicitly considered in the design.

Attachment A provides some previous evaluations for integral welded attachments with favorable results.

6.3 Temperature Cut-Off - The temperature below which an explicit thermal analysis was not required was defined at CR3 as 150 degree F. Several systems which had temperatures in excess of 150 degree F. may not have been analyzed for thermal expansion. The establishment of a cut-off temperature for the performance of a thermal flexibility analysis varies from licensee to licensee. It generally varies between 100 degrees F. to 200 degrees F. Previous licensing activity at another nuclear plant concerning the restart of the plant established a cut off temperature of 200 degrees F.

Current industry practice is to perform flexibility analysis for piping systems using a piping analysis computer code. Implicit in this type of analysis is that the stresses and loads are directly proportional (linear) to the temperature. The input and modeling approaches as they were developed were directed toward elevated temperature systems; e.g. 500°F. These approaches were designed to be conservative at these temperatures. However, when applied to lower temperature lines, they tend to lead to overly conservative results; i.e. over predict pipe stresses and support/nozzle loads.

Some of these assumptions have been discussed in detail in industry literature. Included among the items that result in overly conservative results at low temperatures are:

- Effects of Gaps at Supports. At low temperatures, the effects of gaps are perhaps the most dominant of the analytical assumptions used in the standard piping analysis. In the conventional piping analysis, the normal assumption is made that there are no gaps and the expanding pipe engages the support immediately. No allowance is made for the gap to absorb initial pipe expansion prior to loading the supports. For higher temperature lines this is a reasonable assumption; however, for lower temperatures it is very conservative.

Gaps exist for most all types of supports. These gaps are in the form of clearances between the pipe and the support steel for U-bolt or box type supports, or in the form of clearance around the bolts and bolt holes for other type supports. The clearance between pipe and structural support members is typically between 1/16" and 1/8". Therefore the total gap or clearance available to absorb thermal expansion between two opposing restraints is up to twice the magnitude of that available at a single support. Gap ranging from 1/8" to 1/4" then may be available for thermal expansion growth. For low temperature piping systems, this amount is substantial.

- Support Stiffness Effects on Thermal Expansion. Generally in modeling piping systems the supports and equipment attachments are modeled as rigid. Modeling the support as rigid implies that there is no deflection of the support under load in the direction of restraint. However, in general, there is some flexibility in the support structure and associated building/structural steel. Normally this is not considered in the design of pipe systems. The loads calculated for thermal expansion are conservative when rigid support stiffness' are used.

Use of the rigid support stiffness assumption is a standard modeling practice throughout the industry. This is due to several reasons. First, if actual, calculated stiffness values are used, all of the support stiffness' (including equipment/ anchor stiffness') within a given analytical boundary must be used. Using actual stiffness values for only a portion of a model will, in most cases, provide inaccurate results. Calculating stiffness' for pipe supports is very time consuming and usually done by someone other than the pipe stress analyst. Additionally, equipment nozzle stiffness' are often unavailable and there is usually not sufficient data on the vendor drawing available to calculate them. Second, if an analysis used actual support stiffness', and support modifications are required, a recalculation f that supports stiffness would be required. This usually results in a redistribution of support loads within that analytical model and reanalysis of supports seeing increased loads. It is for these reasons that analysts tend to stay away from using actual support stiffness', however, it is recognized that by using them, the magnitude of piping stresses and support loads would be substantially reduced.

- Local Flexibility Effects at Support Points with Large D/t Values - This is similar to the support stiffness effect. For large, thin wall pipe (large Diameter / Thickness ratios) the local deformations to the pipe wall under loading have th same effect as support flexibility. If this is considered, the piping and support loads in the area of the attachment will be reduced. However, this is not normally considered in conventional piping analysis.

- Equipment Flexibility Effects - This is also similar to the support stiffness effect. NUREG 1061 and WRC Bulletin 300 recommend that these effects be considered. NUREG/CR-3599, "*Sources of Uncertainty in the Calculation of Loads on Supports of Piping Systems*" includes an evaluation of this effect and clearly shows that it is significant. As discussed in support stiffness effects, inclusion of these considerations will reduce thermal loads on the affected nozzles and adjacent supports.

In addition to these modeling conservatism's, there are inherent conservatism's in the code allowable associated with thermal expansion. In the thermal expansion calculations, once the thermal expansion stress is calculated, it is compared to an allowable stress range, S_A. This allowable is a function of the material allowable stress in the cold an hot condition and number of thermal cycles.

$$S_A = f\,(1.25\,S_C + 0.25\,S_H)$$

where S_C = allowable stress in the cold condition
S_H = allowable stress in the hot condition
f = stress range reduction factor for cyclic conditions (=1 for 7000 cycles or less)

It should be noted here that this check on expansion stress range is a fatigue evaluation. The stress allowable, S_A, is a function of the applied number of thermal cycles through the use of a stress range reduction factor for cyclic conditions (f). Use of a reduction factor equal to 1 would qualify the system for 7000 cycles. Designing for a minimum of 7000 cycles (which roughly conforms to a cycle a day for 20 years) represents a significant conservatism (even over a typical 40 year plant life) for most nuclear plant piping systems which see a limited number of shutdowns.

In the case of CR-3, the start-up and shut down cycles are no more than 240. The start-up and shutdown cycles represent the full thermal range that most piping systems experience. Accounting for these minor temperature fluctuations, and applying a factor of

2 for conservatism, we can assume 480 cycles for full thermal range. Using the fatigue curve equation developed by Markl (Ref 7):

$$i\,S = 245{,}000N^{-0.2}$$

where, i = 1.0 (girth butt weld)
S = thermal expansion stress allowable (includes factor of safety = 2)
N = number of design cycles

An allowable value of thermal expansion stress range, S, for 480 cycles is 71,000 psi. This allowable, based on a conservative actual number of cycles, is at least 3 time higher than the typical value of S_A used in CR-3 design. This is sufficient margin available in the design to offset any stress increases as a result of consideration of thermal effects various sections of the piping system.

In conclusion, should the above mentioned items be considered in a thermal expansion analysis demonstration of code compliance for piping and supports will be easily achieved and does not represent an operability concern.

6.4 Anchor Design - This item of the Wais report concerns itself with two separate issues. The first issue is the local stress effects similar to the issue described in Item 6.2 above. The discussion provided in Item 6.2 is applicable for this issue as well. The second issue deals with the appropriateness of the mathematical model used in the piping analysis. The concern is that the physical anchor does not represent a rigid restraint as assumed in the mathematical model. This will result in a change in the overall stiffness matrix for the system. Stresses and loads will redistribute across the anchor if the actual stiffness of the anchor were used in the mathematical model as opposed to a rigid anchor. This will have a nominal effect on the thermal stresses and loads and is concluded not to represent an operability concern. The seismic effect is also concluded to be nominal since the overall system response will be driven to the low frequency side of the floor response spectra.

6.5 Uncinched U-Bolts acting as Two-Way restraints - There has been significant work performed in the determination of allowable side loadings for U-bolts. Attached is a copy of a standard applicable to TVA and is provided for information only. This standard establishes design values for unidirectional horizontal loads and an interaction methodology for biaxial (tension/shear) loadings. These load ratings were established based on testing and included a deflection criteria. U-bolts are considered to be component standard hardware typical of that supplied by any pipe support vendor, i.e., Power Piping, Bergen Patterson. The TVA data is considered to be appropriate for making an operability determination. A review of this data indicates a substantial capacity for horizontal loadings. For purposes of the operability review, the emergency load rating is considered to be acceptable and indicates no operability concern. Some specific evaluations for side loads on U-bolts at CR-3 is provided in Attachment A.

6.6 Dual Snubbers - While it is preferable to use a single snubber at a support installation to eliminate any concern with respect to relative load distribution to the multiple snubbers, the evaluation of dual snubbers locking at different rates was not a design or licensing commitment at CR-3 any more than requiring rigid supports to have identical stiffnesses. Individual members of a redundant support system are expected to behave compositely and shed load to other members of the support system such that the support will act compositely. This is a common engineering assumption used throughout the industry and is not indicative of any operability concerns.

6.7 Consistency of Damping Values Used in Seismic Analysis - Piping system design damping used with the response spectra based on the CR-3 median shaped Ground Response Spectra is 0.5 percent. This value of pipe system damping was commonly used with median shaped spectra at the time CR-3 piping was designed. Use of 1% damping for OBE and 2% for SSE in a response spectrum analysis would result in approximately 30% lower seismic pipe stresses and support loads (depending upon the system frequencies of the system analyzed). Typical operability acceptance criteria for piping and supports (ASME Section III, Appendix F, NRC Bulletin 79-02) would provide a much higher than a 30% increase over CR-3's current code acceptance criteria.. While use of higher damping in a response spectrum analysis is clearly outside of CR-3's licensing basis it is not an operability concern.

6.8 Strut/Snubber Angularity - For skewed pipe supports, restraint direction is modeled into a piping analysis by the use of direction cosines. Should there be some deviation from the as-analyzed versus actual support orientation, actual support loads and pipe stresses will be different from that analyzed. However, should the support orientation be off by even as much a 45°, as much as 70% (cosine 45°) of the analyzed degree of restraint is provided by that support. This is clearly less severe than if the support were totally inactive or degraded. Past evaluations of inoperable or incorrectly modeled support orientations have not indicated (see attachment A) any operability concerns. This is primarily due to the low seismic demand for CR-3 as well as the large increase allowable in going from code acceptance (1.2 Sh) to operability acceptance (1.0 Sy for past evaluations, 2.0 Sy per ASME Section III, Appendix F).

6.9 Modeling of Spring Hangers in Seismic Analysis - It is common piping design practice to ignore spring hanger restraint in the seismic analysis of piping. Such hangers are very flexible and have little effect on the dynamic response. Conversely, such springs are active during seismic excitation, and while they take very little load and have insignificant influence on seismic response, their inclusion in the model cannot be considered an error. This modeling technique is not indicative of any operability concerns.

6.10 Modeling of Valves/ Valve Accelerations - Valves are typically identified as in-line components (i.e. they are supported by their attached piping). Due to the concentrated mass valves add to a piping run, they are usually located in close proximity to one or more pipe supports. Hence, the valves seismic excitation is usually limited by the motion of the pipe support(s) adjacent to the valve rather than the overall response of the piping system.

In addition, any load coming from the valve is transferred primarily to the pipe support rather than the piping due to the close proximity to the support. Previous evaluations of increased operator weights and/or revised C/G's (see attachment A) indicate acceptable results with few modifications required.

Regarding the qualification of valves to the applied accelerations, a program was performed in 1983(calculation 5079-049-DI-1) to screen all large bore safety related valves to determine acceptance with the original requirements as defined in Requirement Outline (RO) specifications. Out of this review 27 outliers were identified that exceeded the maximum RO acceleration acceptance criteria. A detailed evaluation was later conducted for these valves (NUC contract #NUC-10407D) and indicated that all of the valves are qualified for the applied accelerations.

6.11 Consideration of Seismic Anchor Motions (SAMS) - Seismic anchor (support) motions, which induce secondary stresses in the piping system, are not directly addressed in USAS B31.1-1967 and were not considered in the analytical evaluation of CR-3 piping. Generally, the threshold for consideration of SAMs' varies from plant to plant but typically ranges between 1/16" and 1/8". With the maximum out of phase displacements between buildings being less than 1/16" for SSE (.1g ground acceleration) at CR-3 (see attachment B) the lack of SAM consideration for CR-3 piping is not an operability concern.

6.12 Inadequate Truncation of Seismic Class I/III boundaries (PC 97-5390) - As discussed in section 4.6, FSAR section 5.4.5.2 requires that the non-seismic pipings influence on the seismic piping be evaluated. Since this cannot be determined to be true in all cases, we are currently not in compliance with this portion of the FSAR.

It is felt that a detailed, rigorous analysis of this concern (i.e. significant modeling beyond the seismic class break) will yield favorable results for the following reasons:

1) CR-3 is in a low seismic zone and generically has low seismic stresses. The seismic portion of the piping was analyzed and supported using very conservative analytical techniques (conservative definition of SSE equivalent zero period ground acceleration and the design basis floor spectra) as well as a conservative acceptance criteria (SSE loads compared to 1.2Sh versus 3.0Sh for ASME Section III-1989, NC-3655).

2) It is felt that more modern analytical techniques (not commonly available during CR-3 design) such as time history and finite element can be used to demonstrate acceptance with code allowable and not challenge the safety related pressure boundary. Additionally, todays computer programs are much more sophisticated the programs used during the design and licensing of CR-3

3) Industry Experience. As documented in NUREG/CR-6239, *Survey of Strong Motion Earthquake Effects on Thermal Power Plants in California with Emphasis on Piping*

Systems, even in plants that have experienced earthquakes with zero period ground accelerations (ZPGA) in excess of 0.30g's, little damage to the non-seismic piping was seen. With CR-3 being in a low seismic zone (0.05 g's maximum ground acceleration) even less potential for pipe damage/failure exists. For the plants inspected, the number of such seismic related damage to nuclear power plant piping averaged less than one piping or support failure per unit per earthquake. For each unit there were several thousand feet of pipe and several hundred supports typically at risk.

6.13 No Equipment Specific Response Spectra (PC 97-5822) - As discussed in section 5.11, FSAR section 5.4.5.2 states that either equipment specific response spectra is used when the piping is anchored to a piece of flexible equipment or the equipment will be lumped as a part of the model. It is likely that more detailed rigorous analysis techniques (time history analysis, independent support motion using multiple response spectra, increased damping) will likely demonstrate code compliance and certainly will not cause exceedance of operability allowables. The most likely result from using equipment specific response spectra or considering the stiffness of the equipment in the piping model is:

1) Slightly increases seismic nozzle loads.
2) Slightly higher pipe stresses in the area of the nozzle.
3) Higher support loads in the area of the nozzle.

None of the above items will exceed operability limitations and cause pressure boundary failure or reduce the ability to deliver rated flow.

6.14 No Original Support Calculations - These items represent conditions contrary to 10CFR50, Appendix B but are considered to be outside the scope of an operability evaluation. The inability to retrieve qualification documentation to demonstrate compliance with the design and licensing basis does not necessarily mean that it is not within those bases, just that the documentation is not available to demonstrate that it is within those bases.

CUMULATIVE EFFECTS:

To address the cumulative effects (i.e. extent of condition) of the identified concerns resulting from the Wais Report and subsequent Precursor Cards, FPC had Dr. John D. Stevenson perform a third party review of all piping and pipe support concerns (Reference 3). The conclusion drawn from his evaluation confirmed the Suspected Design Basis Issue evaluation done for PC 97-0048. As discussed in his final report "*... there is no safety concern with respect to the "as designed" and "as installed" safety related large bore pipe at CR-3.*" The basis for his conclusion included over three weeks of CR-3 documentation review and walkdowns as well as referencing past industry efforts. Section 6.0 of his summary report (Reference 3) details his safety significance review (see attachment C). The following is a summary of that review.

1) A U.S. NRC sponsored Systematic Evaluation Program (SEP) to evaluate the seismic adequacy of structures, mechanical and electrical distribution systems and mechanical and electrical distribution components in older operating nuclear power plants. The results of the SEP ultimately led to the Unresolved Safety Issue A-46 which excluded piping due to the lack of safety concerns (except for piping flexibility between structures). This conclusion regarding the seismic safety of installed safety related piping in older nuclear power plants was later confirmed in NUREG/CR-4334.

2) A comparison of the way CR-3 piping is supported relative to the SEP plants and approximately 20 other A-46 plants identified no safety significant issues. Additionally, it was noted, CR-3 has the second lowest probalistically defined mean design basis ground acceleration levels of all nuclear power plants in the U.S. CR-3 has a $0.65x10^{-4}$/yr probability (NUREG-1488) for a mean peak ground acceleration of 0.1g. This probability value is more conservative by a factor of more than 2.0 as compared to most nuclear plants operating in the U.S. today and is less than the NRC's A-46 reevaluation criteria of 10^{-4}/yr.

3) CR-3 piping design, because of the excessive conservatism contained in both the definition of SSE equivalent zero period ground acceleration, the design basis floor spectra and allowable piping stresses, results in failure probabilities which are several orders of magnitude less than currently required by ASME and NRC piping design criteria and has therefore resulted in extremely safe design.

In summary, due to the above discussion, large bore safety related piping at CR-3 is considered operable in its current configuration. This is based industry experience, plant specific experience in dealing with many of these issues in the past (Attachment A) and the assessment of a third party reviewer (Dr. John D. Stevenson). Additionally, several plant upgrade programs have been conducted in the past to improve design margins in piping and pipe supports. Extensive reevaluation of concrete anchorages (Wej-Its) for large bore pipe supports were performed in 1985 and 1992 (see attachment A). During those programs many concrete anchorages were reevaluated and replaced. Also, in 1993 a reevaluation of pipe supports anchored using Unistrut anchor bolts was conducted. Out of 758 pipe supports evaluated, 44 required redesign. All modifications associated with these efforts have been completed.

7.0 <u>Corrective Action to Obtain Full Qualification</u>

FPC plans to perform a comprehensive and rigorous inspection and revalidation/ requalification of CR-3 large bore safety-related piping and pipe supports. A project scoping report is currently in development that will define the scope and duration of this effort. This effort will address the concern with lack of adequate engineering documentation as well as address the various technical issues associated with the Wais Report.

The specific Pipe Stress and Support calculations to support the resolution of identified issues are being developed. In addition, a project plan for establishing the programmatic tasks (e.g., computer program purchases, master list development, reviewing licensing commitments, project staffing, etc.) is underway. FPC currently anticipates that the program will take approximately 4-6 years (2-3 fuel cycles) to implement. All currently identified code compliance issues associated with large bore piping and supports will be corrected prior to restart. Modifications are being implemented where necessary.

In summary, operability is ensured based on the SDBI done for PC 97-0048 and the third party review conclusion that there are no safety concerns associated with large bore piping at CR-3. However, if future code compliance problems are identified during the revalidation effort, they will be documented and individual operability evaluations performed in accordance with our corrective action program (Precursor Cards). Based upon our assessment and results of the assessments of third party reviewers, FPC concludes that no condition exists that would challenge the ability of systems, structures or components to perform their safety function of preventing or mitigating design basis events.

8.0 References

1) Wais and Associates, Inc., Report Number 96-04-002 dated October 28, 1996, "Evaluation of Pipe Support Documentation for Crystal River 3"
2) FPC Precursor Card (PC) 97-0048
3) John D. Stevenson, Consulting Engineer, Report Number 97.174-1 dated October 30, 1997, "Overview of Safety Related Large Bore Piping and Piping Support Design and Construction Currently Existing at Crystal River-3 Nuclear Power Plant"
4) FPC Precursor Card (PC) 97-5390
5) FPC Precursor Card (PC) 97-5822
6) 1989 ASME B&PV Code Section III Division 1 - Subsection NC
7) Markl, A.R.C., "Piping Flexibility Analysis", Transactions ASME, Vol. 77, No. 2, 1955, pp. 127-143

CR-3 Large Bore Safety Related Piping
Operability Evaluation

Attachment A
Past Operability/Code Evaluations for Piping and Support Concerns

Rod Hanger Uplift

Calculation	Date	Description
DC-5520-091.1 PE	7/29/92	CR-103 Rod Evaluation - uplift on rod supports CHH-26 and CHH-32. Results acceptable.
M74-0009 Rev 2	10/15/97	Evaluation of Raw Water piping for heavier spool piece. Rod support RWH-15 uplifting. Analysis ran with and without RWH-15. All Piping and supports code qualified with and without.

Evaluation of Welded Attachments/ Axial Trunion Supports on Elbows

Calculation	Date	Description
M-91-0009	9/24/91	Evaluation of the structural adequacy of the shear lugs at supports RCH-49A and RCH-46. Lug attachments and pipe wall stresses are code qualified.
S-92-0084	5/7/92	Evaluation of Integral Welded Attachments for pipe supports MSH-190, MSH-191 and MSH-192. Results are acceptable.
M97-0125	12/11/97	Reevaluation of EDS-23 and 25 due to higher thermal loads. Evaluates the welded attachment at SWR-522. Local pipe wall stresses are acceptable.

Uncinched U-Bolts Acting as 2-Way Restraints

Calculation	Date	Description
M74-0029	11/29/97	U-bolts for supports SWH-274 and SWH-261 evaluated for higher thermal loads. SWH-274 failed code and piping was reanalyzed with and without SWH-274. Enveloped supports loads and pipe stresses were within code allowables.
M97-0125	12/11/97	U-bolts for supports SWH-9, SWH-522, CIH-047 and CIH-049 evaluated for increased thermal loads. All supports are code qualified.

Strut or Snubber Angularity/ Degraded or Inoperable Supports

Calculation	Date	Description
5079-287-PAC-1	1/23/85	Inadequate concrete anchorages (Wej-Its) on supports DHH-533 and DHH-603. Also contains poor seismic overlap beyond valves DHV-9 and DHV-10. Piping reanalyzed w/o supports DHH-533 and DHH-603. Piping within operability limits.
5079-287-PAC-2	1/25/85	Inadequate concrete anchorages (Wej-Its) on supports SWR-504 and SWR-522 and poor seismic overlap. Piping and adjacent supports operable due to degraded restraint capability. Also reference calculations 5079-256-SWR-504-C01, 5079-256-SWR-504-C02, 5079-256-SWR-522-C01, 5079-256-SWR-522-C02

Modeling of Valves / Valve Accelerations

Calculation	Date	Description
5079-259-PAC-1	10/4/84 & 11/13/84	Evaluated the affects for the installation of a heavier valve - Results acceptable.
5500-514-8-PAC-1	10/1/86	Piping Analysis CR-80 and CR-84. Justify increase valve weight on SFV-18 and SFV-19. 600# valve to 1300#. Results acceptable.
5500-139-15-PAC	6/12/87	Justified the increase in valve weight on valves EFV-109 and EFV-111.

Inadequate Truncation of Seismic Class I/III Boundaries

Calculation	Date	Description
5079-287-PAC-1	1/23/85	Inadequate concrete anchorages (Wej-Its) on supports DHH-533 and DHH-603. Also contains poor seismic overlap beyond valves DHV-9 and DHV-10. Piping reanalyzed w/o supports DHH-533 and DHH-603. Piping within operability limits.
S97-0354	10/31/97	Inadequate seismic overlap for DW piping from containment penetration 117 outside containment. Piping and supports qualified w/ no modifications. Max sustained stress ratio= 0.19.

WEJ-IT PROGRAM NO. 1

Beginning in the 1984 to 1985 time frame, the overall capacity of the Wej-it concrete expansion anchors were being questioned. At this point FPC took an active roll in determining the correct capacity by doing on site testing. This testing program resulted in reduced tension/shear capacities for the expansion anchors. A program was then initiated which reviewed all safety related large bore pipe supports which had a Factor of Safety of less than 8. This Factor of Safety was based on the 79-02 calculations which evaluated prying effects of large bore pipe supports with concrete expansion anchors Small bore pipe supports containing concrete expansion anchors were also reviewed on a sample basis.

The results of this program was that all pipe supports containing concrete expansion anchors that had a Factor of Safety of 8 or less has been evaluated and meets IE Bulletin 79-02 allowables.

WEJ-IT PROGRAM NO. 2

An additional program was completed on the Wej-it anchor bolts in the 1992 time frame. These evaluations looked at pipe supports which had a Factor of Safety of between 8 and 16 to address prying issues versus the reduced anchor allowable capacity as previously described. Again, this Factor of Safety was based on the 79-02 calculations which evaluated prying effects of large bore pipe supports with concrete expansion anchors. A total of 331 pipe supports were evaluated for this project. The overall results of the evaluations determined that twenty-six supports did not meet a Factor of Safety of 4.0 as required by NRC Bulletin 79-02.

UNISTRUT EVALUATIONS

A program was instituted in early 1993 to address several problems with Unistrut anchor bolts. During a review of a piping stress analysis, it was discovered that several Unistrut structural pipe hangers did not meet the FPC design requirement for factor of safety greater than 2.0 for safe shutdown earthquake. This problem was apparently caused by a design error by the support designer, Power Piping, Inc. Apparently, the eccentric loading of the support angle was not accounted for in the original designs. A total of 758 pipe supports with Unistrut anchors were evaluated in this effort. The conclusion of these evaluations was that these supports did not create any operability concern. The Factor of Safety of all supports was greater than 1.0 for all of the required design conditions and thus the structural integrity of the supports would be maintained during a design basis (OBE or SSE) event. However, 44 pipe supports did require redesign, since their Factor of Safety did not meet the requirements as stated in the CR3 Pipe Support Design Guide or other requirements.

The Unistrut anchor bolts were not a part of the NRC Bulletin 79-02. This bulletin addressed concrete expansion anchors only.

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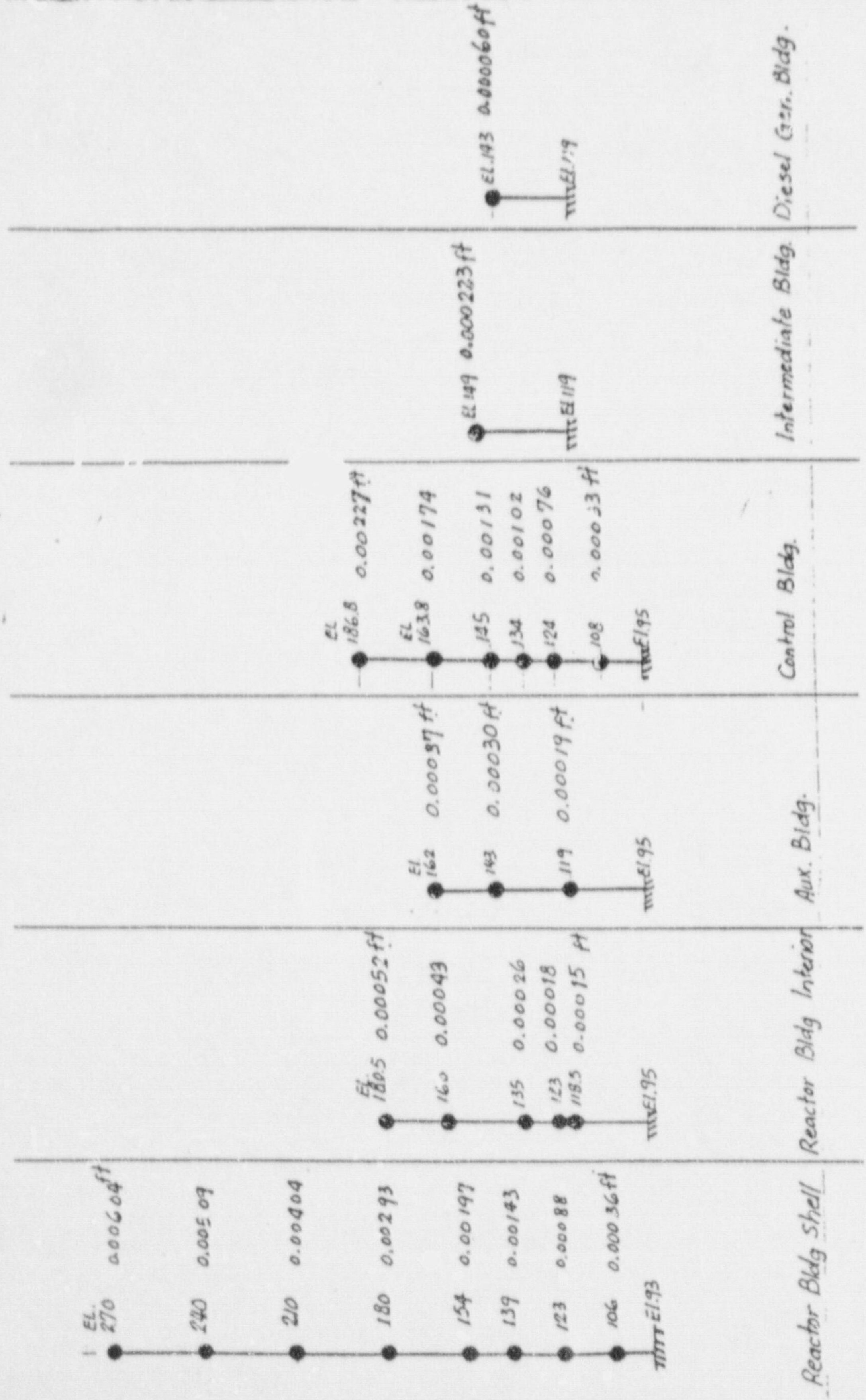
FIGURE 7.4.6-2 STRUCTURAL DISPLACEMENT

FLORIDA POWER CORP. CRYSTAL RIVER PLANT UNIT 3		GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA.
Structural Displacement (Earthquake) For Pipe Stress Analysis.	MPH	4203 1 Aug 29 · 1973

Attachment B
Page 1 of 1



Horiz. Displ. of Structure due to Earthquake Force of 0.05g.

Use (2/3 x Horiz. Disp.) for Vert. Displ

Horiz. Displ. of Turbine = 0.04" = 0.00333 ft

5.2.4 Some Stress Calculations Have a Number (in excess of 5) of Discrepancies

The Reanalysis of Safety Related Large Bore Piping Project will be conducted in accordance with the current edition of the CR-3 Quality Assurance Program which will eliminate this issue.

5.2.5 Seven Different Computer Programs Have Been Used for Pipe Stress Analysis

This condition is indicative of the rapid change in piping analysis procedures which have occurred since the initial construction of CR-3 piping. Existing commercially available Nuclear Quality Assurance qualified computer programs are being evaluated with the intent of using such a program as part of the Reanalysis of Safety Related Large Bore Pipe Project.

5.2.6 Uncontrolled Documents

The Reanalysis of Safety Related Large Bore Piping Project will be conducted in accordance with the current edition of the CR-3 Quality Assurance Program which will eliminate this issue.

5.2.7 Accessibility of Pertinent Documents

The Reanalysis of Safety Related Large Bore Piping Project will be conducted in accordance with the current edition of the CR-3 Quality Assurance Program which will eliminate this issue.

5.2.8 Consistency Between Design Packages

The Reanalysis of Safety Related Large Bore Piping Project will be conducted in accordance with the current edition of the CR-3 Quality Assurance Program which will eliminate this issue.

6.0 SAFETY SIGNIFICANCE OF THE CURRENT DESIGN AND INSTALLATION OF LARGE BORE SAFETY RELATED PIPING AT CR-3

It can not be stated too strongly that there is no safety concern with respect to the "as designed" and "as installed" safety related large bore piping at CR-3. Any reanalysis of large bore safety related piping at CR-3 would be to better document the design adequacy of the piping not because there is any concern with regard to the design and installation adequacy or safety of such piping which is much more conservative than would be required by currently applicable criteria.

6.1 HISTORICAL STUDIES TO DETERMINE SAFETY SIGNIFICANCE AND DESIGN ADEQUACY OF NUCLEAR POWER PLANT SAFETY RELATED PIPING

Starting in 1978 the U.S. NRC sponsored a Systematic Evaluation Program to evaluate the seismic adequacy of structures, mechanical and electrical distribution systems and mechanical and electrical components in older operating nuclear power plants. There were 11 power plants included in that study all of which received construction permits before 1967. A Senior Seismic Review Team drawn from the Nuclear Industry was convened and charged with the responsibility of "estimating the safety of the selected older nuclear power plants relative to those designed under current (1978) standards, criteria, and procedures and to recommend generally the nature and extent of retrofitting to bring these plants to acceptable levels of capability if they are not already at such levels."[23] This review did develop some generic seismic issues with regard to active mechanical and electrical components and electrical distribution systems (cable trays) as well as vertical tank and heat exchange supports. However, detailed evaluation of samples of piping in these plants indicated there were no safety concerns with respect to such piping except for the need of piping flexibility between adjacent structures. The results of this Systematic Evaluation Program ultimately lead to the Unresolved Safety Issue A-46[24] seismic review of all older nuclear power plant safety related to active mechanical and electrical equipment, cable trays and supports for tanks and heat exchangers. Excluded from the detailed A-46 effort was safety related piping because of the experience gained in the Systematic Evaluation and other programs.

This conclusion regarding the seismic safety of installed safety related piping in older nuclear power plants was confirmed in NUREG/CR-4334[25] in August 1985 which except for the evaluation of the piping flexibility between buildings did not recommend a need for detailed walkdown evaluation of piping when the design basis peak ground acceleration is below 0.5g. This value of 0.5g is 5 times the SSE equivalent peak ground acceleration at CR-3 of 0.1g.

6.2 COMPARISON OF THE SAFETY SIGNIFICANCE OF INSTALLED SAFETY RELATED PIPING IN OLDER NULCEAR POWER PLANTS AND THAT FOUND INSTALLED IN CR-3

A brief walkdown of large bore safety related piping installed in CR-3 similar to those walkdowns performed for piping in the SEP plants and in approximately 20 other A-46 plants did not result in the observation of any safety significant issues. Lateral support spacings were somewhat longer than in plants typically designed for 0.1g OBE or 0.2g SSE 1 due primarily to the fact that the CR-3 plant safety related SSC consistent with the very low seismicity site are designed to only an 0.05g OBE and 0.10g SSE equivalent loading.

It should also be noted that CR-3 has the second lowest probalistically defined mean design basis ground acceleration levels of all nuclear power plants in the U.S. CR-3 has a 0.65×10^{-4}/yr probability[26] for a mean peak ground acceleration of 0.1g. This probability value is more conservative by a factor of more than 2.0 as compared to most nuclear power plants operating in the U.S. today and is less than the NRC's A-46 reevaluation criteria of 10^{-4}/yr.

It addition, CR-3 large bore safety related criteria was compared to the B31.1.0 designed piping observed in 8 power plants in California with approximately 400,000 feet of large bore pipe at risk[27]. These plants have experienced at least one of a total of 10 strong motion earthquake peak ground accelerations in excess of 0.2g (twice the CR-3 SSE equivalent) which have effected nuclear power plants in California since 1952. A total of 6 large bore pipe failures occurred in more than 400,000 feet of piping at risk in these 8 power plants. It should also be understood that most of the piping in these plants was not designed to resist any seismic load. The large bore safety related piping at Crystal River 3 is installed with considerably more seismic lateral support than that observed at the 8 power stations in California which successfully resisted seismic levels at least twice that used in design of CR-3 piping.

As a result of these installation comparisons it can be concluded that CR-3 safety related large bore piping is safe in a relative sense when compared to other nuclear power plants in the U.S. and is safe in an absolute sense when compared to large bore power plant piping which has experienced seismic excitations at least twice that which CR-3 piping is required to resist.

6.3 COMPARISON OF THE SAFETY MARGINS REQUIRED IN CURRENT DESIGN OF SAFETY RELATED PIPING IN NUCLEAR POWER PLANTS AND THAT USED AT CR-3

From a safety significance or design basis probability of failure stand point, existing CR-3 safety related large bore piping is much more resistant to seismic induced pipe failure than new nuclear power piping design currently required by the ASME and NRC pipe design criteria.

A task committee of the Design Subgroup of the Subcommittee on Nuclear Power (Section III) of the ASME Boiler and Pressure Code has been reviewing piping component seismic test data for the past two years in an attempt to establish design margins associated with current design of safety related nuclear power plant piping. The allowable stress in ASME Class 2 and 3 piping is limited to $3.0S_h$ as required by the NRC (since 1994 ASME has permitted a value of $4.5S_h$). With the allowable stress limit of $3.0S_h$ the test results indicate that there is a margin of at least 2 against a 10^{-2}/yr probability of failure induced by a design basis earthquake (SSE) using a R.G.1.60 based (spectral shape) and ASME Code Case N411 (damping).[27]

When coupled with the conditional mean probability of a design basis earthquake of 10^{-4}/yr this results in an estimated overall seismic induced probability of failure of safety related piping of between 10^{-7} to 10^{-8}/yr. This failure mode thus would contribute much less than one percent to the overall probability of core melt in nuclear power plants which typically ranges between 10^{-4} to 10^{-5}/yr in operating nuclear power plants. This failure contribution is considered negligible and therefore an acceptable design basis.

With regard to margins associated with CR-3 large bore piping, the seismic input as a function of spectral shape and damping values is approximately equal to the current R.G. 1.60 and ASME Code Case N-411 criteria as shown in Figure 1. When converted to floor spectra for design purposes the R.G.1.60 and Code Case N-411 compatible criteria typically yield floor spectra magnitudes which range from 0.67 to 0.5 of those used in the design of CR-3 piping.

The mean probability of occurrence of the SSE equivalent earthquake as defined by the peak ground acceleration for CR-3 is 0.65×10^{-4}/yr [25] which is considerably less than the NRC's A-46 reevaluation criteria of 1×10^{-4}/yr. In addition, the allowable stress in

CR-3 safety related large bore piping under the SSE equivalent earthquake is $1.2S_h$ as compared to the $3.0S_h$ currently permitted by both the ASME and the NRC design criteria for the SSE.

CR-3 piping design, because of the excessive conservatism contained in both the definition of the SSE equivalent zero period ground acceleration, the design basis floor spectra and the allowable piping stresses, results in piping failure probabilities which are several orders of magnitude less than currently required by ASME and NRC piping design criteria and therefore has resulted in an extremely safe design.

7.0 SUMMARY AND CONCLUSION

After review of the issues identified in Table 2 and 3 and Section 5 of this report, it can be concluded that CR-3 large bore safety related piping has been designed to a much more conservative criteria and installed in a manner similar to safety related piping of some 50 other operating nuclear power plants of the same vintage. The seismic safety of safety related piping in such plants has been validated by NRC studies conducted in the mid 1980's [7,8,9] and by walkdowns of power plant piping systems designed to the same construction code as used in CR-3 which have experienced actual earthquake motions at least twice as intense as that specified for design of CR-3[2,8].

However, the detailed documentation of the design basis and configuration management of "as built" piping systems does not meet current quality assurance expectations for safety related nuclear power plant piping at CR-3. For this reason, it is recommended that a reanalysis of large bore safety related piping be performed in order to document design adequacy of the existing piping and piping supports.

Of the 27 technical issues identified in Tables 2 and 3, and addressed in Section 5.1, Nine of them have been determined to beyond the state-of-the-art of the Code of Record used in the construction of the safety class pipe. The other issues would be addressed as part of a reanalysis effort or in separate effects studies. In addition to the comprehensive large bore project there should be 4 separate effects studies conducted which include:

(1) Evaluation of Welded Attachments
(2) Effect of Branch Pipe on Run Pipe
(3) Overlap Evaluations[2]
(4) Nozzle Load Allowables

in order to validate the assumptions and provide limiting loads or capacities as input to a reanalysis project.

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[2]See Attachment B for a preliminary evaluation.