HOPE CREEK GENERATING STATION UNIT 1

SAFETY EVALUATION FOR THE

ELIMINATION OF ARBITRARY

INTERMEDIATE PIPE BREAKS

Docket No. 50-354

SEPTEMBER 1985

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division Of Engineering
Mechanical Engineering Branch

TABLE OF CONTENTS

HOPE CREEK GENERATING STATION UNIT 1
SAFETY EVALUATION FOR THE ELIMINATION OF ARBITRARY INTERMEDIATE PIPE BREAKS

I. INTRODUCTION

In the "Background" to Branch Technical Position (BTP) MEB 3-1 as presented in Standard Review Plan (SRP) Section 3.6.2 (Ref.1), the staff position on pipe break postulation acknowledged that pipe rupture is a rare event which may only occur under unanticipated conditions such as those which might be caused by possible design, construction, or operation errors, unanticipated loads or unanticipated corrosive environments. The BTP MEB 3-1 pipe break criteria were intended to utilize a technically practical approach to ensure that an adequate level of protection had been provided to satisfy the requirements of 10 CFR Part 50 Appendix A, General Design Criterion (GDC) 4. Specific guidelines were developed in MEB 3-1 to define explicitly how the requirements of GDC 4 were to be implemented. The SRP guidelines in BTP MEB 3-1 were not intended to be absolute requirements but rather represent viable approaches considered to be acceptable by the staff.

The SRP provides a well-defined basis for performing safety reviews of light water reactors. The uniform implementation of design guidelines in MEB 3-1 assures that a consistent level of safety will be maintained during the licensing process. Alternative criteria and deviations from the SRP are acceptable provided an equivalent level of safety can be demonstrated. Acceptable reasons for deviations from SRP guidelines include changes in emphasis of specific guidelines as a result of new developments from operating experience or plant-unique design features not considered when the SRP guidelines were developed.

The SRP presents the most definitive basis available for specifying NRC's design criteria and design guidelines for an acceptable level of safety for light water reactor facility reviews. The SRP guidelines resulted from many years of experience gained by the staff in establishing and using regulatory requirements in the safety evaluation of nuclear facilities. The SRP is part of a continuing regulatory standards development activity that not only documents current methods of review, but also provides a basis for an orderly modification of the review process when the need arises to clarify the content, correct any errors, or modify the guidelines as a result of technical advancements or an accumulation of operating experience. Proposals to modify the guidelines in the SRP are considered for their impact on matters of major safety significance.

The staff has recently received a request from the applicant for Hope Creek Generating Station, Unit 1 (HCGS) to consider an alternate approach to the guidelines in SRP 3.6.2, MEB 3-1 regarding the postulation of intermediate pipe breaks (Ref. 2). For all high energy piping systems identified in Reference 2, the applicant proposes to eliminate from design considerations those breaks generally referred to as "arbitrary intermediate breaks" (AIBs) which are

defined as those break locations which, based on piping stress analysis results, are below the stress and fatigue limits specified in BTP MEB 3-1, but are selected to provide a minimum of two postulated breaks between the terminal ends of a piping system. The applicant has stated that occupational radiation exposure during inspection, maintenance and repair will be reduced over the life of the plant. The applicant is requesting approval of alternative pipe break criteria to provide the flexibility to remove or not to shim restraints in the future, if deemed necessary. However, the applicant has stated that the elimination of AIBs will not impact the environmental qualification of safety related equipment. The break postulation for environmental effects is performed independently of break postulation for pipe whip and jet impingement.

In the early 1970s when the pipe break criteria in MEB 3-1 were first drafted, the advantages of maintaining low stress and usage factor limits were clearly recognized, but it was also believed that equipment in close proximity to the piping throughout its run might not be adequately designed for the environmental consequences of a postulated pipe break if the break postulation proceeded on a purely mechanistic basis using only high stress and terminal end breaks. As the pipe break criteria were implemented by the industry, the impact of the pipe break criteria became apparent on plant reliability and costs as well as on plant safety. Although the overall criteria in MEB 3-1 have resulted in a viable method which assures that adequate protection has been provided to satisfy the requirements of GDC 4. it has become apparent that the particular criterion requiring the postulation of arbitrary intermediate pipe breaks can be overly restrictive and may result in an excessive number of pipe rupture protection devices which do not provide a compensating level of safety.

At the time the MEB 3-1 criteria were first drafted, high energy leakage cracks were not being postulated. In Revision 1 to the SRP (July 1981), the concept of using high energy leakage cracks to mechanistically achieve the environment desired for equipment qualification was introduced to cover areas which are below the high stress/fatigue limit break criteria and which would otherwise not be enveloped by a postulated break in a high energy line. In the proposed elimination of arbitrary intermediate breaks, the staff believes that the essential design requirement of equipment qualification is not only being retained but is being improved since all safety-related equipment is to be qualified environmentally, and furthermore certain elements of construction which may lead to reduced reliability are being eliminated.

In addition, some requirements which have developed over the years as part of the licensing process have resulted in additional safety margins which overlap the safety margin provided in the pipe break criteria. For example, the criteria in MEB 3-1 include margins to account for the possibility of flaws which might remain undetected in construction and to account for unanticipated piping steady-state vibratory loadings not readily determined in the design process. However, inservice inspection requirements for the life of the plant to detect flaws before they become critical, and staff positions on the vibration monitoring of safety-related and high energy piping systems during preoperational testing, further reduce the potential for pipe failures occurring from these causes.

Because of the recent interest expressed by the industry to eliminate the arbitrary intermediate break criteria and, particularly, in response to the submittals provided by several utilities including PSEG, the staff has reviewed the MEB 3-1 pipe break criteria to determine where such changes may be made.

II BASES FOR THE ELIMINATION OF ARBITRARY INTERMEDIATE PIPE BREAKS

In a letter from PSEG dated June 11, 1985 (Ref. 2), the applicant presents its request for the elimination of arbitrary intermediate breaks and the technical bases for its proposal. There is a general consensus in the nuclear industry that current knowledge and experience support the conclusion that designing for the arbitrary intermediate pipe breaks is not justified. The reasons for this conclusion are discussed in the following paragraphs.

1) Operating Experience Does Not Support Need for Criteria

The combined operating history of commercial nuclear plants (extensive operating experience in over 80 operating U.S. plants and a number of similar plants overseas) has not shown the need to provide protection from the dynamic effects of arbitrary intermediate breaks.

2) Piping Stresses Well Below ASME Code Allowables

Currently, AIBs are postulated to provide a minimum of two pipe breaks at the two highest stress locations between piping terminal ends. Consequently, arbitrary intermediate breaks are postulated at locations in the piping system where pipe stresses and/or cumulative usage factors are well below ASME Code allowables. Such postulation necessitates the installation and maintenance of complicated mitigating devices to afford protection from dynamic effects such as pipe whip and/or jet impingement. When these selected break locations have stress levels only slightly greater than the rest of the system, installation of mitigating devices lends little to enhance overall plant safety.

3) Unanticipated Thermal Expansion Stress

Unanticipated stresses due to restraint of thermal expansion can be introduced into the piping system if pipe rupture protection devices come into contact with the pipes. The potential for this happening is greater than that for mechanistic failure at an arbitrary break point. To prevent a consequent decrease in the overall reliability of the pipe system, an additional as-built verification step is involved in the design process for each installed pipe whip restraint. Elimination of AIBs would significantly reduce the effort involved in designing and installing pipe rupture protection devices.

4) Access

Access during plant operation for maintenance and inservice inspection activities can be improved due to the elimination of congestion created by these pipe rupture protection devices and the supporting structural steel associated with arbitrary pipe breaks.

5) Reduction in Radiation Exposure

In addition to the decrease in maintenance effort, a corresponding reduction in man-rem exposure can be realized from fewer manhours spent in radiation areas, per ALARA.

6) Decrease in Heat Loss

The elimination of pipe whip restraints associated with arbitrary breaks will preclude the requirement for cutback insulation or special insulating assemblies near the close fitting restraints. This will reduce the heat loss to the surrounding environment, especially inside containment.

III STAFF EVALUATION OF THE BASES FOR THE ELIMINATION OF ARBITRARY BREAKS

The technical bases for the elimination of the arbitrary intermediate break criteria as discussed in the preceding section of this report provided many arguments supporting the applicant's conclusion that the current SRP guidelines on this subject should be changed. However, it is not apparent that a unilateral position by the utility concluding an unconditional deletion of the arbitrary intermediate break criteria can be justified without a clear understanding of the safety implications that may result for the various classes of high energy piping systems involved. In this section, we will discuss the bases behind the current arbitrary intermediate break criteria from an ASME Code design standpoint and put into perspective the uncertainty factors on which the need to postulate arbitrary intermediate breaks should be evaluated.

While the ASME Code design requirements for Class 1 piping systems differ from those for Class 2 and 3 piping systems, there are other design considerations that are common to Class 1, 2 and 3 systems. These other design considerations (viz. (1) intergranular stress corrosion cracking, (2) water/steam hammer, and (3) thermal fatigue can affect the safety of the systems in which AIBs are eliminated. Therefore, while evaluating the acceptabiltity of the applicant's proposed deviation from SRP Section 3.6.2, we have examined the significance of the above three additional design considerations for the specific Hope Creek piping systems proposed by the applicant for elimination of AIBs.

ASME Code Class 1 Piping Systems

In accordance with BTP MEB 3-1 (paragraph B.1.c.(1)) breaks in ASME Code Class 1 piping should be postulated at the following locations in each piping and branch run:

(a) at terminal ends;

(b) at intermediate locations where the maximum stress range as calculated by Eq. (10) and either Eq. (12) or (13) of ASME Code NB-3650 exceeds 2.4 Sm;

(c) at intermediate locations where the cumulative usage factor exceeds 0.1.

(d) If two intermediate locations cannot be determined by (b) and (c) above, two highest stress locations based on Eq. (10) should be selected.

The arbitrary intermediate break criteria are stated in (d) above. It should be noted that the request for alternative criteria does not propose to deviate from the criteria in (a), (b), and (c) above. Pipe breaks will continue to be postulated at terminal ends irrespective of the piping stresses.

Pipe breaks are to be postulated at intermediate locations where the maximum stress range as calculated by Eq. (10) and either (12) or (13) exceeds 2.4 Sm. The stress evaluation in Eq. (10) represents a check of the primary plus secondary stress intensity range due to ranges of pressure, moments, thermal gradients and combinations thereof. Equation (12) is intended to prevent formation of plastic hinges in the piping system caused only by moments due to thermal expansion and thermal anchor movements. Equation (13) represents a limitation for primary plus secondary membrane plus bending stress intensity excluding thermal bending and thermal expansion stresses; this limitation is intended to assure that the K_e - factor (strain concentration factor) is conservative. The K_e - factor was developed to compensate for absence of elastic shakedown when primary plus secondary stresses exceed 3 Sm.

With respect to piping stresses, the pipe break criteria were not intended to imply that breaks will occur when the piping stress exceeded 2.4 Sm (80% of the primary plus secondary stress limit). It is the staff's belief, however, that if a pipe break were to occur (in one of those rare occasions), it is more likely to occur at a piping location where there is the least margin to the ultimate tensile strength.

Similarly, from a fatigue strength standpoint, the staff believes that a pipe break is more likely to occur where the piping is expected to experience large cyclic loadings. Although the staff concurs with the industry belief that a cumulative usage factor of 0.1 is a relatively low limit, the uncertainties involved in the design considerations with respect to the actual cyclic loadings experienced by the piping tend to be greater than the uncertainties involved in the design considerations used for the evaluation of primary and secondary stresses in piping systems. The staff finds that the conservative fatigue considerations in the current SRP guidelines provide an appropriate margin of safety against uncertainties for those locations where fatigue failures are likely to occur (e.g. at local welded attachments).

ASME Code Class 2 and 3 Piping Systems

In accordance with MEB 3-1 [paragraph B.1.c.(2)] breaks in ASME Code Class 2 and 3 piping should be postulated at the following locations:

(a) at terminal ends

(b) at intermediate locations selected by one of the following criteria:

(i) at each pipe fitting, welded attachment, and valve
(ii) at each location where the stresses exceed 0.8 (1.2 S_h + S_A) but at not less than two separated locations chosen on the basis of highest stress.

In its proposal the applicant has not proposed changing criterion (a) above. Postulation of pipe breaks at terminal ends will not be eliminated in the proposed SRP deviation for Class 2 and 3 piping systems.

The "arbitrary intermediate break criteria" is stated in (b)(ii) above where breaks are to be postulated at intermediate locations where the stresses exceed 0.8 (1.2 S_h + S_A) but "at not less than two separated locations chosen on the basis of highest stress." The stress limit provided in the above pipe break criterion represents the stress associated with 80% of the combined primary and secondary stress limit. Thus, a break is required to be postulated where the maximum stress range as calculated by the sum of Equation (9) and (10) of NC/ND-3652 of the ASME Code, Section III, exceeds 80% of the combined primary and secondary stress limit, when we consider those loads and conditions for which level A and level B stress levels have been specified in the system's design specification (i.e. sustained loads, occasional loads, and thermal expansion) including an operating basis earthquake (OBE) event. However, the Class 2 and 3 pipe break criteria do not have a provision for the postulation of pipe breaks based on a fatigue limit since an explicit fatigue evaluation is not required in the ASME Code for these classes of construction because of favorable service experience and lower levels of operating cyclic stresses.

For those Class 2 and 3 piping systems which experience a large number of stress cycles (e.g., main steam and feedwater systems), the ASME Code has provisions which are intended to address these types of loads. The rules governing considerations for welded attachments in ASME Class 2 and 3 piping which do preclude fatigue failure are partially given in paragraph NC/ND-3645 of the ASME Code. The Code states:

> "External and internal attachments to piping shall be designed so as not to cause flattening of the pipe, excessive localized bending stresses, or harmful thermal gradients in the pipe wall. It is important that such attachments be designed to minimize stress concentrations in applications where the number of stress cycles, due either to pressure or thermal effect, is relatively large for the expected life of the equipment."

Code rules governing the fatigue effects associated with general bending stresses caused by thermal expansion are addressed in NC/ND-3611.2(e) and are generally incorporated into the piping stress analyses in the form of an allowable stress reduction factor.

Thus it can be concluded that when the piping designers have appropriately considered the fatigue effects for Class 2 and 3 piping systems in accordance with NC/ND-3645, the likelihood of a fatigue failure in Class 2 and 3 piping caused by unanticipated cyclic loadings can be significantly reduced.

Additional Design Considerations

In its presentation to the ACRS on June 9, 1983 and in an October 5, 1983 meeting between a group of PWR near-term operating license utilities and the NRC staff, the staff indicated that the elimination of arbitrary intermediate breaks was not to apply to piping systems in which stress corrosion cracking, large unanticipated dynamic loads such as steam or water hammer, or thermal fatigue in fluid mixing situations could be expected to occur. In addition, the elimination of arbitrary intermediate breaks was to have no effect on the requirement to environmentally qualify safety-related equipment and in fact this requirement was to be clarified to assure positive qualification requirements.

(a) Intergranular Stress Corrosion Cracking

At HCGS, the applicant has taken steps to minimize the potential for intergranular stress corrosion cracking (IGSCC) in high energy lines. The IGSCC potential is likely to be reduced if the following factors are controlled: high residual tensile stresses, susceptible piping material and a corrosive environment. The NRC Piping Review Committee (NUREG-1061, Vol. 5, April 1985) has indicated the type of materials that are considered resistant to IGSCC. For example, stainless steel types 304L, 308L and 316L are considered resistant to IGSCC. In addition, certain treatments given to the materials also will make them resistant to IGSCC. Also, certain mitigating processes applied to the welds may reduce the likelihood of IGSCC.

The applicant has reported in Reference 2 that only a low carbon content stainless steel (type 304L) has been used in the portion of the RHR system connecting to the Recirculation system. The remainder of the affected system piping is ferritic carbon steel that has been found not to be susceptible to IGSCC. Furthermore, the applicant has taken steps to minimize the existence of a corrosive environment by specifying stringent criteria for internal and external cleaning and by controlling the water chemistry during power ascension and normal operation.

NUREG-1061 (NRC Piping Review Committee Report, Vol 5) indicates that, in the event that any unanticipated severe conditions occur, the break would most likely be located at terminal ends, at connections to components, and at other locations that introduce higher stress concentration or that exceed the stated

threshold limits specified in SRP 3.6.2. Since breaks are postulated for these locations, the staff concurs with the applicant's conclusion that elimination of AIBs would not introduce adverse effects.

(b) Water/Steam Hammer

According to Reference 3 (NUREG-0927), BWR plants report a higher frequency of water/steam hammer events than PWR plants primarily because of two factors: line voiding and presence of steam-water interfaces in BWRs. Line voiding was the largest single cause of BWR water hammers and was responsible for at least 39 of the 69 unanticipated water hammer events in BWR plants that were reported from 1969 through mid-1981. Reference 3 also reports that the addition of keep-full systems to BWR plants has reduced the frequency of water hammers. Keep-full systems continuously supply water to idle lines to prevent voiding.

The applicant has incorporated several water hammer minimization features into piping design operations at HCGS. The discharge lines of the Residual Heat Removal System, Low Pressure Coolant Injection System, High Pressure Coolant Injection (HPCI) System, Core Spray System (CS) and Reactor Core Isolation Cooling (RCIC) System are maintained in a full condition. They are kept full up to the injection isolation valves by jockey pumps. Beyond the injection isolation valves, the line is not drained when the system is on standby, thus, maintaining the discharge lines full (Ref.4). The feedwater system is started with flow intitially through bypass and recirculation lines to avoid water hammer during startup. During operation the lines will remain filled thus minimizing the potential for water hammer. The reactor water cleanup system is continuously in operation to purify the reactor water and the lines will be kept full minimizing the potential for water hammer.

The applicant has reported that the main steam, HPCI and RCIC steam lines that experience transients as a result of fast valve closure, have been designed to accommodate the effects of these loadings (Ref. 2). The steam supply lines are sloped to allow moisture collecting in the lines to drain to a collecting pot. The main steam isolation valve drain lines are sloped such that any condensate collecting in the lines will drain to the condenser.

As stated in Reference 4, the applicant has committed to conduct piping preoperational and start-up testing for steam and water hammer. The staff concurs with the applicant's conclusion that the design features and operating procedures described above will minimize the potential for water/ steam hammer occurrence in several systems discussed above.

(c) Thermal Fatigue

The applicant has concluded, and the NRC staff concurs, that the systems for which AIBs are to be eliminated are not susceptible to thermal fatigue and mixing for the following reasons:

1) The fatigue analysis performed by the applicant for all Class 1 piping systems shows that all of the Class 1 AIB locations involve cumulative usage factors well below the AIB postulation limit of 0.1 (Ref.5). For Class 2 and 3 piping components, fatigue failure protection is assured by the allowable stress range checks and a stress range reduction factor for thermal expansion stress. The mandatory breaks are postulated at 80 percent of the Code allowable stresses, even after eliminating the AIBs identified in Reference 2.

2) The applicant has minimized the cyclic thermal stresses and the resultant thermal fatigue in the HCGS piping systems by limiting the mixing of low velocity, low temperature water with high temperature water. The piping systems for which AIBs are to be eliminated will not exhibit temperature gradients due to flow stratification (Ref.5). The applicant has come to this conclusion based on a review that showed that one or more of the following conditions exist:

   (a) the affected pipes have no flow during normal plant operation (eg. HPCI, RCIC),

   (b) the piping layout consists of vertical runs or sloped horizontal runs with valves and fittings to promote mixing,

   (c) the piping is preheated (eg. HPCI and RCIC steam supply lines) to minimize thermal stresses during system initiation.

<u>Class 1 Piping Systems Evaluation</u>

For Class 1 piping, a considerable amount of quality assurance in design, analyses, fabrication, installation, examination, testing, and documentation is provided which ensures that the safety concerns associated with the uncertainties discussed above are significantly reduced. Based on the staff evaluation of the design considerations given to Class 1 piping, the stress and fatigue limits provided in the MEB 3-1 break criteria, and the relatively small degree of uncertainty in unanticipated loadings, the staff finds that the need to postulate arbitrary intermediate pipe breaks in ASME Code Class 1 piping in which large unanticipated dynamic loads, stress corrosion cracking, and thermal fatigue such as in mixing situations are not present and in which all equipment has been environmentally qualified is not compensated for by an increased level of safety. In addition, systems may actually perform more reliably for the life of the plant if the SRP criterion to postulate arbitrary intermediate breaks for ASME Code Class 1 piping is eliminated. The staff has concluded that the above described requirements are present for those ASME Code Class 1 piping systems identified in the applicant's submittal of June 11,1985 (Reference 2).

Class 2 and 3 Piping Systems Evaluation

Based on the staff evaluation of the design considerations given to Class 2 and 3 piping, the stress limits provided in the SRP break criterion, and the relatively small degree of uncertainty in unanticipated loadings the staff finds that dispensing with arbitrary intermediate pipe breaks is justified for Class 2 and 3 piping in which stress corrosion cracking, large unanticipated dynamic loads, or thermal fatigue in fluid mixing situations are not expected to occur provided 1) the piping designers have appropriately considered the effects of local welded attachments per NC/ND-3645, and 2) all safety-related equipment in the vicinity of Class 2 and 3 piping systems have been environmentally qualified for the non-dynamic effects of a non-mechanistic pipe break with the greatest consequences on the equipment. The staff has concluded that the above described requirements are present for those ASME Code Class 2 and 3 piping systems identified in the applicant's letter dated June 11, 1985 (Reference 2).

Piping Systems Not Included in Proposal

For those piping systems, or portions thereof, which are not included in the applicant's submittal (Reference 2), the staff requires that the existing guidelines in BTP MEB 3-1 of the SRP (NUREG-0800) Revision 1 be met. However, should other piping lines which are not specifically identified in the applicant's submittal (Reference 2) subsequently qualify for the conditions described above, the implementation of the proposed elimination of the arbitrary intermediate break criteria may be used provided those additional piping lines are appropriately identified to the staff.

Conclusion

The applicant has proposed a deviation from the current guidelines of the SRP by requesting relief from postulating arbitrary intermediate pipe breaks in high energy piping systems which are not susceptible to intergranular stress corrosion cracking, steam or water hammer effects and thermal fatigue in fluid mixing. The SRP guideline which requires that two intermediate breaks be postulated even when the piping stress is low resulted from the need to assure that equipment qualified for the environmental consequences of a postulated pipe break was provided over a greater portion of the high energy piping run. This proposal is based, in part, on the condition that all equipment in the spaces traversed by the fluid system lines, for which arbitrary intermediate breaks are being eliminated, is qualified for the environmental (non-dynamic) conditions that would result from a non-mechanistic break with the greatest consequences on surrounding equipment. In addition, the applicant has committed to perform preoperational testing of all the systems identified in Reference 2 and also monitor those systems for vibration during preoperational and startup testing.

The staff has evaluated the technical bases for the proposed deviation with respect to satisfying the requirements of GDC 4. Furthermore, the staff has considered the potential problems identified in NUREG/CR-2136 (Ref. 6) which could impact overall plant reliability when excessive pipe whip restraints are installed. Based on its review, the staff finds that when those piping system conditions as stated above are met, there is a sufficient basis for concluding that an adequate level of safety exists to accept the proposed deviation.

Thus, based on the piping systems having satisfied the above conditions, the staff concludes that the pipe rupture postulation and the associated effects are adequately considered in the design of the Hope Creek Generating Station Unit 1 and, therefore, the deviation from the Standard Review Plan is acceptable.

REFERENCES

1) "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants", NUREG-0800 (Revision 1) dated July 1981.

2) Letter from R.L. Mittl, PSEG, to W. Butler NRC, subject, "Elimination of "Arbitrary Intermediate Pipe Breaks Hope Creek Generating Station," dated June 11, 1985

3) "Evaluation of Water Hammer Occurrence in Nuclear Power Plants," NUREG-0927 (Revision 1) dated March 1984.

4) Letter from R.L. Mittl, to W. R. Butler, NRC, subject, "Elimination of "Arbitrary Intermediate Pipe Breaks Hope Creek Generating Station," dated August 9, 1985.

5) Letter from R.L. Mittl to W. R. Butler, NRC, subject, "Elimination of "Arbitrary Intermediate Pipe Breaks Hope Creek Generating Station ," July 3, 1985.

6) "Effect of Postulated Event Devices on Normal Operation of Piping Systems in Nuclear Power Plants", NUREG/CR-2136 dated May 1981.