SHEARON HARRIS NUCLEAR POWER PLANT UNIT 1

SAFETY EVALUATION FOR THE

ELIMINATION OF ARBITRARY

INTERMEDIATE PIPE BREAKS

Docket No. 50-400

June 1985

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

TABLE OF CONTENTS

SHEARON HARRIS NUCLEAR POWER PLANT 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 Carolina Power & Light (CP&L), the applicant for Shearon Harris Nuclear Power Plant, Unit 1 (SHNPP), to consider an alternate approach to the existing 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 refs. 2 and 3 at SHNPP the applicant proposes to eliminate from design considerations those breaks generally referred to as "arbitrary intermediate breaks" (AIBs) which are defined as those 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 documented the cost savings and reduced radiation exposure benefits resulting from the elimination of the structures associated with the protection against the effects of pipe rupture. The applicant has further stated that all dynamic effects associated with previously postulated arbitrary intermediate pipe breaks will be excluded from the plant design basis and that pipe whip restraints associated with previously postulated arbitrary intermediate breaks will be eliminated. However, the applicant has stated that pipe breaks related to equipment qualification (EQ) requirements will not be affected by elimination of AIBs. Breaks are postulated non-mechanistically for EQ purposes.

In the early 1970's 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 detailed submittals provided by several utilities including CP&L, 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

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 bases 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 not only lends little to enhance overall plant safety, but also provides the potential for inadvertent restraints of piping during thermal growth and seismic motion.

3) Arbitrary Intermediate Breaks Complicate the Design Process

The design of piping systems is an iterative process and, therefore, the location of the highest stress points usually change several times during design. Although SRP Section 3.6.2 (Ref. 1) provides criteria intended to reduce the need to relocate the intermediate break locations when high stress points shift due to piping reanalysis, in practice, these criteria provide little relief from moving arbitrary break locations since the revised break locations must still be evaluated as to their effects on essential equipment and structures.

4) Substantial Cost Savings

The cost benefits to be realized from the elimination of the arbitrary intermediate break locations center primarily on the elimination of the associated pipe whip restraints. While a substantial reduction (approx. $3.0 million) in capital and engineering costs for these restraints and structures can be realized in the design and construction stages of the plant, there are also significant operational benefits to be realized over the 40 year life of the plant, as reduced manhours for inservice inspection and maintenance will result.

5) Improved Inservice Inspection

Pipe whip restraints are normally located adjacent to or surrounding the welds at changes in pipe direction. Access during plant operation for inservice inspection activities can be improved due to the elimination of congestion created by these pipe rupture protection devices and the supporting structural framing associated with arbitrary pipe breaks.

6) Reduction in Radiation Exposure

In the event of a radioactive release or spill inside the plant, decontamination operations could be more effective if the pipe whip restraints and jet shields associated with AIBs and the large structural frameworks supporting the restraints were eliminated. Recovery from unusual plant conditions would also be improved by reducing the congestion in the plant. A significant reduction in man-rem exposure can be realized through fewer man hours spent in radiation areas.

The applicant, as part of its justification for the elimination of arbitrary intermediate breaks has estimated that the reduction in operational radiation exposure due to elimination of arbitrary intermediate pipe breaks and the resulting decrease in pipe whip restraints over the 40 year life of the plant will be 150 to 180 person-rem (Refs. 2 & 3).

7) Improved Operational Efficiency

The elimination of pipe whip restraints associated with arbitrary breaks will reduce the heat loss due to better insulation of the piping at points where pipe whip restraints are deleted. There would also be a concurrent reduction in building cooling costs.

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 provide 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. We further evaluate the acceptability of the applicant's proposed deviation from SRP Section 3.6.2

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).

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.

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 the 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 February 13, 1985 (Reference 2).

<u>ASME Code Class 2 and 3 Piping Systems</u>

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. Breaks are required to be postulated at terminal ends irrespective of piping stresses.

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. The applicant has stated in Appendix B to its February 13, 1985 submittals that fatigue effects were considered to Class 2 and 3 piping systems in accordance with the applicable provisions of the ASME Code, Section III. The staff has concluded that this representation is acceptable.

Because of the susceptibility to water hammer of main feedwater (FW) systems in several nuclear plants, the applicant has incorporated water hammer minimization/prevention features into the design and operation of the main FW piping system at SHNPP (Ref. 3). The SHNPP steam generators (SG) are Westinghouse Model D-4 and are characteristically called "bottom feed" or "preheat" steam generators. The main FW supply enters at the preheater located at the bottom. Auxiliary feedwater (AFW) is provided through an AFW nozzle above the U-tubes.

As stated in SHNPP SER Section 10.4.7 (NUREG-1038), the condensate and feedwater system is designed with features to preclude the potential for damaging flow instabilities (water hammer). The applicant has also agreed to follow the guidance in Branch Technical Position ASB 10-2 by performing tests to verify that unacceptable feedwater hammer will not occur when the plant operating procedures are being used for normal and emergency restoration of steam generator waterlevel following a loss of normal feedwater in accordance with the recommendations of NUREG/CR-1066. SER Section 10.4.9 states that the Auxiliary Feedwater System (AFWS) is designed to supply water to the steam generators without flow throttling, thus avoiding throttling as a potential source of water hammer. Water hammer is prevented by filling lines with water before AFW system startup. The suction and discharge side of the AFWS will be kept full because of the higher elevation of the condensate storage tank (CST) that is the primary water supply source while the discharge side of the AFWS pumps will be full of water because of leaks through pumps and valves, as stated in NUREG-1038. The applicant states that vents have been provided at all high points and that these are opened before startup of any test to vent any trapped air. The applicant has stated (Ref. 3) that it has performed necessary analyses and designed the piping/supports to accommodate the loads resulting from rapid closure of the FW isolation and FW control valves. Based on the above information, the staff has concluded that the Shearon Harris main feedwater piping has been designed to minimize the occurrence of water hammer.

Based on the staff evaluation of the load uncertainties, the design considerations given to Class 2 and 3 piping, and the stress limits provided in the SRP break criterion, 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. This finding is based on appliants representation in references 2 and 3 that 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. Therefore, the requested deviation from the SRP for Class 2 and 3 is acceptable.

Piping Systems Not Included in Proposal

For those piping systems, or portions thereof, which are not included in the applicant's submittals (References 2 & 3), 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 submittals (Reference 2 & 3) 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 References 2 and 3 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. 4) 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 Shearon Harris Nuclear Power Plant, Unit 1 and, therefore, the deviation from the Standard Review Plan is acceptable.

IV 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 A. B. Cutter, CP&L, to H. R. Denton, NRC, subject, "Elimination of Postulated Arbitrary Intermediate Breaks in Class 1, 2, and 3 Pipes," dated February 13, 1985.

3) Letter from A. B. Cutter, CP&L, to H. R. Denton, NRC, subject, "Elimination of Postulated Arbitrary Intermediate Breaks in the Main Feedwater System," dated February 13, 1985.

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