LASALLE COUNTY STATION UNITS 1 AND 2

SAFETY EVALUATION FOR THE

ELIMINATION OF ARBITRARY

INTERMEDIATE PIPE BREAKS

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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 licensee for LaSalle County Station (LCS) Units 1 and 2 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 ASME Code Class 1 high energy piping systems

identified in Reference 2, the licensee 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 licensee has documented the benefits such as reduced radiation exposure benefits resulting from the elimination of the structures associated with the protection against the effects of pipe rupture. Since pipe whip restraints associated with previously postulated AIBs are already in place, those restraints determined not required would be removed as access time and ALARA considerations allow during plant shut down conditions. However, the licensee 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 CECo, 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 CECo dated April 30, 1985 (Ref. 2), the licensee presents its request for the elimination of arbitrary intermediate breaks in certain ASME Code Class 1 piping systems 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 licensee'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 ASME Code Class 1 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 in ASME Code Class 1 piping systems 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 licensee's proposed deviation from SRP Section 3.6.2, we have examined the significance of the above three additional design considerations for the specific LaSalle piping systems proposed by the licensee 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 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).

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 LaSalle, the licensee 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.

There are only four piping systems in which the licensee proposes elimination of AIBs (Ref. 2). Of these four, the main steam and reactor water cleanup systems are made from carbon steel which is not considered susceptible to IGSCC. The third system, main steam miscellaneous piping is made from low alloy steel in which the alloy used (5% Cr, 1/2 % Mo) has erosion inhibiting characteristics. A portion of the fourth system, Residual Heat Removal (RHR) system, is made of 304 stainless steel (304SS), while the rest of this system is made from carbon steel. The staff believes that the portion of RHR system made from 304SS may be susceptible to IGSCC. There is only one break and one associated pipe whip restraint in this portion of the RHR system. The NRC staff does not accept elimination of this one break and the associated pipe whip restraint, and has informed the licensee of this position in a telecon with the licensee's staff on August 22, 1985.

NUREG-1061 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 licensee's conclusion that elimination of AIBs (except the one in the portion of the RHR system made from 304SS) 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 atleast 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 licensee has incorporated several water hammer minimization features into piping design operations at LCS (Ref. 2). The discharge lines of the ECCS are maintained in a full condition. They are kept full up to the discharge valves by fill pumps (i.e., jockey pumps to replace any leakage from the lines). Beyond the discharge valves, the line is not drained when the system is on standby, thus, maintaining the discharge lines full. The High Pressure Core Spray (HPCS) system is motor-operated and has no steam supply line.

In the Reactor Core Isolation Cooling (RCIC) system, water hammer will be prevented during RCIC startup by sequentially opening the RCIC steam supply isolation valves, as described in detail in Reference 2. Additionally, the steamlines are built sloping downward so that any condensation in the lines may drain off to drain pots when the system is not operating. Therefore, the steam supply line will be a dry steam line even after a cold shutdown. Hence the steam supply line will be at the reactor temperature corresponding to 50 psi when the inboard isolation valve is opened, thus preventing water hammer. As the reactor pressure increases, the temperature of the line will increase, matching the corresponding saturation points (Ref. 2).

The licensee has reported that the main steam and feedwater systems are expected to experience steam and water hammer loadings, respectively. However, it has analyzed these loadings and designed these systems to accommodate and minimize the effects of these loadings.

The staff concurs with the licensee'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

For ASME Code Class 1 pipelines, the licensee has defined anticipated flow conditions that could result in piping thermal transient stresses. It has calculated these stresses and included them in cumulative usage factors (which are required to be less than 0.1 for all AIB locations).

Class 1 Piping Systems Evaluation

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 fluid 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 licensee's submittal of April 30, 1985 (Reference 2), except that portion of the RHR system constructed with 304SS material.

Piping Systems Not Included in Proposal

For those piping systems, or portions thereof, which are not included in the licensee'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 licensee'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 licensee 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. Preoperational and startup piping vibration programs have been successfully completed at LaSalle Units 1 and 2.

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 specified portions of 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 LaSalle County Station Units 1 and 2, and, therefore, the deviation from the Standard Review Plan is acceptable for the piping systems identified in Reference 2 except for that portion of the RHR system made of 304SS material.

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 J. G. Marshall, CECo, to H. R. Denton, NRC, subject, "Proposed Elimination of Pipe Whip Restraints Associated with Arbitrary Intermediate Pipe Breaks," dated April 30, 1985.

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

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