November 8, 1982

Docket No. 50-409
LS05-82-11-021

Mr. Frank Linder
General Manager
Dairyland Power Cooperative
2615 East Avenue South
LaCrosse, Wisconsin 54601

Dear Mr. Linder:

SUBJECT: SEP TOPIC III-5.A, EFFECTS OF PIPE BREAK ON STRUCTURES, SYSTEMS AND COMPONENTS INSIDE CONTAINMENT LACROSSE BOILING WATER REACTOR

In your letter dated February 24, 1982 (LAC-8113), you submitted a safety assessment report on the above topic. We have completed our evaluation which is enclosed. We conclude that the plant is adequately protected from the dynamic effects of pipe break inside containment subject to resolution of the following in the Integrated Plant Safety Assessment.

1. Clarification concerning the effects of jet impingement and pipe whip motion on mitigating systems.

2. Confirmation that the portion of the steel vessel not protected by the 9" concrete would not be damaged by any postulated high energy line breaks.

3. Installation of a valve on decay heat cooling system blowdown line to the main condenser and administrative controls to maintain it in a closed position during power operation.

4. Acceptability of damage to control rod drive mechanisms from postulated high energy line breaks.

5. Resolution of postulated breaks in boron injection system piping damaging the containment ventilation exhaust damper operators.

6. Justification of the design adequacy of anchor bolts for the existing pipe whip restraints in the Alternate Core Spray (ACS) lines.

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The need to actually implement changes as a result of these items will be determined during the integrated safety assessment. This safety evaluation may be revised in the future if your facility design is changed or if NRC criteria relating to this topic are modified before the integrated assessment is completed.

Sincerely,

Original signed by:

Dennis M. Crutchfield, Chief
Operating Reactors Branch No. 5
Division of Licensing

Enclosure:
As stated

cc w/enclosure:
See next page

SEPB
CGrimes
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OFFICE	SEPB	SEPB	SEPB	SEPB	SEPB	ORB#5	ORB#5
SURNAME	PYChen:bl	EMcKenna	TMichaels	RHermann	WRussell	RDudley	DCrutchfield
DATE	10/19/82	10/22/82	10/22/82	10/27/82	10/28/82	10/ /82	11/8/82

Docket No. 50-409
LaCrosse
Revised 8/82

Mr. Frank Linder

cc
Fritz Schubert, Esquire
Staff Attorney
Dairyland Power Cooperative
2615 East Avenue South
La Crosse, Wisconsin 54601

O. S. Heistand, Jr., Esquire
Morgan, Lewis & Bockius
1800 M Street, N. W.
Washington, D. C. 20036

Mr. John Parkyn
La Crosse Boiling Water Reactor
Dairyland Power Cooperative
P. O. Box 275
Genoa, Wisconsin 54632

Mr. George R. Nygaard
Coulee Region Energy Coalition
2307 East Avenue
La Crosse, Wisconsin 54601

Dr. Lawrence R. Quarles
Kendal at Longwood, Apt. 51
Kenneth Square, Pennsylvania 19348

U. S. Nuclear Regulatory Commission
Resident Inspectors Office
Rural Route #1, Box 276
Genoa, Wisconsin 54632

Town Chairman
Town of Genoa
Route 1
Genoa, Wisconsin 54632

Chairman, Public Service Commission
of Wisconsin
Hill Farms State Office Building
Madison, Wisconsin 53702

U. S. Environmental Protection
Agency
Federal Activities Branch
Region V Office
ATTN: Regional Radiation Representative
230 South Dearborn Street
Chicago, Illinois 60604

James G. Keppler, Regional Administrator
Nuclear Regulatory Commission, Region III
799 Roosevelt Road
Glen Ellyn, Illinois 60137

Mr. Ralph S. Decker
Route 4, Box 190D
Cambridge, Maryland 21613

Charles Bechhoefer, Esq., Chairman
Atomic Safety and Licensing Board
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dr. George C. Anderson
Department of Oceanography
University of Washington
Seattle, Washington 98195

SEP EVALUATION

OF

EFFECTS OF PIPE BREAK ON STRUCTURES, SYSTEMS AND COMPONENTS INSIDE CONTAINMENT

TOPIC III-5.A

FOR

LA CROSSE BOILING WATER REACTOR

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SYSTEMATIC EVALUATION PROGRAM

TOPIC III-5.A

LACROSSE BOILING WATER REACTOR

TOPIC: III-5.A, Effects of Pipe Break on Structures, Systems and Components Inside Containment

I. INTRODUCTION

The safety objective of Systematic Evaluation Program (SEP) Topic III-5.A, "Effects of Pipe Break on Structures, Systems and Components Inside Containment," is to assure that pipe breaks would not cause the loss of required functions of "safety-related" structures, systems and components and to assure that the plant can be safely shutdown in the event of such breaks. The required functions of "safety-related" systems are those functions required to mitigate the effects of the pipe break and safely shutdown the plant.

II. REVIEW CRITERIA

General Design Criterion 4 (Appendix A to 10 CFR 50) requires in part that structures, systems and components important to safety be appropriately protected against dynamic effects, such as pipe whip and discharging fluids, that may result from equipment failures.

III. RELATED SAFETY TOPICS AND INTERFACES

1. This review complements that of SEP Topic VII-3, "Systems Required for Safe Shutdown."

2. The environmental effects of pressure, temperature, humidity, and flooding due to postulated pipe breaks are evaluated under USI A-24, "Environmental Qualification of Safety-Related Equipment."

3. The effects of potential missiles generated by fluid system ruptures and rotating machinery are evaluated under SEP Topic III-4.C, "Internally Generated Missiles."

4. The effects of containment pressurization are evaluated under SEP Topic VI-2.D, "Mass and Energy Release for Possible Pipe Break Inside Containment."

5. The original plant design criteria in the areas of seismic input, analysis, and design criteria are evaluated under SEP Topic III-6, "Seismic Design Considerations."

6. The effects of core cooling are evaluated under SEP Topic XV-19, "Loss of Coolant Accidents Resulting from Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary."

IV. REVIEW GUIDELINES

The current criteria for review of pipe breaks inside containment are contained in Standard Review Plan 3.6.2, "Determination of Break Locations and Dynamic Effects Associated with the Postulated Rupture of Piping," including its attached Branch Technical Position, Mechanical Engineering Branch 3-1 (BTP MEB 3-1).

The licensee's break location criteria and methods of analysis for evaluating postulated breaks in high energy piping systems inside containment have been compared with the currently accepted review criteria as described in Section II above. The review relied upon information submitted by the licensee, Dairyland Power Cooperative, in Reference 1.

The scope of review under this topic was limited to avoid duplication of effort since some aspects of the topic were previously reviewed by the staff or are included under other SEP topics (see III above).

When differences from the review criteria are identified, engineering judgement is utilized to evaluate the consequences of postulated pipe break and to assure that pipe break would not cause the loss of required function of "safety-related" structures, systems and components and to assure that the plant can be safely shutdown in the event of such break.

V. EVALUATION

A. Background

On July 20, 1978, the SEP Branch sent a letter (Reference 2) to KMC, Inc. requesting an analysis of the effects of postulated pipe breaks on structures, systems and components inside containment. In that letter, the staff included a position that stated three approaches were appropriate for postulating breaks in high energy piping systems (either $P \geq 275$ psig or $T \geq 200°F$). The approaches are:

1. Mechanistic
2. Simplified Mechanistic
3. Effects Oriented

The staff further stated that combinations of the three approaches could be utilized if justified.

In response to our letter, the licensee submitted Reference 1 concerning postulated high energy pipe rupture inside containment.

B. APPROACH AND CRITERIA

The licensee has utilized the effects-oriented approach in its high energy line break (HELB) study (Reference 1). Breaks were postulated at terminal ends and points of closest approach to components of essential equipment to determine the effects of pipe whip or jet impingement. This method of approach has been approved for the SEP review of high energy pipe break analysis. The licensee has identified the following essential systems inside the containment:

1. High Pressure Core Spray - both pumps and associated piping
2. Alternate Core Spray - piping and check valves
3. Boron Injection System - boric acid storage tank and associated piping
4. Manual Depressurization System - valves, piping and the shutdown condenser
5. Control Rod Drive Hydraulic Scram Accumulators
6. Essential Instrumentation - reactor vessel water level and reactor vessel pressure

The licensee has classified high energy fluid systems as those that are maintained under conditions where either or both the maximum operating temperature and pressure exceed 200°F and 275 psig. This is consistent with current MEB criteria. Using this criteria, the licensee has identified systems inside containment that meet the criteria for high energy for at least part of the piping as follows:

1. forced circulation
2. main steam
3. feedwater
4. alternate core spray
5. high pressure core spray
6. seal injection system
7. control rod drive hydraulic system
8. control rod drive effluent system
9. shutdown condenser
10. boron injection
11. decay heat
12. purification

Based on a review of Reference 1 and further discussion with the licensee, we have determined that the licensee has not adequately addressed the effects of jet impingement and pipe whip motion on the other piping systems. In addition, in determining the damage criteria for target piping, the licensee has utilized the assumption that the effect of pipe whip and jet impingement will only damage smaller diameter piping. The staff concurs the effects of pipe whip will not damage equal diameter or larger piping with equal or greater wall thickness. However, in accordance with staff positions transmitted on January 4, 1980 (Reference 3), the effects of jet impingement should be considered and evaluated regardless of the ratio of impinged and postulated broken pipe sizes. In a discussion with the licensee, the licensee stated that the effects of jet impingement from the broken ACS line directly on the HPCS line is the most limiting case from the standpoint of energy level of fluid issuing from the broken pipe, the extreme proximity of the two lines, and the potential for adverse consequences if both the ACS and HPCS are affected. However, the HPCS line was demonstrated not to be damaged by this particular break location. The licensee should verify that there are no other high energy lines or break locations which could damage both the HPCS and the ACS lines considering the damage criteria discussed above.

C. INTERACTION EVALUATIONS

Using the effects-oriented approach, the licensee evaluated the effects of the postulated pipe breaks on a system by system basis. Each system has been analyzed for the effect that postulated pipe breaks would have on the ability to safely shutdown shut the plant down or to stay shutdown. The results of potential interactions for each postulated pipe break were summarized in Table 2 of Reference 1. It is noted that the only targets addressed in Table 2 by the licensee were safety-related equipment. A discussion with the licensee concerning the additional targets such as the containment wall, the biological shield, etc., revealed that the largest and the most energetic high energy fluid system line inside containment that could conceivably impact the containment wall and the biological shield following pipe rupture is the 10"/8" main steam line to the shutdown condenser. The licensee stated that the inside surface of the 1.16" thick steel containment vessel is protected by 9" of concrete and the damage to the containment boundary by main steam pipe whip should not be of concern. The staff agrees with the licensee's conclusion. However, the licensee should confirm that the portion of the steel vessel not protected by the 9" concrete would not be damaged by any postulated high energy line breaks.

Break locations in the main steam and decay heat cooling piping were identified that could affect a containment isolation valve. This valve is on the 2" blowdown line from the decay heat cooling system to the main condenser. The licensee stated in Reference 1 that a manual valve will be installed in the turbine building reheater area which will be closed by procedure following a high energy line break.

The staff considers that installation of a manual valve will resolve this interaction provided the valve is administratively maintained in a closed position during power operation. This will minimize the possibility of the blowdown line to the condenser as a release path following a postulated rupture of the reactor coolant pressure boundary.

In Table 2 of Reference 1, the licensee indicated that no safety-related equipment could be affected by the postulated breaks in the Alternate Core Spray (ACS) lines because the lines were restrained. Further discussion with the licensee concerning the design of the restraints and cursory review of Reference 4 revealed that the allowable maximum pull out and shear loads, the load combination and the effect of base plate flexibility for the assessment of anchor bolts do not meet current criteria. The licensee is requested to justify the design adequacy of anchor bolts for the existing pipe whip restraints.

Breaks in boron injection system (BIS) piping could affect safety-related equipment. The licensee has noted that this piping is included in the inservice inspection program for Class 1 systems (ASME Section XI) and that the welds have been examined in accordance with the augmented ISI program.

One of the postulated breaks in BIS could damage the containment ventilation exhaust damper operators. Failure to close of the damper would result in a loss of containment integrity following the loss of coolant accident. The licensee should do one of the following:

1. Demonstrate that the consequences of this scenario are acceptable,

2. Provide protection for the operators; or

3. Use the attached staff guidance to demonstrate that the postulated rupture will not occur.

Another postulated break in the BIS could damage the reactor water level instrumentation. A postulated break in the purification system would have a similar effect. These breaks constitute below-core LOCA's. For these breaks, inventory loss from the primary system will continue until the vessel water level equalizes with the containment level.

Damage to the water level instrumentation would result in a low level reading which would cause the ECCS to come on automatically. With a low level indication, the operator would not terminate ECCS. Containment water level instruments could then be used. Therefore, the staff concludes that damage to the reactor vessel water level instrumentation will not prevent reaching a safe shutdown condition.

A break in the high pressure core spray system could result in loss of the transmitters for both reactor safety channels of reactor pressure. These channels would not be needed to perform their high pressure scram function, and a physically separated transmitter would be available for monitoring.

Three break locations (seal injection, main steam and control rod effluent) were identified that could cause damage to control rod drive (CRD) mechanisms. Damage could result in partial failure to insert control rods. The boron injection system has been designed with sufficient capacity to place the core in a shutdown condition with all control rods removed. Operator action would be required to realign the system from its high pressure core spray mode (following the pipe break) to the boron injection mode. Acceptability of impairment of the CRD mechanisms will be addressed in the Integrated Plant Safety Assessment.

VI. CONCLUSION

Based on the information submitted by the licensee, we have reviewed the criteria pertaining to the locations, types, and effect of postulated pipe breaks in high energy piping systems inside containment. We have concluded that the criteria used to define the break locations, and types are in accordance with currently accepted standards. We have also determined that it is acceptable under current SEP criteria to use the interaction study to evaluate the effects of postulated pipe breaks and to determine the acceptability of plant response to pipe breaks.

However, we have found that the following aspects should be considered for the Integrated Assessment:

1. Clarification concerning the effects of jet impingement and pipe whip motion on mitigating systems.

2. Confirmation that the portion of the steel vessel not protected by the 9" concrete would not be damaged by any postulated high energy line breaks.

3. Installation of a valve on decay heat cooling system blowdown lines to the main condenser, and administrative controls to maintain it in a closed position during power operation.

4. Acceptability of damage to control rod drive mechanisms from postulated high energy line breaks.

5. Resolution of postulated breaks in boron injection system piping damaging the containment ventilation exhaust damper operators.

6. Justification of the design adequacy of anchor bolts for the existing pipe whip restraints in the Alternate Core Spray lines.

VII. REFERENCES

1. Report, "SEP TOPIC III-5.A, EFFECTS OF PIPE BREAK ON STRUCTURES, SYSTEMS AND COMPONENTS INSIDE CONTAINMENT - LACROSSE BOILING WATER REACTOR," Dairyland Power Cooperative (DPC), dated February 24, 1982.

2. Letter, D. Davis (NRC) to J. McEwen (KMC, Inc.), "ASSESSMENT OF POSTULATED PIPE BREAKS INSIDE CONTAINMENT FOR SEP PLANTS," dated July 20, 1978.

3. Letter, D. Ziemann (NRC) to F. Linder (DPC), "EVALUATION OF PIPE WHIP IMPACT AND JET IMPINGEMENT EFFECTS OF POSTULATED PIPE BREAKS FOR SEP TOPICS III-5.A AND III-5.B," dated January 4, 1980.

4. Letter, J.P. Madgett (DPC), to Director of NRR (NRC), Enclosure TR-14, dated July 21, 1976.

GUIDANCE FOR RESOLUTION OF HIGH ENERGY PIPE BREAK LOCATIONS WHERE REMEDIAL MODIFICATIONS ARE IMPRACTICAL

From the results of reviews conducted to date, the staff has concluded that the relocation of equipment or other modifications to mitigate the consequences of some postulated pipe breaks may be impractical due to physical plant configurations or other considerations. Therefore, the staff has determined that for specific locations where relocation of equipment or other modifications to mitigate consequences of pipe breaks are shown to be impractical, fracture mechanics evaluation of the piping should be performed to determine if unstable ruptures could occur in piping that contained service induced large undetected flaws.

The intent of the guidance provided by the staff is to provide reasonable assurance that the mitigation of pipe breaks are addressed. The approach taken is to provide assessment that condition which could lead to a double ended pipe rupture do not exist thereby making it unecessary for high energy pipe break considerations to mitigate effects of a guillotine rupture. This would be accomplished using a defense in depth approach that is a combination of augmented inservice inspection (ISI), local leak detection and fracture mechanics evaluations. Augmented inservice inspections would be performed with the goal of detecting and limiting any service induced flaws to limits prescribed by the ASME B&PV Code, Section XI, approximately 10% thru wall. Should the flaws go undetected, a local leak detection system would be provided with the requisite sensitivity to identify leakage from a through crack, either longitudinal or circumferential, of a length of twice the wall thickness for minimum flow rates associated with normal (Level A) operating conditions. Fracture mechanics evaluations would be performed to determine that for a circumferential or longitudinal through crack of four wall thickness subjected to maximum ASME design code loads (Level D) that:

(1) substantial crack growth does not occur.

(2) local or general plastic collapse (instability) does not occur.

(3) flow through the crack or the effects of a jet from the crack does not impair safe system shutdown.

To provide assurance that a double ended rupture could not occur by unanticipated loads being applied to a large undetected crack, a fracture mechanics evaluation would be performed to demonstrate that a through crack of a length of four times the wall thickness, 90° total circumferential length, or a larger crack if justified for system service experience would remain stable for local fully plastic large deformation bending conditions. The basis for performance of this more conservative fracture mechanics evaluation to assure a double ended pipe rupture would not occur is as follows:

(1) operating experience has shown that unanticipated and undefined loads in access of design can and do occur in piping systems, i.e., water hammer events have failed piping system supports.

(2) uncertainty in: (a) current analysis methods to accurately predict piping loads analysis and (b) prediction of the energy and frequency content of earthquakes and their effect on piping loads.

(3) SEP criteria for evaluation of structures and system resistance to postulated earthquake loads depend on global structural ductility. This assumption is based on the ability to have load redistributions occur. For unflawed piping, the necessary local ductility is certainly provided. However, for flawed sections of piping the ability to sustain fully plastic behavior without crack instability is required to assure prudently that local ductility is preserved.

The details of the guidance for the combined augmented ISI, leak detection and fracture mechanics evaluations are appended as Appendix 1.

ALTERNATIVE SAFETY ASSESSMENT FOR SELECTED HIGH ENERGY PIPE BREAK LOCATIONS AT SEP FACILITIES

This assessment is required only if a LWR high energy piping system (i.e., 275 psi or higher; or 200 F or higher, etc.) is being considered. It is only required, if a postulated double ended pipe break would impair safe system shutdown by pipe whip (lacking pipe whip constraints) consequences, or by the consequences of the implied leakage or its jet action. The following guidance is for a safety assessment that may be permitted as an alternative to other system modifications or alterations for locations where the mitigation of the consequences of high energy pipe break (or leakage) have been shown to be impractical.

Guidance for Alternate Safety Assessment

The suggested guidance are as follows:

A. Detectability Requirements

Provide a leak detection system to detect through-cracks of a length of twice the wall thickness for minimum flow rates associated with normal (Level A) ASME B&PV Code operating condition. Both circumferential and longitudinal cracks must be considered for all critical break or leak locations. Methods for estimation of crack opening areas are attached in Appendix 2. Surface roughness of the crack should be considered.

B. Integrity Requirements

(1) Loads for Which Level D is Specified

(a) Show that circumferential or longitudinal through-cracks of four wall thicknesses in length subjected to maximum Level D loading conditions do not exhibit substantial monotonic loading crack growth (e.g., staying below J_{IC} or K_{IC} by plastic zone corrected linear-elastic fracture mechanics methods or a suitable alternative[1]. Also assure that local or general plastic instability does not occur for these loading conditions and crack sizes.

[1] For 4t flaws that are calculated to be greater than K_{IC} or J_{IC}, consideration will be given to; (1) flaw growth arguments; (2) postulation of small flaws sizes than 4t if justified by leak detection sensitivity.

(5) Under conditions in "B.(1)" show that the flow through the crack and the action of the jet through the crack will not impair safe shutdown of the system.

Acceptable methodology for the estimation of crack opening area for a circumferential through crack in a pipe in tension and bending and for longitudinal cracks subject to internal pressure are attached.

(2) Extreme Conditions to Preclude a Double-Ended Pipe Break

Using elastic-plastic fracture-mechanics or suitable alternative show that circumferential through-cracks will remain stable for local fully plastic large-deformation bending conditions under the following additional conditions:

(a) Fully plastic bending of the cracked section is to be assumed, unless other load limiting local conditions (such as elbow collapse) dictate maximum bending loads, for all critical locations.

(b) Assume all system anchors are effective. To simplify the analysis, supports may conservatively be considered inoperative. If supports are included, consideration should be given to the adequacy of the support to resist large loads.

(c) Other as built displacement limits or constraints may be assumed as especially justified (such as displacement limits of a pipe running through a hole in a sufficiently strong concrete wall or floor, etc.).

(d) Assume a through-crack size of 4t or 90° total circumferential length whichever is greater; or a larger crack only if especially justified.

(e) Assume large deformations means deformations proceeding to as built displacement limits or other especially justified limits.

(3) Material Properties

Conservative material properties should be used in the analyses. Sufficient justification must be provided for the properties, both weldment and base metal, used in the analyses.

C. Subcritical Crack Development

Consideration should be given to the types of subcritical cracks which may be developed at all locations associated with this type of analysis. From prior experience and, r direct analysis it should be shown that:

(1) there is a positive tendency to develop through-wall cracks.

(2) if there is a tendency to develop long surface cracks in addition to through-wall cracks, then it should be further demonstrated that the long surface crack will remain sufficiently shallow.

D. Augmented Inservice Inspection

Piping system locations for which corrective measures are not practicable should be inspected volumetrically in accordance with ASME Code, Section XI for a Class 1 system regardless of actual system classification.

Acknowledgement

Assistance in developing this guidance have been provided by Dr. Paul C. Paris, Del Research Corporation (and Washington University, St. Louis, MO) under subcontract K-8195 in support of technical assistance provided by Idaho National Engineering Laboratory, Idaho Falls, Idaho (FIN A-6456).