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September 12, 1983

Mr. Robert Gilbert
Project Manager
Operating Reactors Branch No. 5
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington D.C. 20555

Subject: Dresden Station Unit 2
Integrated Assessment Follow-up
Item Pipe Break Inside Containment
SEP Topic III-5.A, Section 4.7.4
NRC Docket No. 50-237

References (a): Letter, March 16, 1983, from D.M. Crutchfield to D.L. Farrar. Enclosure 2, Paragraph 2

(b): Phone Call; May 17, 1983, B. Rybak, N.P. Smith, D. Skolnik to G. Cwalina. Subject: Pipe Interaction with Containment Wall

(c): Phone Call; May 23, 1983, I. McKenna to D. Skolnik. Subject: Clarification of Ref. (a) Information Request

(d): Bibliography, "October 1982" Effects on Pipe Breaks on Systems, Structures and Components Inside Containment", Section 8.0

Dear Mr. Gilbert:

Attached is our response to the Reference (a) information request which is a follow-up from our October 1982 report entitled, "Effects of Pipe Break on System, Structures, and Components Inside Containment." Our response to the Information Request was discussed during the referenced, (b) (c), phone conversations.

The attached response is divided into four sections:

- Section 1.0 Purpose
  Restates Enclosure 2, Paragraph 2 questions

- Section 2.0 Oyster Creek Results
  Applicability of CB&I tests to Dresden's Piping and Containment.

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- Section 3.0 Dresden 2 Results
  Analysis of postulated pipe WHIP/LINER interactions at Dresden 2

- Section 4.0 Conclusions
  Answer to Enclosure 2, Paragraph 2 Questions

To recap the status of the remaining reference (a) questions, our response to Enclosure 2, Paragraph 1 was submitted April 13, 1983, and our response to Enclosure 1 (Ref a) are to follow soon.

One signed original and forty (40) copies of this transmittal and the attachment are enclosed for your use.

Very truly yours,

B. Rybak

B. Rybak
Nuclear Licensing Adminisrator

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Attachment

cc: Region III Inspector (Dresden w/a)
Don Chery, SEP Project Manager (w/a)

7289N

July 20, 1983

DRESDEN 2 SEP TOPIC III-5.A

PIPE WHIP INTERACTION WITH THE CONTAINMENT WALL

1.0 PURPOSE

The purpose of this document is to respond to the Nuclear Regulatory Commission's (NRC) request for information on the subject of pipe whip interaction with the containment. The most recent specific questions raised by the NRC on this subject are the following:

1) Regarding pages 4 - 14 of the October 1982 report as transmitted by your letter of November 17, 1983 (T.J. Rausch to P. O'Connor), please clarify your basis for concluding that the impact from the reducer is less severe than the end-on pipe impact.
2) Confirm that none of the postulated interactions would result in a jagged pipe-end impacting the liner.

A continuing technical dialogue between the NRC and CECo on the subject of pipe whip interaction with the containment wall has been in progress since July, 1982. Numerous questions have been raised by the NRC and responses prepared by CECo. The response to the above specific questions incorporates applicable background information from earlier submittals to the NRC.

2.0 OYSTER CREEK RESULTS - REFERENCE (1)

The technical discussion presented in Reference (1) with respect to pipe whip interaction with containment is also applicable to Dresden 2. The following material is quoted directly from Reference (1):

"a. The NRC SER questioned the validity of static tests performed by CB&I, which showed that if the loading area is sufficiently large, the containment wall can deform without failure until deformation is limited by the concrete shield wall. The SER indicates that suitable dynamic load factors must be considered, and requests further justification that the impact load or energy produced as a result of postulated pipe breaks for piping greater than 14-inch diameter does not exceed the load or energy required to penetrate containment.

In addition, the NRC SER indicated that the impact area of a 14-inch or larger pipe may be smaller than the assumed contact area, i.e., the area of a 14-inch diameter circle. Specifically, with regard to 4-1/2-inch pipe crush test data used to show that whipping pipes would flatten on contact with containment, the NRC SER indicated that correlation of such data is difficult.

"b. The GPUN report of July 30, 1979, included an evaluation of the applicability of the CB&I static tests to dynamic loading conditions which would be experienced as a result of pipe whip. The following examples of a beam loaded by a weight, W, illustrate the basis for this evaluation:

- When loading is static, a beam loaded with a weight, W, will experience a deflection of δ and an applied load of W.

- For the classic dynamic loading condition, where the weight is initially suspended above the beam and is then dropped onto the beam, the beam must deflect by 2δ to absorb the energy of the weight. The applied loading in this case is 2W, i.e., there is a dynamic load factor of two.

- For a dynamic load situation where deflection is limited to δ, the beam load is also limited, i.e., to W, and the dynamic load factor is one. The difference from the static load case is that the deflection is achieved faster (i.e., at a higher strain rate). This case is similar to the pipe whip situation, where deflection and load are limited by contact with the concrete shield wall.

- Similarly, strain rates of the containment wall would be higher in the event of pipe whip interactions than the strain rates experienced during the CB&I tests, but load required to produce the required deflection (2.75 inches) would be the same <u>unless</u> there are significant strain rate effects on the material strength of ductility. Accordingly, the evaluation in the GPUN report of July 30, 1979, covered the effects of strain rate on the carbon steel (A212B) containment material. This evaluation showed:

  (1) High strain rate does not significantly affect the ductility of the containment wall material.

  (2) Material strength is increased slightly, which would be beneficial.

- Accordingly, it was concluded that the static CB&I tests are applicable to dynamic loading conditions.

"c. The GPUN report of March 16, 1982, showed that the load required to flatten any of the high energy piping greater than 14-inch diameter is a small fraction of the interaction load. Specifically, the flattening load is less than 16 percent of the load required to deform the containment wall until it makes contact with the concrete shield.

The flattening load was determined based on correlation of 4-1/2-inch diameter pipe crush test data. The test data agreed well with a simple theoretical model. The model was applied conservatively to large sized pipes, i.e., high values of pipe strength compared to code allowable values were assumed and increased strength at high strain rates was accounted for. There is a large margin between the predicted flattening load and allowable load (a factor of about six), so that a highly accurate model is not necessary. For the same reason, differences in the detailed loading configurations between the model and an actual impact would not affect the overall conclusion. Accordingly, it is considered that this evaluation provides sufficient basis for concluding that large whipping pipes (greater than or equal to 14 inches) would flatten on contact with the containment wall and provide contact area at least as large as a 14-inch diameter circle, the configuration used in the CB&I tests.

The evaluation contained in the GPUN report of March 16, 1982, assumed that contact occurs between a rounded surface of the piping and the containment wall. Additional evaluations have been performed of the piping system configurations to determine if there are more limiting situations with regard to pipe/wall contact area. These evaluations are based on the circumferential breaks which have previously been identified in large size piping systems in the GPUN report of July 30, 1979. The conclusions of the evaluations may be summarized as follows:

- There is no configuration which could result in the broken end of a pipe impinging directly on the containment wall. The basic reason for this is that the jet loads from a break cause the pipe to move away from the break, with the broken end the "trailing" rather than "leading" surface of the pipe.

- There are configurations which could result in contact occurring with the side of a pipe and at its broken end. This situation would occur, for example, where the configuration upstream of the break consists of a straight pipe section, an elbow, and then a plastic hinge. The broken pipe could move in an arc around the plastic hinge, and make contact with the containment wall at an oblique angle. Such "glancing blows" are not considered limiting, however, because:

  (1) The load required to flatten the pipe end is less than the flattening load for contact with a rounded section of piping.

(2) The jet load would be oriented nearly parallel to the contacted surface. The loads would be substantially lower than for cases where the jet is normal to the contacted surface.

(3) The specific loading configuration of the CB&I tests bounds this type of localized loading. In particular, the load in the CB&I tests was applied through a two-inch thick plate of 14-inch diameter. The plate was stiff relative to the tested segment of containment wall, so that all load was applied via the rim of the plate. Accordingly, the actual contact area for the test was likely well below the contact area for "glancing blow" type of contact."

3.0 DRESDEN 2 RESULTS - REFERENCE (2)

The technical information applicable to this subject which was presented in Reference (2) is quoted below:

"The effects of postulated break locations in lines greater than 14 inches in diameter have been reviewed. Eleven break locations were identified as having interactions with the containment liner. Scaled drawings depicting the movement of the whipping pipe into the containment liner have been prepared. The velocity component normal to the liner at impact is in the range of 10 to 236 feet per second for the above eleven interactions. The lower bound of the normal velocity range results from postulated pipe break locations in lines which have a relatively small gap initially between the piping and the liner with the result that the velocity buildup prior to impact is relatively low.

* References 5 and 6 present empirical formulations and test results of missile impact on steel plates. One of the test configurations included a Schedule 40, 12-inch diameter steel pipe weighing 743 lbs. impacting the target panel (3/4 inch thick) end-on at 210 feet per second. In the region of plate impact, the rectangular area unsupported by stiffeners was approximately 3'-6" by 6'-1". Although the test configuration appears to be stiffer than the free standing drywell liner at Dresden 2, the test target place displacement was greater than 3 inches. As the drywell liner at Dresden 2 is backed up by concrete after a 3 inch displacement of the liner, the pipe test results can be considered to be an upper bound on postulated pipe whip impact on the Dresden 2 liner.

* Attached Bibliography

The test velocity of the 12 inch pipe at impact was 210 feet per second. A review of the normal velocities for the eleven postulated pipe whip/liner interactions indicates that ten of the interactions have velocities 114 feet per second or less. The only interaction which is greater than the test velocity of 210 feet per second is for a postulated break location in the feedwater line. The feedwater line appears to make contact with the liner at an 18" x 12" reducer in the feedwater line, and the impact for this interaction is considered not to be as severe as the 12 inch pipe end-on impact in
* Reference 6."

4.0 CONCLUSIONS

The results referred to in Section 3.0 reflect another approach to the resolution of the problem of pipe whip interaction with the containment. Consideration of either one of the two technical approaches, i.e., Dresden 2 or Oyster Creek, should be sufficient to close-out this concern. Conclusions with respect to the specific issues identified in Section 1.0 are as follows:

(1) In order to evaluate the nature of the contact between the 18" x 12" reducer and the containment liner, a scaled drawing (1/4" = 1'-0) was prepared of the piping configuration. A plastic hinge was assumed at the first elbow and the whipping pipe segment was rotated from the initial (unbroken) position to the final (contact) position with the containment liner. A visual examination of the resulting drawing indicates that the reducer makes initial contact with the liner along a line rather than the broken edge of the pipe. Because the reducer will tend to flatten after it has made contact with the liner, and the liner will deform expanding the contact area of the reducer/liner, based on engineering judgment and Reference (1) results, it is concluded that this interaction is less severe than the end-on pipe impact.

(2) On the basis of similar evaluations as previously reported in Reference (2), it is concluded that none of the postulated interactions will result in a jagged pipe-end impacting the liner.

REFERENCES

(1) Letter P.B. Fiedler, GPU Nuclear, to D.M. Crutchfield, NRC, dated August 31, 1982.
(2) Dresden Unit 2 SEP Topic III-5.A, "Effects of Pipe Breaks on Systems Structures and Components Inside Containment, TTL Final Report 1105 CECO-01, October 8, 1982.

* Attached Bibliography

BIBLIOGRAPHY

1. Enis, R.O., Bernal, D.B., and Burdette, E.G., "A Design Guide for Evaluation of Barriers for Impact from Whipping Pipes" - Paper from Second ASCE Conference on Civil Engineering and Nuclear Power, September, 1980.

2. "Design Basis for Protection of Light Water Nuclear Power Plants Against Effects of Postulated Pipe Rupture," ANSI/ANS-58.2-1980, published by the American Nuclear Society, December 31, 1980.

3. "Protection Against Pipe Whip Inside Containment," Regulatory Guide 1.46, Directorate of Regulatory Standards, U.S. Atomic Energy Commission.

4. Thullen, P., "Loads on Spherical Shells," Oak Brook Engineering Department, Chicago Bridge and Iron Company, August, 1964.

5. "Report of the ASCE Committee on Impactive and Impulsive Loads" - Civil Engineering and Nuclear Power, Volume V, September, 1980.

6. "Special Criteria Developed for the Design and Analysis of Floating Nuclear Plant Containment Structures," Tsai, J.C., Orr, R.S., Transactions of the 4th International Conference on Structural Mechanics in Reactor Technology, Vol. J(a), August 19, 1977.

7. Roark, R.J., and Young, W.C., Formulas for Stress and Strain, 5th Edition, McGraw-Hill, 1975.

8. "Code Requirements for Nuclear Safety Related Concrete Structures" ACI 349-80.

9. Salmon and Wang, Reinforced Concrete Design, Intext Press, Inc., 1973.

10. Kraus, H., Thin Elastic Shells, John Wiley, June, 1967.

11. "Loss-of-Coolant Accident Analysis Report" for Duane Arnold Energy Center, NEDO-21082-02-1A, Class I, July 1977, Appendix A, Revision 1.

12. "Loss-of-Coolant Accident Analysis Report" for Dresden Units 2, 3 and Quad Cities Units 1, 2 Nuclear Power Stations, NEDO-241146A, 79NED273, Class 1, April 1979, Revision 1.

From October 1982 Report: "Effects of Pipe Break on Systems, Structures and Components Inside Containment."