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April 2, 1992

Docket No. 50-336
B14079

Mr. Thomas T. Martin
Regional Administrator, Region I
U. S. Nuclear Regulatory Commission
475 Allendale Road
King of Prussia, PA 19406-1415

Dear Mr. Martin:

Millstone Nuclear Power Station, Unit No. 2
Additional Response to NRC Region I
Augmented Inspection Team Report

By letter dated December 12, 1991,[1] the NRC transmitted the Region I Augmented Inspection Team (AIT) Inspection Report, No. 50-336/91-81, concerning the failure of a moisture separator reheater drain line elbow at Millstone Unit No. 2 which occurred on November 6, 1991. While the team reviewed a large quantity of complex information in a limited time, the AIT Report contained a number of conclusions that, upon further review, we believe have been shown to be inaccurate or premature. By letter dated January 3, 1992,[2] Northeast Nuclear Energy Company (NNECO) and Connecticut Yankee Atomic Power Company (CYAPCO) submitted an initial response to the AIT Report. The response focused on NNECO's and CYAPCO's restart program and the actions that were necessary to comply with the AIT Report's recommendations and findings. The initial response made no effort to clarify the AIT Report's conclusions, because NNECO's review of the issues was incomplete at that time.

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1 M. [illegible] Hodges letter to J. F. Opeka, "NRC Region I Augmented Inspection Team Report (50-336/91-81)," dated December 12, 1991.

2 J. F. Opeka letter to T. T. Martin, "Haddam Neck Plant, Millstone Nuclear Power Station, Unit Nos. 1, 2, and 3 -- Erosion/Corrosion Program Update, Response to NRC Region I Augmented Inspection Team Report," dated January 3, 1992.

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Since November 6, 1991, NNECO has been engaged in a detailed investigation of the pipe rupture at Millstone Unit No. 2 and of its secondary piping inspection programs in general as part of enhancement of our larger erosion/corrosion programmatic efforts. As a result of those investigations, we believe it is appropriate to provide you this additional information. As further discussed below, Millstone Unit No. 2 has undertaken additional technical studies intended to clarify certain issues that remain ambiguous. As appropriate, we plan to further supplement this letter.

For convenience of reference, in the text that follows we have restated various AIT Report excerpts in bold type together with the page reference from the AIT Report. NNECO's supplemental information is stated in ordinary type beneath each such conclusion.

- **"The AIT concluded that the moisture separator reheater drain lines were not included in the Millstone Unit 2 erosion/corrosion program. The omission was caused by the program selection criteria being based on engineering judgment and not a systematic review of components vulnerable to erosion/corrosion." (Cover letter, p. 1; see also Executive Summary)**

  The AIT statement may be misleading in that it ignores the erosion/corrosion program review and enhancement being conducted by NNECO at the time of the subject event. NNECO's review, which included the development of a more comprehensive erosion/corrosion program for Millstone Unit No. 2, was to have been completed by December 31, 1991, as committed in a letter dated June 27, 1991.[3]

  While the moisture separator reheater drain lines had not been specifically included in the secondary piping inspection program in use at Millstone Unit No. 2 on November 6, 1991, the changeover to a more comprehensive program, which utilized the best available technology (CHEC/CHECMATE) and which would have included this piping, had already been initiated. This changeover was based upon lessons learned from the December 31, 1990, Millstone Unit No. 3 line break event. The target date for the establishment of more systematic selection criteria at Millstone Unit No. 2 was achievable. As recognized in the NRC's Inspection Summary that was issued following a review of the erosion/corrosion programs at

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[3] E. J. Mroczka letter to T. T. Martin, "Haddam Neck Plant, Millstone Nuclear Power Station, Unit Nos. 1, 2 and 3 -- Erosion/Corrosion Program," dated June 27, 1991.

Millstone Unit Nos. 1, 2, and 3, from September 30-October 4, 1991, "[s]ignificant effort has been put forth by NU to improve its E/C program, and the commitment date of December 31, 1991 appears to be attainable." (Attachment 2 to AIT Report, p. 5)

The moisture separator reheater drain lines were specifically included in the developing program, and the technical inputs for the system were correctly specified. If the line had not ruptured on November 6, 1991, we believe the new program would have identified this piping section as a high wear area by December 31, 1991, the elbow would have been inspected during the 1992 refueling outage, and actions would have been taken at that time to preclude this rupture.

The suggestion that NNECO could have and should have had in place a more "systematic" approach in 1991 is also potentially misleading. First, erosion/corrosion technology has been evolving since the mid-1980s and is still considered to be in a developmental phase. NNECO has kept fully abreast of this developing technology and was in the process of incorporating current developments into its erosion/corrosion programs at the time of the Millstone Unit No. 2 event. Clearly, however, the integration of the latest technology into an existing erosion/corrosion program cannot be accomplished instantaneously. The computer codes used to select susceptible locations for inspection must be calibrated against plant-specific inspection results. This process requires multiple cycles of operation and inspection before the empirical models are calibrated to reflect plant-specific behavior. Only then can a computer code be considered a reliable predictive tool.

Finally, even the best currently available technology -- the most "systematic" of programs -- does not result in an absolute guarantee against future piping system failures. Short of a program that inspects every pipe in every plant on a regular basis, there will always be a residual risk of secondary system ruptures caused by wall thinning phenomena.

- "In retrospect, had the analyses been completed for Unit 2 by September 30, 1991, the event may have been prevented." (Attachment 3 to AIT Report, p. 8)

The conclusion that the November 6, 1991, pipe rupture would have been prevented if the Millstone Unit No. 2 analyses had

been completed by September 30, 1991, as originally planned, is incorrect. September 30, 1991, was the projected completion date for the execution of analytical models, not for the inspections themselves. These analyses were not intended to provide an absolute indication of imminent component failure. Rather, they were to form the baseline relative ranking of component susceptibility for use in the selection of inspection locations. Benchmark field inspection data are essential to calibrate the analytical model to plant-specific observations. The model becomes increasingly accurate as this cycle is repeated, ultimately resulting in a reliable predictive tool. NNECO is unaware of any nuclear power plant having been shut down solely on the basis of a CHECMATE analysis, particularly one conducted early in a utility's erosion/corrosion inspection program when benchmark data are unavailable, as was the case at Millstone Unit No. 2.

Regardless of when the Millstone Unit No. 2 analyses were completed, the actual inspections would not have been undertaken before the spring of 1992. Ultrasonic inspection techniques do not yield reliable data if applied to operating piping systems. Further, ultrasonic testing of operating systems exposes the inspection technician to undue risk of injury. Therefore, NNECO planned to perform the targeted inspections during Millstone Unit No. 2's next refueling outage, in the spring of 1992. Contrary to the AIT's conclusion, the fact that the enhancement completion date was delayed from September 30, 1991, to December 31, 1991, did not affect the timing of the inspections, and the earlier completion date would not have precluded the rupture.

- **In its summary of the design and operating conditions of the moisture separator reheater drain line system, the AIT Report states that "the approximate fluid velocity" is "7 ft/sec at the entrance to the elbow." (p. 7)**

  The fluid velocities presented in the AIT Report are based upon values predicted by the CHECMATE computer model, not actual values. Depending on the characteristics of the fluid stream exiting the control valve, actual local fluid velocities could vary significantly from those predicted by CHECMATE. Northeast Utilities has executed a contract with Creare, Inc. to evaluate the system characteristics and determine the actual local flow patterns. Initial findings indicate that, although the bulk fluid velocity at this location is approximately 4 ft/sec, liquid velocities at the elbow may reach 45 ft/sec due to the high void fraction of the

fluid stream. These findings exemplify the complexity that is inherent in two-phase flow regimes and the necessity for eliminating bulk velocity exclusion criteria from the piping inspection program.

- **"A backing ring was used during construction in the fit-up of the reducer to the failed elbow. Its sister elbow in the "A" reheater drain line also used a backing ring." (p. 8)**

  A backing ring was utilized to achieve fit-up of the "B" reheater drain line elbow-to-upstream reducer weld joint. This backing ring was largely intact when the joined components were removed from the system. In contrast, when the sister components were removed from the "A" system, no backing ring was present at the companion weld joint. Subsequent visual and metallurgical analyses revealed no evidence that a backing ring was initially utilized at this fit-up location.

  The presence of a backing ring may be significant because a fluid boundary layer disturbance can induce local flow turbulence. High flow turbulence is a causative factor in a number of wear phenomena. NNECO is currently evaluating the effect that local geometry, including the component mismatch and presence of a backing ring, may have had relative to the differing degrees of wear experienced by the failed and sister components.

- **"Failure of the elbow was attributed to a loss of wall thickness caused by erosion/corrosion." (p. 8)**

  There is insufficient technical evidence currently available to conclusively determine that the predominant active damage mechanism was erosion/corrosion. The causative phenomenon may be cavitation, two-phase erosion/corrosion, or a complex combination of these wear mechanisms. NNECO is actively pursuing technical studies aimed at discriminating between these phenomena. These studies are essential to the development of a comprehensive secondary pipe inspection program. The majority of utility industry efforts to date and the currently available predictive tools focus on erosion/corrosion phenomena only. It is important that all other active damage mechanisms be considered, to ensure that the locations most susceptible to wall-thinning are targeted for inspection, regardless of the active phenomenon.

- "It is not apparent that the licensee used the lessons learned from the Millstone Unit 3 pipe failure to review the other units erosion/corrosion programs to assure that similar lines in the moisture separator reheater drains were included in the erosion/corrosion program." (p. 12)

  Contrary to the AIT statement, the Millstone Unit No. 3 event resulted in a preliminary review of the erosion/corrosion programs at Millstone Unit Nos. 1, 2, and 3, and the Haddam Neck Plant by February 28, 1991, and a comprehensive review that was to be completed by December 31, 1991. The preliminary review did not result in an immediate inspection of the moisture separator reheater first stage drains because the operating conditions in these lines differed substantially from those in the failed Millstone Unit No. 3 lines (bulk velocity of 4 ft/sec vs. 20 ft/sec, and two-phase vs. single-phase flow). The comprehensive review ultimately resulted in the inclusion of the moisture separator reheater drains in the Millstone Unit No. 2 Erosion/Corrosion Program.

  As recognized in the NRC's AIT Report (50-423/91-80)[4] following a rupture of moisture separator drain piping at Millstone Unit No. 3 on December 31, 1990, (1990 AIT Report), NNECO and CYAPCO made specific commitments to enhance their erosion/corrosion programs. The initial commitment was that "a preliminary review of other NU plants' erosion/corrosion programs would be conducted by the end of February 1991." (1990 AIT Report, p. 1) This task was completed by February 28, 1991.[5] The Millstone Unit No. 2 program review correctly identified the reheater drains/vents as a system to be included in the program. It also identified this system as one that was inspected as part of the existing program.

  One reason why the first stage reheater drain line portion of this system was not inspected prior to its rupture on November 6, 1991, is that it operates at the comparatively low fluid velocity of 4 ft/sec. Therefore, it was considered to have relatively limited susceptibility to erosion/corrosion.

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[4] M. W. Hodges letter to E. J. Mroczka, "NRC Region I Augmented Inspection Team Report (50-423/91-80)," dated February 12, 1991.

[5] E. J. Mroczka letter to T. T. Martin,"Response to Augmented Inspection Team Report (50-423/91-80)," dated March 25, 1991.

This resulted in the assignment of a low inspection priority. Another reason the line was not inspected prior to its rupture is of content of the principle regulatory guidance applicable to Millstone Unit No. 2 at that time: Appendix A of the NRC's NUREG-1344, "Erosion/Corrosion-Induced Pipe Wall Thinning in U.S. Nuclear Power Plants." Table 2 of the NUMARC Summary Report (attachment to NUREG-1344) lists suggested piping inspection locations. The list does not include the drain lines that service the moisture separator reheater.

The other major commitment that resulted from the Millstone Unit No. 3 event was the commitment to perform a detailed verification of the Millstone Unit No. 2 erosion/corrosion program by September 30, 1991. Fulfillment of that commitment was delayed until December 31, 1991, but, as described above, the delay had no bearing on the November 6, 1991, event.

In addition to the commitments made to the NRC, NNECO initiated other changes to the secondary pipe inspection program based upon the recommendations of an internal root cause investigation team that evaluated the December 31, 1990, pipe failure at Millstone Unit No. 3. These enhancements include:

(i) establishment of consistent erosion/corrosion programs for all four Northeast Utilities system-owned nuclear units;

(ii) preparation of a corporate computer database to store and evaluate field inspection data, record component parameters, and predict the time to reach critical wall thickness;

(iii) preparation of a corporate erosion/corrosion manual and consistent procedures for each unit.

These initiatives resulted in the elimination of bulk velocity as a program exclusion criterion. Thus, the first stage reheater drain lines were included in the new secondary piping inspection program that would have been operative during the Millstone Unit No. 2 1992 refueling outage.

- "A significant portion of the moisture separator reheater drain system had been inspected by the Unit 2 program; however, the piping section that failed during the November 6, 1991 event was not included in the Unit 2 program due to an oversight because the selection of inspection locations was not systematic." (Attachment 3 to AIT Report, p. 9)

  As explained earlier, the reason that the failed piping section was not included in the original Millstone Unit No. 2 erosion/corrosion program was the characterization of the first stage reheater drain system as one that is not highly susceptible to pipe thinning phenomena. However, that characterization did not result from oversight or from the lack of a thorough and orderly scheme for erosion/corrosion analysis and inspection at Millstone Unit No. 2. NNECO's selection of inspection locations at Millstone Unit No. 2 met or exceeded the existing regulatory guidelines. NUREG-1344, along with its attached NUMARC Summary Report, suggested locations for inspection and specified that an initial sample selection should consist of 15 locations. The Millstone Unit No. 2 program encompassed all the recommended inspection locations listed in Table 2 of the NUMARC Summary Report and had been expanded to the point that 500 locations were inspected during the 1990 refueling outage alone. By contrast, a survey of members of the Electric Power Research Institute's (EPRI) CHEC/CHECMATE User's Group conducted in April 1991 stated that 50-100 inspections per unit per outage was the most common standard, with 100-150 inspections the next most prevalent. (CHUG Currents, September 1991, p. 6)

  Further, the selection of the Millstone Unit No. 2 inspection locations was based on engineering judgment and plant-specific experience that explicitly considered relevant factors such as flow velocity, temperature, chemistry, system configuration, system materials, operating history, and effect on plant availability/reliability. Formal procedures existed to identify plant piping to be inspected, perform the inspections, document the inspection results, and compare the inspection results to the acceptance criteria and previous data. In short, Millstone Unit No. 2's program constituted an aggressive approach to the detection of degraded secondary piping, and its breadth exceeded both the existing regulatory guidance and general industry practice.

> The NRC acknowledged the comprehensive nature of the Millstone Unit No. 2 inspection program on two previous occasions. As stated in Attachment 2 to the Millstone Unit No. 2 AIT Report (the NRC Inspection Summary issued November 3, 1991, immediately before the Millstone Unit No.2 event), "the actual monitoring of the secondary side piping systems performed by Unit 2 appears to be sufficient." (p. 6) The NRC Special Task Force that subsequently evaluated NNECO's erosion/corrosion control program on November 12-15, 1991, found that "[a]t Unit 2, inspections of piping had been commonplace prior to and after the Surry Event. Their inspection program was substantial compared to the other units and exceeded industry practice." (AIT Report, Attachment 3, p. 5)

Northeast Utilities has been an industry leader in the development and implementation of erosion/corrosion technology, sponsoring research in this area as early as 1985 and developing, with the assistance of the Massachusetts Institute of Technology, its own computer-based erosion/corrosion prediction tool. Northeast Utilities also cooperated extensively with EPRI during the development of the CHEC/CHECMATE computer codes, which now constitute the main analytical tools for erosion/corrosion prediction in the utility industry. Furthermore, Northeast Utilities has been actively involved in the development of ASME Section XI initiatives to address erosion/corrosion phenomena, and it continues to participate in the CHEC/CHECMATE User's Group. This involvement evidences a strong and longstanding commitment to understanding erosion/corrosion phenomena and to using and sharing the knowledge achieved through this research.

As discussed above, NNECO is continuing to evaluate the circumstances surrounding the November 6, 1991, pipe rupture through studies to be performed by various outside consultants. The studies currently being considered include scale model testing, two-phase computational analysis, and the statistical evaluation of field inspection data. NNECO believes that these studies will result in a clearer understanding of the November 6, 1991, event at Millstone Unit No. 2 and will contribute to the industry's still-evolving ability to cope with these complex phenomena. NNECO will keep you apprised of the results of these studies.

Please do not hesitate to contact us if you have any questions.

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY

J. F. Opeka
Executive Vice President

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