U.S. NUCLEAR REGULATORY COMMISSION
REGION I

Report No. 50-336/91-81

Docket No. 50-336

License No. DPR-65

Licensee: Northeast Nuclear Energy Company
P. O. Box 270
Hartford, CT 06141-0270

Facility: Millstone Nuclear Power Station, Unit 2

Inspection at: Waterford, CT

Dates: November 7 - 18, 1991

Inspectors: P. Habighorst, Resident Inspector, Unit 2
H. Kaplan, Materials Section
K. Kolaczyk, Resident Inspector, Unit 3
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P. Patnaik, Materials Section
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P. K. Eapen 12/10/91
for J. Trapp, Sr. Reactor Engineer, Systems Section, EB, DRS, AIT Leader — Date

Approved by: [signature] 12/12/91
J. Durr, Chief, Engineering Branch, Division of Reactor Safety, AIT Manager — Date

Inspection Summary: See the Executive Summary

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EXECUTIVE SUMMARY

On November 6, 1991, at 0642 a.m., one eight-inch diameter elbow, located in the first stage moisture separator reheater drain line, failed. This failure caused the operators to initiate a manual reactor/turbine trip. There were no personnel injuries and only minor equipment damage as a result of this event. Two similar events have occurred at Northeast Utilities nuclear units in the past twelve months. On December 31, 1990, two six-inch moisture separator drain lines failed at Millstone Unit 3. On April 22, 1991, one 1-1/2 inch drain line failed at Millstone Unit 2. All three pipe failures were a result of erosion/corrosion.

All four Northeast Utility nuclear units were shutdown at the time of this inspection. Millstone Unit 2 was shutdown for the erosion/corrosion pipe failure, and the other units were shutdown for various other reasons. The licensee has committed to completing the erosion/corrosion program enhancements, take ultrasonic testing (UT) wall thickness measurements of components vulnerable to erosion/corrosion, and make appropriate repairs, prior to startup of the units.

The safety significance of this event with regard to the public health and safety was determined to be minimal. However, the personnel safety significance of this event was determined to be significant. If the pipe failure had occurred with personnel in the vicinity, the consequences could have resulted in substantial personnel injury.

The licensee routinely inspects a considerable number of components (i.e. elbows, reducers, tees, pipe) to identify potential wall thinning during each Millstone Unit 2 refueling outage. However, the section of piping which failed was not included in the erosion/corrosion inspection program. The team concluded that a systematic approach was not used to select components to include in the erosion/corrosion inspection program. This deficiency had been previously identified by the augmented inspection team (AIT) dispatched following the Millstone Unit 3 pipe failures. Based on the findings following the Millstone Unit 3 pipe failures, the licensee committed to enhancing the erosion/corrosion inspection program for all four Northeast Utilities nuclear units by December 31, 1991. This enhancement was in progress at the time of the Millstone Unit 2 pipe failure. The team concluded that had this enhancement been completed, and had wall thickness measurements been taken of identified vulnerable locations, this failure would have been prevented.

1.0 INTRODUCTION

On November 6, 1991, at 0642 hours and with Millstone Unit No. 2 at 100% power, an eight-inch diameter elbow located in the first stage moisture separator reheater drain failed. The failed elbow discharged steam and water into the turbine building. The control room operators manually tripped the reactor/turbine and closed the main steam isolation valves in response to this failure. On November 6, 1991, the Nuclear Regulatory Commission (NRC), Region I Regional Administrator dispatched an Augmented Inspection Team (AIT) to the Millstone site. The team was tasked with documenting relevant facts, determining the probable cause(s), evaluating the licensee's erosion/corrosion program, reviewing corrective actions, and evaluating the potential generic aspects of this event. This inspection report describes the findings and evaluations of the AIT. Attachment 1 is the AIT charter describing the inspection scope and delineating responsibilities for the inspection.

The NRC dispatched a second inspection team to review the Northeast Utilities management response for the recurring secondary pipe failures. This team conducted it's inspection independent of the AIT. The findings of the management review inspection are provided as Attachment 2 of this inspection report.

Just prior to the Unit 2 piping rupture on November 6, 1991, the NRC conducted an inspection of the licensee's corporate erosion/corrosion program and the site specific erosion/corrosion procedures between September 30 - October 4, 1991. The results of this inspection are provided as Attachment 3 of this inspection report.

2.0 SEQUENCE OF EVENTS

A sequence of the events which occurred during the pipe rupture at Unit 2 was compiled by interviewing cognizant personnel and reviewing relevant records including the computer generated sequence of events, analog pre/post trip printout, and trends of relevant plant parameters. A detailed sequence of events is provided in Appendix B.

On November 6, 1991, Millstone Unit 2 was at full power in the fourteenth day of continuous operation. The "A" emergency diesel generator had been removed from service for scheduled maintenance. During the midnight to 8:00 a.m. shift, the emergency boration valve (2-CH-514) failed it's stroke-time test. Therefore, manual operation was required for normal or emergency boration from the boric acid storage tanks.

The control room was first informed about the moisture separator reheater drain line failure by a health physics supervisor who stated that an unusual noise was heard coming from the turbine building. At the time of the call, operators observed the actuation of various turbine building electrical equipment ground and fire protection annunciators.

Upon identification of a steam leak at 6:42 a.m., the shift supervisor and a plant equipment operator exited the control room and proceeded to the 31'6" elevation of the turbine building to identify the source of the leakage. After identifying a leak in the area near the first point feedwater heaters, the shift supervisor and plant equipment operator returned to the control room. A shutdown was ordered by the shift supervisor. At this time, the primary plant parameters were stable with only small changes in reactor temperature and steam generator level caused by the loss of the affected feedwater heater. The reactor operator began to reduce power by boration and the control rod insertion. Boration was initiated within four minutes of the identification of the leak by manually repositioning the boration isolation valve.

Following the initiation of the plant shutdown, a number of main electrical generator and main turbine abnormal indications and annunciators were received, including fluctuating reactive ampere loading on the main generator. Based on abnormal main electrical generator indications, the reactor and turbine were manually tripped six minutes following the line failure at 6:49 a.m. The plant responded to the trip as expected. Control room operators completed the reactor plant trip response procedure and reviewed the excess steam demand procedure. The main steam isolation valves were closed, and the feedwater and condensate systems were secured to limit leakage from the failed line. Search and rescue teams were established with the assistance of oncoming shift personnel. Security was notified to restrict personnel access to the turbine building, and health physics personnel took action to identify potential radiological hazards. The NRC Resident Inspectors arrived on-site at approximately 6:30 a.m. and observed recovery activities. The NRC operations officer was notified of the manual reactor trip per 10CFR 50.72 (b)(2)(ii) at approximately 7:30 a.m.

High temperature in the vicinity of the ruptured steam pipe melted two fusible links in the fire protection sprinkler system and caused the sprinkler system to actuate. A fire pump started on the low fire header pressure caused by the sprinkler actuation. Two carbon dioxide tanks, used for fire suppression of main generator equipment, were overpressurized by the heat generated from the steam leak causing the relief valves to lift. Once personnel verified the absence of fire in the turbine building, the sprinkler system was isolated and a fire watch posted in accordance with the licensee's compensatory fire measures.

As part of the recovery effort, the licensee initiated inspections of motors and breakers for moisture or heat damage. Damage to some piping insulation and a bent floor grate in the area of the leak were the only damages observed.

Operators were diligent during this event and they responded to control room indications as required by the procedure. When it was identified that the leak was affecting the main electrical generator, prompt actions were taken to shutdown the plant. The operators effectively followed normal and emergency station operating procedures. Appropriate actions were taken to mitigate the consequences of the pipe failure and to prevent personnel injury. There were sufficient licensee personnel to respond to this event. Shift turnover was delayed until plant conditions were stable. The event was adequately classified and timely notifications were made. There were no radioactive releases to the environment or plant contamination as a result of this event.

No personnel injuries occurred and damage to equipment was minimal. However, the potential for personnel injury was significant. The location of the failure was in the vicinity of a walkway and there were routine operator tours in the affected area. Fortunately, no personnel were present in the immediate vicinity when the pipe ruptured.

3.0 DESIGN, MATERIALS ANALYSIS, AND REPAIRS

The secondary steam cycle has two moisture separator reheaters and two parallel first stage moisture separator reheater drain systems. The failed elbow was located in the "B" moisture separator reheater drain system. The companion elbow in the "A" moisture separator reheater drain system did not fail but was later removed for examination. The failed line, 8"-GBD-37, is located between the first stage moisture separator reheater drain tank and the 1B feedwater heater. The failure occurred downstream of a control valve. The system fluid is single phase water, however flashing of water to steam at the discharge of the control valve may cause limited two phase flow inside the elbow.

The configuration of the failed component was an eight-inch diameter, long radius, 90 degree pipe elbow, approximately 2 feet long. The pipe elbow was welded between a 4-inch flow control valve 2-ES-791 (LV-4144) and a manual isolation valve 2-ES-11B. A 4-inch by 8-inch reducer was welded between the control valve and the elbow. The piping system was designed and fabricated to the American National Standards Institute ANSI B.31.1 Power Piping Code. The as-built pipe specifications indicate that the long radius elbow conforms to American Society for Testing and Material ASTM A-234, grade WPB, carbon steel wrought material. The following are the relevant design and operating conditions of the system:

Design Temperature:	500 degrees F
Operating Temperature:	463 degrees F
Design Pressure:	500 psig
Operating Pressure:	470 psig
Flow:	201,000 lbm/hr
PH:	8.4 to 8.7
Oxygen:	2 ppb approximately
Approximate Fluid Velocity:	109.9 ft/sec inside the control valve 27 ft/sec at the reducer 7 ft/sec at the entrance to the elbow
Pipe Material:	Carbon steel, ASTM A-106, Grade B
Nominal Pipe Size:	8-inch inside diameter
Nominal Wall Thickness:	0.322-inch
Minimum Code Wall Thickness:	0.172-inch
Valves and Fitting:	ASTM A-234, Grade WPB
Pipe Schedule:	Schedule 40

The inspector examined the failed elbow. A backing ring was used during construction to assist in fitting the elbow to the reducer. The failure occurred longitudinally on the extrados (outer radius) of the elbow. The failure was "fishmouth" in appearance and extended axially approximately 9 inches by 4 inches in width. Visual examination of the fractured surfaces revealed a ductile fracture pattern. The inner surface of the failed elbow exhibited uniform pitting. The inner surface of the reducer, upstream from the failed elbow, starting at the backing ring, showed a tightly adherent oxide. Three samples, representing various sections of the failed elbow along its length, were examined microscopically. The following observations were noted:

- The wall at the fractured edge was 0.017" thick. Other areas away from the failed edge had wall thicknesses ranging from 0.020" to 0.250".

- The structure, both at the failure and away from the failure, consisted of well refined pearlite and ferrite, typical of wrought carbon steel. The material was found to be relatively clean and free of gross non-metallic inclusions.

- The amount of decarburization observed on the outer surface was negligible.

- Hardness testing measured Rockwell "B" values of 73-74, corresponding to an appropriate tensile strength of 64,000 psi. The specified minimum tensile strength for A-234 grade WPB is 60,000 psi.

- The largest pit in the failed elbow measured 0.01" deep by 0.03" long.

The companion elbow in the "A" moisture separator reheater was removed and examined. The following observations were made:

- The minimum measured wall thickness of the sister elbow from the "A" moisture separator reheater drain line was 0.214" thick.

- 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. The backing ring used on the failed elbow was not uniformly attached to the reducer. This resulted in a 3/32" gap between the reducer and the backing ring. The companion elbow's backing ring exhibited a better fit up than the failed elbow. The poor fit up may have aggravated the turbulence generated by the presence of the backing ring. The difference in turbulence, caused by the backing rings, may be a contributor in the difference in wear rates observed between the failed elbow and its companion elbow.

Failure of the elbow was attributed to a loss of wall thickness caused by erosion/corrosion. The elbow was found to be typical of ASTM A-234, Grade WPB material, free of metallurgical anomalies and deficiencies.

4.0 EROSION/CORROSION PROGRAM

The principal goal of the Augmented Inspection Team (AIT) was to determine why the licensee's erosion/corrosion program failed to identify and repair the moisture separator reheater drain pipe prior to it's catastrophic failure. In addition, a review of the status of the licensee's erosion/corrosion programs for all four Northeast Utilities nuclear units was conducted. As a result of findings made following the Millstone Unit 3 pipe failure, the licensee's erosion/corrosion programs were being revised at the time of the Millstone Unit 2 pipe failure. Following the Millstone

Unit 2 pipe failure, the licensee's committed to make additional revisions to the erosion/corrosion programs prior to startup. This section of the report describes the status of the erosion/corrosion programs and corrective actions taken by the licensee following the pipe failures.

4.1 Corrective Actions Implemented in Response to Millstone Unit 3 Moisture Separator Drain Line Failures (December 1990)

At the January 7, 1991 NRC exit meeting, for the Millstone Unit 3 AIT, the licensee agreed to the following corrective actions.

1. A preliminary review of all Northeast Utilities erosion/corrosion programs would be conducted by the end of February 1991.

2. Millstone Unit 3 would verify the EPRI CHEC/CHECMATE erosion/corrosion program models to assure that valid locations were being selected for inspection.

3. A detailed verification for Millstone Units 1 & 2, and Haddam Neck plants would be performed with the completion dates of December 31, 1991, September 30, 1991, and June 30, 1991, respectively.

On March 25, 1991, Northeast Utilities provided a response to the NRC on the status of the above corrective actions. The licensee stated that a preliminary review of other Northeast Utilities plants, Millstone Unit 1, Millstone Unit 2, and Haddam Neck, erosion/corrosion programs was completed on February 28, 1991. The initial NUSCO review generated a list of potentially susceptible systems which were not included in the site specific erosion/corrosion programs. Only Millstone Unit 1 and Haddam Neck had systems in this category. The licensee stated that systems which were identified as potentially susceptible, but not included in the erosion/corrosion program, will be further evaluated to determine a basis for inclusion/exclusion.

NUSCO engineering performed the preliminary review of systems for inclusion in the unit-specific erosion/corrosion programs based on three principal criteria: past failures within the industry; historic plant-specific failures; and, a set of exclusion criteria. The exclusion criteria were predicated on NRC Bulletin 87-01 criteria, chemistry conditions, general fluid characteristics, and piping material composition.

The site engineers evaluated the systems that were identified as not being included in the existing erosion/corrosion programs. The Northeast Utilities operating facilities determined that it was not necessary to shut the units down specifically to inspect components of systems not previously included in the program. Licensee selected Haddam Neck to implement their pilot program for the inspection of locations identified as susceptible by CHEC/CHECMATE program during the October 1991 outage. Based on the results at Haddam Neck, a generic NUSCO-controlled erosion/corrosion program was to be developed. The generic program would standardize selection criteria and ultrasonic testing methodology.

In the licensee's March 25, 1991 response, the previous commitment made at the exit meeting with regard to the Millstone Unit 3 modeling of all vulnerable systems by CHEC/CHECMATE prior to startup from the refueling outage was revised. The licensee stated Northeast Nuclear Energy Company's (NNECO) was unable to complete modeling of all susceptible systems by the CHEC/CHECMATE program prior to the startup. However, NNECO stated that they would complete inspections of all susceptible systems prior to startup. These inspections were to focus on component locations considered to be the most susceptible to erosion/corrosion thinning based on engineering judgement.

The licensee also documented in the March 25, 1991 response their commitment to perform a detailed verification of the erosion/corrosion programs for other Millstone units and Haddam Neck.

On June 27, 1991, Northeast Utilities submitted a followup letter to the NRC revising certain commitments made in the March 25, 1991 letter. The licensee stated in this letter that NNECO had completed inspections of all susceptible components in the Millstone Unit 3, Phase I, evaluation prior to the startup from the third refueling outage. In addition, the commitment to perform a detailed verification of the other units erosion/corrosion programs was changed to December 31, 1991 for all units. This change was based on a preliminary review of work involved, the decision to complete the program for each unit in parallel rather than in series, and discussions with the vendor (ALTRAN). In addition, the CHEC/CHECMATE analysis performed in support of the Millstone Unit 3 refueling outage was to be repeated by ALTRAN to assure consistency.

During the development of the CHEC/CHECMATE input, the need to verify the "as-built" balance-of-plant configuration drawings was identified. Specifically, the operational design data were identified in numerous cases to be in error. System walkdowns were performed to identify and resolve the "as-built" drawing deficiencies.

At the time of this inspection, the CHEC/CHECMATE analyses were in various stages of completion for the four units. The Haddam Neck analysis was completed and was being used for the selection of inspection points for the present refueling outage. The input files for CHEC/CHECMATE were essentially complete for the Millstone Units. A quality verification of the input files for Millstone 1, 2, and 3 were 70, 80, and 90 percent complete, respectively. Less than 5% of the input files were executed by the CHEC/CHECMATE code for Millstone Unit 2. The failed Millstone Unit 2 line was not run by CHEC/CHECMATE; however, the input file including this line had been completed.

The CHEC/CHECMATE analysis for the failed Millstone Unit 2 moisture separator reheater pipe was performed following the failure. The CHEC/CHECMATE analysis identified a high wear rate at the failed elbow.

The AIT made the following observations with regard to the licensee's corrective actions following the December 31, 1990, moisture separator pipe failures at Millstone Unit 3.

- A systematic approach for identifying vulnerable components to include in the erosion/corrosion program, developed in response to the Millstone 3 failure, would have identified the failed line for inspection. This failure could have been prevented if the corrective actions committed to by the licensee following the Millstone Unit 3 pipe failure, had been fully implemented.

- A small number of systems were identified by the licensee following the preliminary review to have been excluded from the erosion/corrosion programs for Haddam Neck and Millstone Unit 1. No ultrasonic testing (UT) wall thickness measurements were taken for these systems. All vulnerable Millstone Unit 2 systems were included in the Millstone Unit 2 erosion/corrosion program.

- The preliminary review completed on February 28, 1991, for Millstone 2 did not look at the component level. Therefore, this review did not identify the Millstone Unit 2 moisture separator reheater drain line as being a system requiring UT inspections.

- The CHEC/CHECMATE analysis, which was to be completed by December 31, 1991, was nearly complete for all Northeast Utilities units. The analysis was complete for Haddam Neck. The results of the CHEC/CHECMATE analysis was used to select UT inspection locations for the erosion/corrosion program being implemented at Haddam Neck at the time of this inspection. It appears that the licensee was on schedule to have this analysis completed by December 31, 1991.

- 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. As a result, wall thicknesses were not measured at the Unit 2 moisture separator reheater drain lines.

The licensee fulfilled the short-term commitments made following the NRC-AIT inspection at Millstone Unit 3. However, action was not taken to perform pipe/component measurements to systems not previously incorporated in the operating plant erosion/corrosion program or potentially vulnerable locations identified by the Millstone Unit 3 failure.

4.2 Corrective Actions Planned in Response to Millstone Unit 2 Moisture Separator Reheater Drain Line Failure (November 1991)

The licensee removed from service all of its nuclear facilities immediately after the moisture separator drain line rupture at Millstone Unit 2 for investigation. The licensee stated that the failed elbow as well as the companion elbow in the "A" moisture separator reheater drain line would be replaced with elbows made of chrome-molybdenum steel. Steel with a chromium content of greater than 5% is less susceptible to erosion/corrosion. The AIT found the licensee's material selection for the replacement elbows to be acceptable.

The licensee stated at the exit meeting, held on November 18, 1991, that the following items would be completed for Northeast Utilities nuclear units, prior to the startup of each unit:

- The CHEC/CHECMATE analysis will be completed for all systems vulnerable to erosion/corrosion for pipes with diameters of 2-inch and greater. A representative sample of existing UT wall thickness measurement data will be input into CHEC/CHECMATE to obtain more accurate wear rates.

- The CHEC/CHECMATE analysis will be used to select approximately 100-150 locations for wall thickness inspections for pipes with diameters of 2-inch or greater.

- An additional 100-150 locations for wall thickness measurements will be selected for inspection based on engineering judgement and industry experience. Included in this sample will be locations downstream of all control valves and downstream of at least one of parallel orifices and nozzles for pipes with diameters of 2-inches or greater.

- Based on the above selected inspection locations, the existing UT data base will be reviewed to identify locations where wall thickness measurements have been previously made. Where existing wall thickness measurements do not exist, new measurements will be taken.

- For piping systems less than 2-inches in diameter and vulnerable to erosion/corrosion, approximately 100 locations will be selected for UT measurements based on engineering judgement.

- As inspection data warrants, the inspection sample size will be expanded.

- A technical criteria document will be issued to provide administrative guidance for this inspection effort.

5.0 GENERIC ASPECTS

The following generic information was identified by the AIT:

1. The bulk flow velocity of a system is not acceptable for screening systems to include in the erosion/corrosion program. Local velocities downstream of control valves, orifices and nozzles may greatly exceed bulk flow velocities. For example, the bulk velocity in the Millstone Unit 2 moisture separator drain line was approximately 4 ft/sec. However, local velocity in the valve and in the reducer downstream of the valve were 110 ft/sec and 27 ft/sec, respectively.

2. Low usage lines during normal plant operation should be reviewed for inclusion in erosion/corrosion programs based on both the potential wear rate and time in use. Wear rates of lines, particularly those discharging to the main condenser, can have extremely high wear rates and should not be excluded from the erosion/corrosion program. An example of this type of line is the Millstone Unit 2, April 22, 1991, line failure.

3. The basis for excluding "small diameter" piping from an erosion/corrosion program needs to be justified based on an engineering evaluation. Small diameter, high energy lines can present a significant risk to personnel safety.

4. The practice of using one line to predict the wear rates of similar, parallel lines, needs to be evaluated and considered in program scope expansion criteria. Millstone Unit 2 had similar elbows in parallel lines which had significantly different wear rates. For this failure, differences in a backing ring alignment, which cannot be predicted by CHEC/CHECMATE, may have contributed to the differences in wear rates.

6.0 OVERALL CONCLUSIONS AND ASSESSMENTS

The plant safety and control systems responded as designed to minimize the plant transient caused by the drain line rupture and the resulting manually initiated reactor/turbine trip. The plant operators responded effectively to the failure of the moisture separator reheater drain line failure by manually tripping the reactor/turbine, closing the main steam isolation valves, and securing the feedwater and condensate systems. The damage to the equipment and insulation from this line rupture was minimal. The fluid from the rupture was contained in the turbine building and no release of radioactive material occurred as a result of this event. The safety significance of this event with regard to the health and safety of the public was minimal. However, the deficiencies in the erosion/corrosion program resulted in unnecessary personal safety risk to the plant staff.

The licensee's existing erosion/corrosion programs were inadequate to provide reasonable assurance in preventing secondary system pipe failures. This conclusion was previously identified during the Millstone Unit 3, Augmented Inspection Team in January 1991. The programs were inadequate because a detailed, systematic, quality, approach was not used to select vulnerable components for wall thickness measurement inspections.

The corrective actions taken following the Millstone Unit 3 pipe failures were in various stages of completion. The preliminary corrective actions were inadequate in that wall thickness measurements were not taken for systems similar to that which failed at Millstone Unit 3 when the opportunities became available. However, the planned actions which were to be completed by December 31, 1991, would have identified the ruptured line for inspection, and had wall thickness measurements been taken, this failure would have been prevented.

The team concluded that corrective actions planned following the Millstone Unit 2 failure are appropriate to provide a reasonable assurance that degraded components will be identified prior to failure. However, the licensee needs to assure that the choice of a relatively small sample size and the use of engineering judgement to identify inspection locations for pipes with diameters less than 2-inches will effectively preclude future pipe failures.

7.0 MANAGEMENT MEETING

The AIT held an entrance meeting with Northeast Utilities management and technical personnel on November 7, 1991. The inspection was performed during the period of November 7-18, 1991. An exit meeting, which was open to members of the public, was held with licensee management on November 18, 1991. The licensee's attendees at the entrance and exit meetings are listed in Appendix A.

The AIT members and NRC Region I management answered public and press questions immediately following the exit meeting.

APPENDIX A

ENTRANCE AND EXIT MEETING ATTENDEES

1.0 Northeast Nuclear Energy Company Corporate and Station Personnel

J. Bergin	Engineering Supervisor, Unit 2
J. Bibby	Project Services Manager, Unit 2
P. Blasioli	Engineering Manager, Unit 1
S. Chandra	Supervisor, Mechanical & Civil Eng.
M. Cheskis	NUSCO Civil & Mechanical Engineer
*C. Clement	Director, Unit 3
*E. DeBarba	Vice President, Engineering Services
J. Ely	Supv. Materials and Welding
J. Harris	Engineering Manager, Unit 3
H. Haynes	Director, Unit 1
W. Hutchins	NUSCO Nuclear Licensing Senior Eng.
L. Johnson	Director, Field Services
*J. Keenan	Director, Unit 2
T. Lyons	Engineering Supervisor, ISI, Unit 3
*S. Scace	Director, Millstone Station
J. Smith	Operations Manager, Unit 2
W. Strong III	Shift Supervisor, Unit 2
W. Quinlan	Project Services Director, Unit 2
J. Quinn	Engineering Supervisor, Unit 1
J. Riley	Engineering Manager, Unit 2
W. Romberg	Vice President, Nuclear Operations
*R. Wells	Project Services, Unit 2

2.0 USNRC Personnel

*M. Hodges	Director, Division of Reactor Safety

* Denotes licensee and NRC management present at November 18, 1991 exit meeting. The exit meeting was open to the public and was conducted at the Millstone training center.

APPENDIX B

SEQUENCE OF EVENTS

0642 Moisture separator reheater drain line breaks downstream of flow control valve 2-ES-791. Health physics personnel in adjacent area hear unusual noise and inform control room by phone of potential problem.

0643 Shift supervisor exits control room to the turbine hall to investigate. Concurrently, the following control room annunciators are received:

- ANNUNCIATOR GROUND (intermittent)
- 125VDC BUS GROUND (intermittent)
- GENERATOR CORE MONITOR ABNORMAL

0644 The following control room annunciator is received:

- MAIN GENERATOR FIELD GROUND

Steam generator levels begin to decrease and feedwater regulating valves open wider due to the addition of cold feedwater.

0645 After 1.5 minutes, shift supervisor returns to control room, informs operators of steam rupture in vicinity of 1B high pressure feedwater heater. The following control room annunciators are received:

- STORAGE AREA FIRE VALVE OPEN
- FIRE SYSTEM ABNORMAL
- FIRE PUMP START
- TURBINE H2 SEAL OIL TROUBLE (intermittent)

Control room operators take action to shutdown the reactor using control rods and boration. The shift supervisor exits control room to attempt to determine the location of the break and to make an initial damage assessment. Control room operators start an additional charging pump; turn on pressurizer heaters, and adjust pressurizer spray flow in preparation of adding boron.

0647:34 STEAM GENERATOR LEVEL DEVIATION annunciator

0647:38 MAIN GENERATOR EXCITER FIELD GROUND annunciator

0647:45 CONDENSER PIT SUMP LEVEL HI annunciator

0648:36	MAIN TURBINE ELECTROHYDRAULIC CONTROL SYSTEM (EHC) SYSTEM ABNORMAL annunciator
0648	GENERATOR CORE MONITOR annunciator (repetitive/intermittent)
0649:23	Manual Reactor Trip is initiated. Operators initiate OP-2525 "Standard Post Trip Actions"
0651	Shift supervisor enters control room. Main steam isolation valves are shut. Auxiliary feedwater is started.
0630	NRC inspectors arrive onsite.
0730	NRC inspectors informed of event via emergency notification system (ENS).
0800	Plant conditions are stable. Shift turnover is conducted.

APPENDIX C

ASSESSMENT OF THE NORTHEAST UTILITIES EROSION/CORROSION PROGRAM

Safety related piping is routinely inspected in accordance with the American Society of Mechanical Engineers (ASME), Boiler & Pressure Vessel Code, Section XI. The ASME Section XI committee is considering changes to address pipe wall thinning by erosion/corrosion for safety related systems. Non-safety related piping, which includes the section of pipe which failed at Millstone Unit 2, is not included in the ASME inspection program.

The NRC has issued correspondence to licensees regarding erosion/corrosion of secondary piping systems. As a result of the failure of the feedwater system elbow failure at Virginia Power's Surry Unit 1, in December 1986, the NRC issued IE Bulletin 87-01, "Thinning of Pipe Walls in Nuclear Power Plant " The bulletin requested information from the licensees regarding programs for monitoring the thickness of pipe walls in high energy carbon steel piping systems. Following a review of responses, the NRC issued Generic Letter 89-08, "Erosion/Corrosion-Induced Pipe Wall Thinning." The generic letter requested that licensees provide assurance that a program, consisting of systematic measures to ensure that erosion/corrosion does not lead to degradation of single and two phase high-energy carbon steel systems, has been implemented. On July 13, 1989, Northeast Utilities responded to the generic letter stating in part that "responsive actions have been taken as evidenced by our existing procedures and surveillance programs for erosion/corrosion control." The NRC has also issued the following information notices and a NUREG describing a variety of erosion/corrosion-induced pipe wall thinning events in nuclear power plants including a 1985 pipe failure, at Haddam Neck, which occurred downstream of the 1B feedwater heater, normal level control valve.

- NRC Information Notice 82-22, "Failure in Turbine Exhaust Lines"
- NRC Information Notice 86-106, Suppl. 1-3, "Feedwater Line Break"
- NRC Information Notice 88-36, "Significant Unexpected Erosion of Feedwater Lines"
- NRC Information Notice 91-18, "High-Energy Piping Failures Caused by Wall Thinning" (Including the Millstone Unit 3 failure of the moisture separator drain lines)
- NRC NUREG 1344, "Erosion/Corrosion-Induced Pipe Wall Thinning in U.S. Nuclear Power Plants."

The industry responded to the Surry event in part by developing tools to identify locations susceptible to erosion/corrosion. In 1987, the Electric Power Research Institute developed a computer model to predict erosion/corrosion in single phase fluid systems (EPRI-CHEC). A two phase model became available in 1989 (EPRI CHECMATE). Northeast Utilities had sponsored research in this area prior to 1987 and developed, with the assistance of the Massachusetts Institute of Technology, it's own computer base erosion/corrosion prediction tool.

Three separate erosion/corrosion induced failures of secondary side piping have occurred at Northeast Utilities nuclear units in the past twelve months. The first event occurred at Millstone Unit 3 on December 31, 1990, when two six-inch moisture separator drain lines failed. The NRC dispatched an AIT to Millstone (NRC Inspection Report 50-423/91-80) to gather facts regarding this event. The team concluded that the failure was due to erosion/corrosion caused by relatively high flow velocities in the failed line. The cause for the ruptured line not being included in the erosion/corrosion program was attributed to a human coding error involving the input to the Electric Power Research Institute (EPRI) CHEC/CHECMATE computer code The AIT concluded that the licensee's erosion/corrosion program required improvement. The licensee presented plans to improve the erosion/corrosion programs for all Northeast Utilities nuclear units at the AIT exit meeting.

On April 22, 1991, a 1-1/2 inch drain line, upstream of a steam trap failed at Millstone Unit 2. The drain line failure occurred because the trap in the drain line failed open allowing extraction steam to the 1B high pressure feedwater heater to be bypassed through this line to the main condenser. The section of pipe where the failure occurred was not included in the licensee's erosion/corrosion program due to the normal low flow velocity. However, following the trap failure, high steam flow rates occurred due to high differential pressure between the condenser and extraction steam line. The licensee performed pipe wall thickness measurements of approximately 520 components with diameters less than 2-inches and made 12 repairs to components inspected. This event is documented in NRC Inspection Report 50-336/91-09.

The third failure of an eight-inch elbow occurred at Millstone Unit 2 on November 6, 1991, and is the subject of this report. The moisture separator reheater drain line downstream of the reheater drain tank (excluding the high level dump lines) was not included in the Millstone Unit 2 erosion/corrosion program document EN 21153, Rev. 3. Documentation of wall thickness measurement data was not available for piping in the area of the failure. Based on past industry experience, the team concluded that this line should have been identified as vulnerable to erosion/corrosion and should have been included in the Millstone Unit 2 erosion/corrosion program. The team concluded that this pipe was not included in the erosion/corrosion program because components selected for inspection were based on industry experience/engineering judgement only without a systematic process.

Millstone Unit 1 Erosion/Corrosion Program

The Millstone Unit 1 erosion/corrosion program was developed in 1982. Between 1982 - 1987, the erosion/corrosion program focused on inspections of the extraction steam and heater drain systems. Replacements of the expansion bellows to the feedwater heaters occurred, based on excessive erosion. The replacement expansion bellows were made of chrome-molybdenum material.

An engineering department instruction, 1-ENG-6.09, was developed in 1987 to document the erosion/corrosion program. This program principally focused on the condensate and feedwater systems. Following the Surry pipe failure event, the Northeast Utilities Service Company (NUSCO) corporate engineering organization modeled the condensate and feedwater systems with the EPRI CHEC computer program. Based on the EPRI CHEC results, approximately 76 component inspections were performed on the condensate and feedwater systems during the 1987 refueling outage. Based on the results of these inspections no components required replacement.

During the 1989 refueling outage, based on EPRI CHEC, NUSCO engineers recommended twelve additional components for inspection. No abnormal wear was identified. Hence no replacement was required.

On December 31, 1990, Millstone Unit 3 had two moisture separator drain lines fail. The responsible Millstone Unit 1 erosion/corrosion representative attended the initial Millstone Unit 3 event meeting. Based on operational experience with heater drain inspections (1982-1987), and lower operating temperature conditions, Millstone 1 engineering concluded that no additional inspections were necessary.

In April 1991, Millstone Unit 1 shutdown for refueling. Site engineering requested that corporate engineering identify components to inspect during the refueling outage. Based on consultation from a Electric Power Research Institute representative, and review of analytical methodology from the ongoing CHEC/CHECMATE program, corporate engineering determined that no additional inspections were necessary during the outage. Millstone Unit 1 staff did not perform any inspections during the 1991 refueling outage.

In summary, Millstone Unit 1 erosion/corrosion program initially focused on extraction steam and heater drain systems. In 1987, the focus of the program shifted to the condensate and feedwater systems. Since the 1989 refueling outage, twelve components have been inspected. The licensee's reasons for the limited scope of erosion/corrosion inspections were based on the higher oxygen concentration, and higher population of piping systems containing chrome molybdenum steel.

Millstone Unit 2 Erosion/Corrosion Program

The Millstone Unit 2 erosion/corrosion program was developed in 1981. The program primarily used engineering judgement and industry experience to select inspection locations. The program inspected sections of piping in all systems designated as being vulnerable to erosion/corrosion. Inspections were performed in the moisture separator reheater drain system. However, the section of moisture separator reheater drain line which failed had not been included in the erosion/corrosion program. The program conducted a large number of UT inspections on various systems during each refueling outage. During the 1986 refueling outage, the licensee inspected approximately 175 components and identified 8 components which were repaired. During the 1989 refueling outage approximately 360 components were inspected and 2 were repaired. Approximately 500 components were inspected during the 1990 refueling outage and 8 were repaired. Following the April 22, 1991 failure of a 1-1/2 inch drain line, 520 inspections were conducted on small diameter piping components. These inspections identified 20 components which were repaired. Of the four Northeast Utilities nuclear units, Millstone Unit 2 has performed the most erosion/corrosion inspections.

Millstone Unit 3 Erosion/Corrosion Program

The Millstone Unit 3 erosion/corrosion inspection program was developed in 1985. Pipe wall thickness measurements have been taken of selected components during each refueling outage. During the first and second refueling outages, locations were selected for inspection using engineering judgement/industry experience and the EPRI CHEC and Massachusetts Institute of Technology (MIT) computer codes. During the third refueling outage all systems vulnerable to erosion/corrosion were modeled using the EPRI CHEC/CHECMATE code. The results of the EPRI CHEC/CHECMATE code were used to select components for inspection.

During the first refueling outage in 1987, a total of 59 components were inspected in the following systems; (25) feedwater, (20) condensate, (5) steam generator blowdown, (4) heater drains, and (5) extraction steam lines. The results of this inspection indicated that all components measured were within allowable nominal wall thickness tolerance. Hence no repairs were required.

During the second refueling outage in 1989, a total of 31 components were inspected in the following systems; (11) feedwater, (10) condensate, (2) steam generator blowdown, (4) heater drains, and (4) extraction steam lines. During the 1989 inspection, fourteen components previously inspected in 1987 were repeated. The results of this inspection indicated that all components were within nominal wall thickness tolerance. Hence no repairs were required.

Subsequent to the moisture separator reheater drain line failure on December 31, 1990, the following locations were inspected prior to returning the unit to service; downstream of trains "A" & "C" heater drain pump level control valves to the fourth point feedwater heater, train "A" turbine driven feed pump recirculation valve, train "A" first point feedwater heater normal level control valve, train "A" moisture separator drain tank emergency level control valve, and the train "A" moisture separator reheater drain tank normal level control valve. No areas were identified as requiring repair. The third refueling outage was scheduled to start approximately six weeks following the failure of the moisture separator drain lines.

During the third refueling outage, in March 1991, a total of 164 components were inspected in the following systems; (2) auxiliary steam, (8) steam generator blowdown, (48) condensate, (3) cold reheat, (6) moisture separator drains, (11) main steam reheater drains and vents, (17) extraction steam, (4) feedwater pump recirculation, (42) feedwater, (6) high pressure feedwater heater drains, (14) low pressure feedwater heater drains, and (2) steam generator feedwater pump exhaust. Sections of pipe in the feedwater, cold reheat, high pressure feedwater heater drain, and low pressure feedwater heater drain systems were repaired. The wall thickness of components repaired were all greater than required minimum wall thickness.

Haddam Neck Erosion/Corrosion Program

The erosion/corrosion program at Haddam Neck was established in 1977. The components selected for inspection were based on engineering judgement and industry experience. Specific criteria used to select locations for inspection included in part, previous inspection results, personnel safety considerations, and plant reliability. The systems inspected between 1977 - 1985 were extraction steam, heater drain, condensate, feedwater, feedwater heater strings, main steam, and pipe between the governor valve and the high pressure turbine.

Between 1977 and 1985, the following components were inspected; (258) elbows, (5) piping spools (downstream of orifices, reducers, backing rings), (53) tees, and (22) reducers. Approximately 338 component were inspected. Approximately 60 components were replaced or repaired based on the inspection results.

In 1986, Haddam Neck evaluated the Surry event, and determined that no additional inspection was necessary.

Between 1986 - 1989 over a span of three refueling outages, the following components wer inspected; (276) 90-degree elbows, (36) tees, (35) reducers, (40) 45-degree elbows, and (30) piping spools. The number of components replaced were: (41) 90-degree elbows; (4) tees; (8) reducers; (13) piping segments; and (13) 45-degree elbows.

During the 1989 refueling outage, site engineers reviewed the CHEC methodology and compared it to the current erosion/corrosion program. However, this analytical tool was not implemented at Haddam Neck.

Following the Millstone Unit 3 event, on December 31, 1990, Haddam Neck staff evaluated the specifics of the event and determined that no immediate inspections were necessary based on the historic program development and results.

In February 1991, based on NUSCO's preliminary evaluation, site engineers added the steam generator blowdown system, auxiliary steam, and gland seal system to the erosion/corrosion program.

Haddam Neck's erosion/corrosion program uses a screening criterion of 87% nominal wall thickness. If the non destructive examination results indicate that the wall thickness is 87% of nominal, a deviation report is sent to NUSCO engineering. NUSCO engineering may resolve the deviation either by replacing the component, increasing the inspection interval, and/or increasing the inspection population.

During the current refueling outage, Haddam Neck's erosion/corrosion program has implemented CHEC/CHECMATE with recommended inspections of 202 components. As of November 11, 1991, the inspections planned for the scheduled refueling outage have been expanded to 235 inspections. As a result of these inspection four components will be replaced.

ATTACHMENT 1

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION I
475 ALLENDALE ROAD
KING OF PRUSSIA, PENNSYLVANIA 19406-1415

November 6, 1991

Docket No. 50-336

MEMORANDUM FOR: Wayne Hodges, Director, Division of Reactor Safety

FROM: Thomas T. Martin, Regional Administrator

SUBJECT: AUGMENTED INSPECTION TEAM CHARTER FOR REVIEW OF THE NOVEMBER 6, 1991, MOISTURE SEPARATOR DRAIN LINE RUPTURE AT MILLSTONE 2

As a result of the November 6, 1991, moisture separator drain line rupture at Millstone 2, I, along with NRR and AEOD senior management, determined that an Augmented Inspection Team (AIT) inspection should be conducted to verify the circumstances and evaluate the significance of the subject event.

The Division of Reactor Safety (DRS) is directed to conduct that AIT with James Trapp as the Team Leader. Further, DRS, in coordination with the Division of Reactor Projects, is responsible for the timely issuance of the inspection report, the identification and processing of potentially generic issues found, and the completion of any enforcement action warranted as a result of the Team's review.

Enclosed is the charter for the Augmented Team delineating the scope of this inspection. The inspection shall be conducted in accordance with NRC MC 0513, NRC Inspection Manual 0535, Inspection Procedure 93800, and this memorandum. The bases for this inspection, per MC 0513, are: the staff's need to determine if there are potential generic issues worthy of staff action associated with this event; similar events on December 31, 1990, for Unit 3 and April 22, 1991, for Unit 2; and, concerns pertaining to the licensee's development and implementation of their erosion/corrosion programs.

Thomas T. Martin
Regional Administrator

Enclosures:
1. Augmented Inspection Team Charter
2. Team Membership/Schedule

cc:
T. Murley, NRR
J. Partlow, NRR
J. Calvo, NRR
C. Rossi, NRR
J. Stolz, PD I-4, NRR
F. Miraglia, NRR
C. McCracken, NRR
W. Russell, NRR
J. Richardson, NRR
A. Thadani, NRR
B. Grimes, NRR
J. Roe, NRR
E. Jordan, AEOD
D. Ross, AEOD
J. Taylor, EDO
J. Sniezek, EDO
R. Lobel, EDO
W. Kane, DRA, RI
C. Hehl, DRP, RI
J. Wiggins, DRP, RI
J. Trapp, DRS, RI
W. Raymond, SRI, Millstone
H. Gray, DRS
G. Vissing, PD I-4, NRR
H. Kaplan, DRS
P. Patnaik, DRS
S. Stewart, DRS
K. Kolaczyk, RI, Millstone
R. Herman, NRR
J. Durr, DRS
W. Hodges, DRS
L. Bettenhausen, DRS
E. Wenzinger, DRP
K. Abraham, PAO, RI
M. Miller, RI

ENCLOSURE 1

AUGMENTED INSPECTION TEAM CHARTER

MILLSTONE 2 MOISTURE SEPARATOR DRAIN LINE RUPTURE ON NOVEMBER 6, 1991

The Augmented Inspection Team (AIT) is to perform an inspection and accomplish the following:

1. Determine the specific circumstances and events which led up to the rupture of the moisture separator drain line. Develop a sequence of events and c ng activities before and after the event. Include in your assessments any prev censee inspections or analyses of this section of piping and its inclusion in the licensee's erosion/corrosion (EC) program. Review the functioning of the installed fire protection systems, their interactions, and any subsequent effects on other plant systems, when actuated. Also, determine the root cause of the event (if possible) and identify whether any other piping vulnerabilities at Unit 2 may exist.

2. Verify and evaluate Northeast Nuclear Energy Company's (NNECo) actions following the event. Include the implementation of Emergency Plan, the response of operators, response of management, the availability of sufficient cognizant staff, and implementation of any additional needed safeguards, fire protection, or event reporting.

3. Determine and evaluate the response of plant systems needed to cope with this event and the impact of the event on, or threat to the operability of, safety related systems. Evaluate the operators' response to the event and their ability to quickly and safely stabilize the plant in a shutdown condition. Review NNECo root cause analysis of the event as well as any corrective actions which they tentatively propose. Within the time limits of this charter, review NNECo plans and schedule for repairing the damage to the facility and returning Unit 2 to service.

4. Assess the adequacy of corrective actions to the previous events of December 31, 1990, on Unit 3, and April 22, 1991, on Unit 2 as they relate to the licensee's erosion/corrosion (E/C) programs. Include an assessment of the status of program development and implementation at all four NNECo facilities (Millstone and Haddam Neck sites), including the basis for management prioritization and existing schedules for full E/C program implementation.

5. Determine if there are any potential generic issues associated with this event. Assess the extent to which NNECo has evaluated their own and relevant industry experience with respect to E/C programs at all four of their nuclear units.

6. Prepare a report documenting the results of this review for signature by the Regional Administrator within 30 days of the completion of the inspection.

ENCLOSURE 2

TEAM MEMBERSHIP/SCHEDULE

Team Membership

James Trapp, Senior Reactor Engineer, DRS (Team Leader)

Herb Kaplan, Senior Resident Engineer, DRS
Kenneth Kolaczyk, Resident Inspector, Millstone
Prakash Patnaik, Reactor Engineer, DRS
James Stewart, Operations Engineer, DRS
Guy Vissing, Project Manager, NRR

Tentative Schedule

11/6/91	2000	Meeting of the team members at the Niantic Inn, Niantic, CT
11/7/91	0800	Arrive onsite, badging, set up interviews
11/7/91	0900	Entrance meeting at site with licensee management
11/7/91	1600	Debrief with RI management
11/8/91	1600	Debrief with RI management
11/12/91	1200	Complete inspection
11/12/91	1300	Debrief with RI management
11/12/91	1400	Debrief with Northeast Nuclear Energy Company's management onsite
--	--	Exit (to be determined)
12/6/91		Issue report

ATTACHMENT 2

U. S. NUCLEAR REGULATORY COMMISSION
REGION I

Docket Nos. 50-245
50-336
50-423

License Nos. DPR-21
DPR-65
NPF-49

Licensee: Northe[illegible] Nuclear Energy Company
P.O. B[illegible] 270
Hartford, Connecticut 06141-0270

Facility Name: Millstone Nuclear Power Station, Units 1, 2 and 3

Inspection At: Waterford, Connecticut

Inspectors: C. D. Beardslee, Reactor Engineer
S. S. Koscielny, Corrosion Engineer

for C. D. Beardslee 11/1/91
H. J. Kaplan, Sr. Reactor Engineer, date
Materials Section, EB, DRS

Approved by: E. H. Gray 11/3/91
E. Harold Gray, Chief, Materials Section, date
Engineering Branch, DRS

Inspection Summary: Announced inspection on September 30 - October 4, 1991

Areas Inspected: The areas inspected are the corporate erosion/corrosion program and the site specific erosion/corrosion procedures.

Results: As the licensee indicated, the erosion corrosion (E/C) Program Manual is in draft form and requires several changes and reviews before it reaches its final form. Additionally, reviews of the completed individual plant analysis will be performed. Significant effort has been put forth by Northeast Nuclear Energy Company (NU) to improve its E/C program and the commitment date of December 31, 1991 appears to be attainable.

It appears that all three units are implementing their E/C programs to varying degrees. There does not appear to be any communication between the three units with regards to this program and communication between site and corporate needs to be improved. In addition, the individual units need to create or revise their site specific E/C procedures to correlate with the E/C Program Manual. They have committed to the NRC to complete these procedures by April 30, 1992.

1.0 Erosion-Corrosion (E/C) Program - Corporate (37700)

1.1 Background

As a direct result of Generic Letter 89-08 and NRC Augmented Inspection Team Report (50-423/91-80), Millstone Units 1, 2 and 3 committed to implementing an E/C Program and to verifying the E/C program models (to assure that valid locations are being selected for Ultrasonic Testing (UT) inspections) by December 31, 1991. Currently, the E/C Program Manual is complete in draft form and the verification of the program models is 15%, 20% and 85% complete for Units 1, 2 and 3 respectively. Persons contacted during this inspection are listed in Attachment 1. Documents referred to during the time of the inspection can be found in Attachment 2.

1.2 Review of Program Manual

The E/C Program Manual, Technical Report TR-91155-01, was prepared by ALTRAN, a consultant hired to develop the methods and criteria of the E/C program. The Northeast Utilities (NU) Engineering Department has overall responsibility for program implementation; Field Engineering is responsible for data collection; and Plant Engineering/ISI is responsible for plant specific procedures and support. Several highlights of the E/C Program are:

- Engineering review of all secondary side systems
- Use of industry accepted exclusion criteria
- Use of QA Category 1 requirements for all evaluations and inspections
- Use of EPRI developed computer code CHECMATE for assessing E/C susceptibility
- Provides guidance on system selection criteria, selection of piping locations for examination, component examinations, acceptance criteria and mitigating actions

The inspector recommended two additions as follows:

- Procure new material from Vendor's Qualified List
- Perform periodic audits of E/C activities

As a result of a review of the E/C Program Manual and interviews with personnel, it appears that the Manual will be complete and comprehensive by the commitment date of December 31, 1991.

1.3 Review of CHECMATE analysis

An ALTRAN analysis (in draft form) of Connecticut Yankee/Haddam Neck secondary side piping systems was reviewed (No analysis was available for Millstone). The analysis will be maintained and updated by NU Engineering Department. The licensee indicated that the input and completed analysis have not yet been reviewed by NU for their concurrence.

The segment of piping (WSD-61) reviewed by the inspector is part of the Moisture Separator Reheater (MSR) Drain System. It runs from MSR 1A to Feedwater Drain Tank 1A. An isometric, heat balance, UT data sheet and CHECMATE users guide were used to verify the quality of the input data. Chemistry History Data, Design Conditions for Piping Segment and Component Information (geometry code, diameter, thickness) all were verified for proper input. It was not possible to verify piping lengths because they were not included on the isometrics. The only information not included in the input was the Network Flow Analysis Data, which was not required for the analysis performed. Network Flow Analysis would optimize the use of the CHECMATE computer code. Several important parameters which were noted are:

- All piping components, including straight sections, were entered into the computer code.

- The input data was reviewed by another employee which minimizes the probability of data input errors.

- The completed analysis and a comparison of CHECMATE predictions with measured wear was reviewed and appears reasonable. It confirms that the licensee is performing this function to check the validity of the computer analysis.

- The licensee indicated that they intend to review the completed analysis.

- It was indicated in a memorandum from EPRI to NU that the consultant, ALTRAN, has been trained in the use of CHECMATE.

- The input data was reviewed by another employee which minimizes the probability of data input errors. However, the piping was modeled as A106 Gr B vice the installed A106 Gr A and the fittings were modeled as A234 WPB vice the installed A234 WPA.

1.4 Conclusions

The licensee indicated that the E/C Program Manual is in draft form and requires several changes and reviews before it reaches its final form. Additionally, reviews of the completed individual plant analysis will be performed. Significant 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.

2.0 Millstone Unit 1

2.1 Site Specific Procedure (57080)

The current site specific E/C procedure for Unit 1 is Departmental Instruction No. 1-ENG-6.09. Several insufficiencies were noted:

Section 3.3

- Indicates that wall thickness may be assessed utilizing visual examination or pipe wall thickness measurement (UT). On the contrary, visual examination alone is not acceptable. For example, it will not provide meaningful results in the case of general corrosion.

Section 3.3.2.4

- Does not define what the "code allowable" thickness is or where it can be obtained.

Section 3.3.6

- Indicates that the Engineering Department will retain all records that are created as part of this program. Contrary to the above, Ultrasonic Testing (UT) was performed in 1987 and 1989, but records provided to the inspector were incomplete and the location of the remaining records was not known. This indicates a lack of communication between site and corporate engineering.

The licensee provided a memo (PSE-EM-89-268) which indicates the locations of inspection for the 1993 refueling outage. The inspector was unable to verify what this decision was based on. No documentation of analysis was provided to support the location of these inspection areas. In addition, the memo referenced the 1987 and 1989 inspection data which were incomplete.

The current procedure which implements the E/C program is lacking in many areas. It has been indicated by the licensee that the site specific procedure will be updated and revised after the completion of the E/C Program Manual.

3.0 Millstone Unit 2 - Site Specific Procedure (57080)

The current site specific E/C procedure (EN 21153) was provided to the inspector for review. The contents of the documented procedure are not comprehensive.

- Guidance is not provided as to the method of UT to be used
- The use of grid patterns, which are necessary for trending of data, is not suggested
- No details are given on what criteria is to be used for piping selection

Contrary to the documented procedure, the actual monitoring, of the secondary side piping systems, performed by Unit 2 appears to be sufficient. The licensee relies heavily on bulk inspection to verify piping integrity in Balance of Plant Systems and the analysis performed to select locations for inspection is strongly based on engineering judgement. A 100% scan UT is performed on each component inspected and data is recorded at grid intersections. UT data is well documented and organized by outage. Many of these features are not documented in procedure EN 21153.

Inspection data was reviewed for a 16 X 8 No. 2 Reducer, Pipe Line No. GBD-8 in the Heater Drain Pump Discharge. The data appears to be complete and the replacement of degraded piping was documented and performed at an appropriate time.

Currently, the site specific procedure does not correlate with the E/C Program Manual. It has been indicated by the licensee that when the E/C Program Manual is complete, the site will update their procedure.

One aspect noted is Unit 2's reluctance to provide their past inspection data to corporate/ALTRAN. The CHECMATE Program increases its effectiveness as the amount of inspection data available increases. This continues to emphasize that communication between site and corporate engineering organizations needs to be improved.

4.0 Millstone Unit 3 (57080)

4.1 Site Specific Procedure

The site specific E/C procedure (EN 31125) appears to be fairly co: ehensive, but will need to be revised when the E/C Program Manual has bee. completed. The licensee has indicated that this will be performed.

4.2 Nondestructive Engineering Inspection

Procedure NU-UT-30, Ultrasonic Examination - Thickness Measurements Using Viewsonics Data Loggers, was reviewed. It consisted of Personnel Requirements, Equipment Description, Calibration of Scope, Recording Thickness Measurements, Thickness Mapping Grid Construction and Records. The inspector observed the licensee's use of procedure NU-UT-30. The component on which UT was performed is FWS 2409E1, Line 3-FWS-024-9-4, Drawing FWS-5-25212-20188 SH20 (Grid Q12 - Q15). The thickness measurements corresponded closely to that which was previously recorded. Several additional documents were reviewed to determine that the employee who conducted the original UT was appropriately qualified.

4.3 Review of Records

During the previous refueling outage (after the December 31, 1990 moisture separator drain pipe failure), one hundred and sixty four components were ultrasonically tested. Of these components, one hundred and fifty seven were acceptable, four needed repair, two needed monitoring and one was labeled monitor/repair. The status of the results is documented on PSE-JFE-91-110. The records of three of these components were reviewed and were found to be consistent with the recorded data.

Component	Line	*Disposition
FWS-3604T6	FWS-36-04-4	Acceptable
3-FWS-2410E1	3-FWS-24-10-4	Monitor
3-HDH-LV21A1	Reducer Downstream	**Repair

*Disposition of wall thickness data
**Resulted in replacement - Nonconformance Report (NCR 391-110)

The inspector reviewed two mainten[illegible]) packages covering (1) 3-HDH-LV21A1 reducer replacement a (2) failed moisture separator drain piping. In the first case, the existing pipe was replaced with A106 Gr. B carbon steel piping and the reducer with A-403-WP304 stainless steel, and in the second case the failed pipe was replaced with A-335-P5, 5% chromium steel. The review indicated that the appropriate ASME Section IX qualified welding procedures (WPS-001, WPS-009 and WPS-201) were used attendant with post weld heat treatment (1350°F cycles), and final visual inspection as required by ANSI B31.1-1986 Code.

5.0 Conclusions

It appears that all three units are implementing their E/C programs to varying degrees. There does not appear to be any communication between the three units with regards to this program and communication between site, and corporate needs to be improved. In addition, the individual units need to create or revise their site specific E/C procedures to correlate with the E/C Program Manual. They have committed to the NRC to complete these procedures by April 30, 1992.

6.0 Miscellaneous - Millstone Unit No. 1 - JCO No. 1-91-01

The subject JCO dated June 28, 1991, described certain high energy locations outside the containment in several components whose failure could adversely affect the turbine building secondary closed cooling water (TBSCCW) system. These components are required for diesel generator operability.

The inspector's review of the augmented in-service inspection (ISI) results which were included in the JCO indicated an inadvertent omission of key ultrasonic data. The licensee provided the necessary data on October 3, 1991. It is noted that ISI data also included comprehensive wall thickness measurements.

7.0 Exit Meeting

An exit interview was held on October 4, 1991 with members of the licensee's staff noted on Attachment 1. The inspector discussed the scope and findings of the inspection.

ATTACHMENT 1

Persons Contacted

Northeast Utilities

J. Bergin, Engineering, Unit II
S. Chandra, Supervisor, Engineering Mechanical Group
M. Cheskis, Mechanical Engineer
*C.H. Clement, Director, Unit III
*B. Enoch, I & C, Unit III
L. Georgian, Inservice Inspection, Unit I
*J. Harris, Engineering Manager, Unit III
*J. Keenan, Director, Unit II
M. Kupinski, Piping Systems Engineering Manager
*T. Lyons, Engineering, Unit III
D. MacNeill, NDE Engineer
*W. Noll, Engineering, Unit I
*T.G. Quinley, Engineering, Unit II

U.S. Nuclear Regulatory Commission

*P. Habighorst, Resident Inspector, Unit II
*K. Kolaczyk, Resident Inspector, Unit III
*J. Medoff, Reactor Engineer
*W. Raymond, Senior Resident Inspector

* Indicates presence at exit meeting

ATTACHMENT 2

References/Requirements

-- Generic Letter 89-08, Erosion/Corrosion-Induced Pipe Wall Thinning

-- NUREG-1344, Erosion/Corrosion-Induced Pipe Wall Thinning in U.S. Nuclear Power Plants

-- NRC Augmented Inspection Team Report (50-423/91-80)

-- Technical Report T-91155-01, Rev. A, Erosion/Corrosion Program Manual

-- Departmental Instruction No. 1-ENG-6.09, Rev. 0, Balance of Plant Piping Inservice Inspection Program

-- PSE-EM-89-268, Millstone Unit No. 1 Erosion-Corrosion Inspection Program for the 1993 Refueling Outage

-- Procedure EN 21153, Rev. 3, Thickness Testing of Secondary Piping (Unit 2)

-- Procedure EN 31125, Rev. 4, Piping Inspection Program for Erosion/Corrosion (Unit 3)

-- Procedure NU-UT-30, Ultrasonic Examination - Thickness Measurements Using Viewsonics Data Loggers

-- PSE-JFE-91-110, Millstone Unit 3 Erosion/Corrosion Program, Baseline Ultrasonic Exam Evaluation Results

-- Nonconformance Report (NCR) 391-110

-- JCO #1-9[illegible]-01, dated 6/28/91 - High Energy Line Breaks

-- Stone and Webster Engineering Corporation General Requirements, SP2-5.55, dated 12/10/65 (For Connecticut Yankee)

U. S. NUCLEAR REGULATORY COMMISSION
REGION I

Licensee: Northeast Nuclear Energy Company
Connecticut Yankee Atomic Power Company
P. O. Box 270
Hartford, Connecticut 06101-0270

Facility Name: Millstone Nuclear Power Plant

Inspection Conducted: November 12-15, 1991

Inspection At: Waterford and Berlin, Connecticut

Inspectors: [signature] 11-29-91
Walter J. Pasciak, Chief, Facilities Radiation Protection Section, DRSS (Task Force member) — date

[signature] 12/4/91
John T. Shedlosky, Senior Allegations Coordinator, Millstone, DRP (Task Force member) — date

Approved: [signature] 12/4/91
Wayne D. Lanning, Deputy Director Division of Reactor Safety (Task Force leader) — date

Areas Inspected: Special Task Force inspection of the licensee's erosion/corrosion control program for the Northeast Nuclear Energy Company Millstone Units-1, -2 and -3, and including a limited review of the Connecticut Yankee Atomic Power Company Haddam Neck Plant.

Results: Weakness were identified in the Northeast Utilities Service Company (NUSCO) management attention to erosion/corrosion control in the period following the Surry Station event (1986) through early 1991. Further, weaknesses were identified in management oversight at Millstone Units-2 and -3 of their erosion/corrosion control programs.

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DETAILS

1.0 PERSONNEL CONTACTED

1.1 Licensee Personnel

- * S. Scace, Millstone Site Director
- * H. Haynes, Millstone Unit-1 Director
- * J. Keenan, Millstone Unit-2 Director
- * C. Clement, Millstone Unit-3 Director
- T. Quinley, Engineering Specialist, Unit-2
- J. Bergin, Engineering Supervisor, Unit-2
- J. Quinn, Engineering Supervisor, Unit-1
- M. Bigiarelli, Engineering Supervisor, Unit-1
- L. Georgian, Engineering Technician, Unit-1
- J. Harris, Engineering Manager, Unit-3
- T. Lyons, Engineering Supervisor, Unit-3
- * E. DeBarba, Vice President Nuclear, NUSCO
- M. Kupinski, Manager of Mechanical & Civil Engineering, NUSCO
- J. Ely, Supervisor of Materials & Welding Testing, NUSCO
- S. Chandra, Supervisor Engineering Mechanics, NUSCO
- G. Alkire, Senior Engineer, NUSCO
- M. Cheskis, Senior Engineer, NUSCO
- J. Delawrence, Engineering Supervisor, Haddam Neck Plant

1.2 NRC Personnel

- * W. Lanning, Deputy Director, DRS, (Task Force leader)
- * W. Pasciak, Chief, Facilities Radiation Protection Section, DRSS, (Task Force member)
- * J. Shedlosky, Senior Allegation Coordinator, DRP, (Task Force member)
- J. Trapp, Senior Engineer, DRS (AIT team leader)
- * W. Raymond, Senior Resident Inspector, Millstone site

* Indicates those attending the exit meeting on November 15, 1[illegible]

2.0 PURPOSE

The purpose of this inspection was to review actions of Northeast Nuclear Energy Company management in the area of erosion/corrosion control of secondary plant systems. In particular, management responses after the pipe failure at the Virginia Power Company Surry Nuclear Power Station and the recent failures at Millstone Units-2 and -3 were reviewed.

3.0 BACKGROUND

There has been a history of incidents of pipe wall thinning and rupture in feedwater and balance of plants systems in nuclear power plants. The sudden, catastrophic rupture of a feedwater pipe at the Surry Nuclear Power Station in 1986 was the most significant because it resulted in the loss of human life, and it occurred in l ,e diameter piping containing high pressure and temperature water. Prior to the Surry event, industry practice for examining pipe wall erosion/corrosion was limited general'y to two-phase systems.

After the Surry event, the nuclear industry and the NRC took initiatives to address the single-phase erosion/corrosion. Industry guidance and NRC generic communications contributed to developing recommended inspection programs. The Nuclear Utility Management and Resource Council (NUMARC) developed the guidelines that industry adopted for selecting initial locations for inspection. The Electric Power Research Institute (EPRI) provided industry with analytical tools (computer programs named CHEC for single-phase flow and later CHECMATE for both single and two-phase flow) to determine the most susceptible areas for pipe wall thinning in conjunction with operating experience.

On December 31, 1990, at Millstone Unit-3, two six-inch diameter moisture separator drain lines ruptured due to single-phase erosion/corrosion thinning--the same failure mode that had occurred at Surry. On April 22, 1991, at Millstone Unit-2, a 1-1/2 inch drain line connected to an extraction steam line drain trap failed due to two-phase erosion. Then, on November 6, 1991, at Millstone Unit-2, an eight-inch moisture separator reheater drain line failed, also due to two-phase failure mode. The NRC Augmented Inspection Teams dispatched for the December 31, 1990 event and the November 6, 1991 event found that none of the failed piping had been included in the erosion/corrosion inspection programs at Millstone. Subsequently, NRC Regional Management sent a three-person t force to evaluate the adequacy of Northeast Utilities (NU) management responses and activities regarding the erosion/corrosion monitoring program.

4.0 RESPONSE TO THE SURRY STATION EVENT OF DECEMBER 6, 1986

4.1 Millstone Unit-1, Unit-2, and Haddam Neck

Prior to the Surry event, Millstone Units-1 and -2 and Haddam Neck had erosion/corrosion inspection programs. All three units experienced some wall thinning at a limited number of locations and had replaced piping.

At Millstone Unit-1, problems had routinely been identified in the turbine extraction steam system. The turbine eighth, ninth and eleventh stage extraction steam lines have been replaced; pipe material was changed from the original carbon steel to a chromium-molybdenum alloy for erosion resistance. Because Unit-1 is a BWR and has higher oxygen concentration in the feedwater systems, Unit-1 has not experienced single-phase erosion/corrosion; thus, its monitoring program was of a smaller scope than the other units. After Surry, the Unit-1 program was expanded to include the condensate and feedwater systems; the inspection locations provided by Northeast Utilities Service Company (NUSCO), the corporate engineering organization, were based on the CHEC code. However, the program encompassed few systems because the failures that had occurred were pin-hole leaks rather than large area thinning. Additionally, most of the susceptible piping is located in concrete shielded radiation areas. Taken together, these conditions did not represent significant personnel risk.

At 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. Inspections were made by a contractor who provided inspectors qualified in ultrasonic non-destructive testing who worked under Quality Assurance work orders. During the 1981-83 period, there were 75-150 inspections per outage, during the 1985-86 period, there were 150-200 inspections per outage, and during the 1987-88 period, there were more than 200 inspections per outage. Components were selected for inspection based on plant experience; erosion was trended; and as a result, some turbine extraction steam lines were replaced with chromium-molybdenum alloy pipe. However, the inspection program was based on engineering judgement, and there was not a systematic approach or criteria for ensuring that all vulnerabilities were inspected.

On March 16, 1985, the Haddam Neck Plant had a significant pipe rupture downstream of the "1B" feedwater heater level control valve. Although they had an inspection program for monitoring elbows in the condensate and feedwater systems as well as other balance of plant systems, they modified that program to include piping downstream of flow control valve configurations, the similar configurations for the two Millstone failures. The plant's initial program had been formed in response to erosion/corrosion incidents occurring earlier in plant life; examples include failures in the high pressure turbine exhaust cross-over steam to the moisture separator/reheater at a twenty-four inch diameter elbow, a moisture separator drain line at an elbow entering the feedwater heater drain tank and a feedwater pump discharge recirculation line to the main condenser, also at an elbow. Because Haddam Neck had an extensive, historical inspection program, which included areas of single phase flow, the data from the program were used by EPRI to validate the CHEC code during its development.

At the time of the Surry event, it was generally felt by NU management and staff that it would be unreasonably costly to inspect all BOP piping at the three units and, as a result, the licensee utilized a system for selecting components that were most vulnerable to erosion/corrosion. The selection of piping for inspection was based on a number of factors. These included evaluations from NUSCO primarily as a result of use of operational experience, the NUMARC guidelines and screening criteria developed by NUSCO in June 1987. Their application was similar to that at Millstone Unit-3, which is discussed in the next section. However, the use of the computer codes for Millstone Units-1 and -2 and Haddam Neck was limited only to a few systems, generally condensate and feedwater piping and each unit believed that its existing program exceeded and encompassed any guidance provided by NUSCO. Each program was developed and implemented independently by a single staff person based on their judgement and knowledge of the unit's operational history. Corporate support was provided by the same technician supporting Unit-3.

4.2 Millstone Unit-3 and NUSCO Actions

The pipe break event at Surry occurred shortly after initial startup of Unit-3. Because Unit-3 had not been operating very long, no erosion/corrosion program had been set up. After the Surry failure occurred, Unit-3 staff worked with the engineering staff at NUSCO to develop a program. However, the program was based only on the analytical results provided by NUSCO, i.e., it lacked operational experience considerations. The NUMARC guidelines and the NUSCO screening criteria were applied to assist the analysis and component selection.

The screening criteria allowed exclusion of systems or a portion of a system from further analysis. The component material along with the fluid oxygen concentration, temperature, pH, and bulk flow velocity for each portion of a system with the same operating conditions were evaluated and compared to the exclusion criteria. If one or more of the parameters fell out of a specified range, that portion did not have to be included in the inspection program. The critical range for bulk flow velocity was over ten feet per second; sections with velocity less than this could be eliminated from analysis using the EPRI CHEC computer code.

The NUSCO staff obtained the EPRI CHEC code for analyzing single-phase flow; additionally, a code was developed for the licensee by the Massachusetts Institute of Technology (MIT) for analyzing two-phase flow. An engineering technician was designated by the corporate staff to work with the site in running the codes and in providing feedback on inspection locations.

It appeared that the program for Unit-3 initially worked well in that the unit provided the information corporate engineering needed to run the codes, and the unit received from corporate the information needed to perform the testing efficiently. A significant problem with the program was that it received little attention or emphasis by NUSCO management as it was primarily conducted on the corporate side by a technician who was provided little or no supervision, and little review was performed of her work. For most of the time, the senior engineer position supervising the technician was vacant as well as was the engineer's supervisor's position. In fact, the pipe break that occurred at Unit-3 on December 31, 1990 would very likely have been avoided had the technician's work been independently verified.

In 1987, the unit sent data on the moisture separator drain (DSM) system, including the two moisture pump discharge lines that failed, to NUSCO for analysis. The technician incorrectly interpreted the data such that none of the system was modeled in the CHEC program; there were no inspections of DSM components prior to the failure. Had the system been modeled, the piping downstream of the pump flow control valves would have been flagged for inspection. Apparently, a velocity exclusion, which was applicable for a portion of a system, was applied to the entire moisture separator drain system because of the manner in which the data were presented. The calculations were viewed as non-safety related, and was not considered under the QA program. Consequently, there was no independent review of the program and its implementation.

Not only was corporate management deficient in providing oversight of the technician's work, but the Unit-3 staff failed to follow up on the issue after providing the data to corporate. The staff also failed to develop a broad based inspection program based on operating experience. At that time, there was considerable industry experience with problems with moisture separator drain lines, both at other sites, and at the three other NU units. In addition, there were major industry initiatives and considerable NRC generic communications regarding wall thinning due to the erosion/corrosion phenomena. These experiences should have alerted the unit staff to question, during the three-year period, why NUSCO did not flag the lines for inspection, especially since the unit staff was aware of the way the erosion/corrosion control program was being handled by corporate. In 1990, the responsible technician left NU, and during the following year, no analytical capability existed. This stagnated Unit-3's program until its pipe failure in December 1990. This further illustrates the lack of NU management attention and support for the erosion/corrosion program.

During the time that the NUSCO staff was working with the Unit-3 staff in supporting the CHEC and MIT code analysis, several NUSCO individuals at the engineer and manager level determined that there was a need to develop a systematic erosion/corrosion program for all four units. Because this would involve a significant expenditure of resources, it was necessary to obtain funding approval. The method by which this support was obtained was through the development of a Project Assignment (PA). Two were developed in 1987 (PA 87-031 for the Millstone Units and 87-032 for Haddam Neck) and were concurred in through several levels of management, including a Vice President, but were ultimately not approved. It was not clear what the reason for disapproval was, but cost for the project was believed to be excessive in a time that cost containment was a NU management primary objective. The NUSCO staff believed that had the erosion/corrosion program received more emphasis, the analytical capability would have been available and probably have predicted the large-bore vulnerabilities in both Units-2 and -3 and precluded both events. This further demonstrates the lack of support provided by NU management to erosion/corrosion control, and represents a missed opportunity to prevent the Unit-2 and -3 events.

5.0 ACTIONS FOLLOWING THE DECEMBER 31, 1990 EVENT AT MILLSTONE UNIT-3

In response to the Unit-3 pipe failure, NU management committed to perform a comprehensive review of the erosion/corrosion programs at the Millstone units and Haddam Neck. By the end of February, NUSCO had identified for each unit a list of systems potentially susceptible to erosion/corrosion based on the NUMARC criteria, industry experience and operational experience at the four NU plants. There was significant emphasis placed on the independent review methodology required to assure quality data. However, except for Unit-3, no inspections were deemed necessary.

For Unit-3, the susceptible systems would be analyzed prior to restart from the February-April refueling outage using CHECMATE, a single and two-phase erosion/corrosion program developed by EPRI. Unit-3 staff performed only limited inspections before restart. The other units would be analyzed by the end of 1991. (The initial commitment was to analyze Unit-1, Unit-2, and Haddam Neck by December 31, 1991, September 30, 1991, and June 30, 1991, respectively. The analyses were delayed due to underestimating the level of required effort and the lessons learned from the Unit-3 evaluations. In retrospect, had the analyses been completed for Unit-2 by September 30, 1991, the event may have been prevented).

5.1 Millstone Unit-1

After the Unit 3 pipe ruptures, December 31, 1991, NUSCO identified seven systems at Unit-1 that were susceptible to erosion/corrosion. However, no immediate actions were deemed necessary based on Unit-1 experience, and consequently, no inspections took place during the 1991 refueling outage in the April-August, 1991 period. Unit-1 supported NUSCO's effort to develop models of the systems for subsequent analyses by the contractor.

After the November 6, 1991 Unit-2 event, inspections by Unit-1 staff identified thirteen thinned piping locations downstream of control valves in moisture separator reheater drains. At this time, it appeared that one location may require pipe replacement.

5.2 Millstone Unit-2

Similarly, after the Unit 3 pipe ruptures, NUSCO identified eight susceptible systems at Unit-2 based on the screening criteria. But because each of the systems had been included in the Unit-2 program, no immediate inspections were required. Unfortunately, neither NUSCO nor the Unit-2 management questioned how extensively the systems had been inspected. 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. Previously, in 1986, Unit-2 had replaced piping downstream of throttling valve 2-HD-109 (the heater drains tank level control valve located in the drain pump discharge to the No. 2 Feedwater Heater) due to erosion thinning. Thus, the Unit 2 staff agreed that piping locations downstream of control valves were generally inspected, and that the failed piping should have been included. After the Surry feedwater line break, only condensate, feedwater and feedwater heater drains and vents were modeled for the CHEC analysis.

After the Unit-3 pipe break, the Unit-2 Director asked the staff several questions concerning the status of corrosion control and testing. The staff felt that the heater drain lines at Unit-2 were adequately inspected. The staff had always felt these lines were susceptible to corrosion and routinely performed inspections during outages. Further, the Unit-2 staff felt that no increase in inspection effort should occur as their inspection program for BOP piping was thought to be already substantially larger than what was being done at the other units at the site and at other nuclear facilities. Because of these conclusions, the Unit-2 staff took no special action as a result of the Unit-3 event. The next refueling outage is scheduled for the spring of 1992; no inspections were considered necessary during 1991.

After the November 6, 1991 pipe break, the piping configuration had been modeled for CHECMATE analysis without application of the bulk velocity screening criteria developed in June 1987. If applied however, the bulk velocity screening criteria of ten feet per second fluid velocity may have excluded from analysis the line that failed on November 6, 1991. Although local velocities were high exiting the flow control valve, bulk velocities were less than the ten feet per second screening criteria. The CHECMATE computer analysis was planned to be run for Millstone Unit-2 systems following the system modeling effort.

5.3 Millstone Unit-3

Prior to the plant startup following the Unit-3 pipe break, nondestructive examinations were made of piping and welds within the moisture separator drain system while that system was being repaired. The licensee also examined piping downstream of eight selected flow control valves for similar erosion/corrosion. There were no additional areas identified as requiring repair. The plant operated for approximately three weeks until the beginning of the 1991 refueling outage.

NUSCO identified fifteen systems that should be included in the erosion/corrosion program at Unit-3 during the refueling outage based on the application of the screening criteria to each of 135 systems and sub-systems. The systems that were considered susceptible to erosion/corrosion were modeled for CHECMATE analysis. To complete these system walkdowns and analysis before the end of the 1991 refueling outage, three contract organizations were retained to support the work. This analysis resulted in the inspections of 164 components by ultrasonic testing.

In addition to the original moisture separator drain piping, three components were found to have less than the minimum wall thickness during examinations conducted during the refueling outage. Repairs were made by replacing the following components: a one inch bypass warm-up line around the electric motor operated feedwater pump discharge check valve; a six inch pipe down stream from the "A" first point feedwater heater level control valve; and, pipe down stream of the "A" fourth point feedwater heater drain pump discharge control valve.

Three other locations were dispositioned as acceptable provided that they were monitored periodically. These were an extraction steam pipe tee from the "A" high pressure turbine cross under pipe, and feedwater inlet and outlet elbows to the "C" first point feedwater heater inlet and outlet piping. The licensee has subsequently replaced the extraction steam pipe tee in both the "A" and "B" high pressure turbine cross under pipe with chromium-molybdenum alloy piping; and, has performed a weld overlay of the "C" first point heater elbows. The elbows are long lead time items and will be available for replacement during the next refueling outage.

5.4 Haddam Neck Plant

Twenty-one systems were identified for the erosion/corrosion program at Haddam Neck. Ten of these systems were already included in the existing program, and no further actions were taken regarding them. Three of the systems were added to the program as a result of the NUSCO analyses in February. Analyses using the CHECMATE code were completed in early November, 1991, and inspections were completed during the current refueling outage. More than 225 components had been identified for ultrasonic testing inspection and five were scheduled to be replaced.

6.0 CONCLUSIONS

The licensee had ample opportunity to avoid the pipe break events that occurred at Unit-3 and at Unit-2. After the Surry event a Project Assignment (PA) was put forward by the group responsible for erosion/corrosion control at NUSCO but the PA never received an implementing signature. This PA was intended to establish a systematic approach to erosion/corrosion control at the four units. Had the PA been implemented, it is very likely that one or both of the large-bore pipe break events would have been avoided. During the period after the Surry event, while the CHEC and MIT codes were extensively used for Unit-3, very little use of these codes was made for Unit-1, Unit-2 or Haddam Neck. Had the codes been used and the identified vulnerabilities inspected at these units, the events at Unit-2 may have been avoided. Although the codes were being used at Unit-3, they failed to identify the pipe that failed there because of errors made in data input. During this period, very little management oversight was provided to the use and running of the codes resulting in the data entry errors. It is concluded that in the time period between the Surry event and the pipe break at Unit-3 there was a lack of management attention at the NUSCO level, which resulted in a lack of emphasis being applied to this area.

Regarding the Unit-3 pipe failure, the Unit-3 staff failed to follow up on experiences of Surry and at other Northeast Utilities units by relying on direction from NUSCO, instead of following up on this area independently. While data were provided to NUSCO for input into the CHEC code, the Unit-3 staff failed to question the lack of NUSCO to highlight the pipe section for examination.

With respect to the Unit-2 pipe failure, there were a number of widely known experiences of failures downstream of flow control valves prior to the pipe failure. The Unit-2 staff failed to factor this experience into their inspection program. Had it been done, it is likely the failure would not have occurred.

Prior to the licensee's initiative as a result of the event at Unit-3, the erosion/corrosion programs at the three Millstone units and Haddam Neck were informal, independent and isolated. The performance of the programs at each unit was conducted without effective communications among the four units, between the units and NUSCO, or with industry, and consequently, the inspection program failed to adequately integrate lessons learned from operating experience. While progress in integrating this program among the units was recently occurring, NU management acknowledged that they were aware that other NU programs had the same weaknesses and had initiated activities to integrate those programs as well.

7.0 EXIT MEETING

The Task Force met with licensee representatives (denoted in Section 1) on November 15, 1991. The purpose, scope and findings of the inspection were summarized.