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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

SUPPORTING AMENDMENT NO. 56 TO FACILITY OPERATING LICENSE NO. DPR-65 AND

DOCUMENTING THE STEAM GENERATOR WATER HAMMER REVIEW FOR

MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2

NORTHEAST NUCLEAR ENERGY COMPANY, ET AL

DOCKET NO. 50-336

1. INTRODUCTION

Steam generator water hammer has occurred in certain nuclear power plants as a result of the rapid condensation of steam in a steam generator feedwater line and the consequent acceleration of a slug of water which, upon impact within the piping system, causes undue stresses in the piping and its support system. The significance of these events varies from plant to plant. Since the total loss of feedwater could affect the ability of the plant to cool down after a reactor shutdown, the NRC is concerned about these events occurring, even though an event with potentially serious consequences is unlikely to happen.

Because of the continuing occurrence of water hammer events, the NRC, in September 1977, informed all pressurized water reactor (PWR) licensees that water hammer events due to the rapid condensation of steam in the feedwater lines of steam generators represented a safety concern and that further actions by licensees for Westinghouse and Combustion Engineering designed nuclear steam supply systems are warranted to assure that an acceptably low risk to public safety due to such events is maintained. Accordingly, these licensees were requested to submit proposed hardware and/or procedural modifications, if any, which would be necessary to assure that the feedwater lines and feedrings remain filled with water during normal as well as transient operating conditions. At the same time, the NRC provided each PWR licensee with a copy of its consultant's report, "An Evaluation of PWR Steam Generator Water Hammer," NUREG-0291.

The means employed at the Millstone Nuclear Power Station, Unit No. 2, to reduce the potential for steam generator water hammer include a feedring in the steam generator that discharges feedwater from the top of the ring instead of the bottom and a favorably short length of horizontal feedwater piping at the entrance to the steam generators.

By letter dated March 21, 1978, Northeast Nuclear Energy Company (NNECO or the licensee) proposed that the following license condition of Facility Operating License No. DPR-65 for Millstone, Unit No. 2 be lifted:

"Steam Generator Feedwater Flow

When the steam generator water temperature is above 212°F and the steam generator water level falls below the feedwater sparger, feedwater flow shall be limited to 600 gpm. If feedwater is not reestablished within 15 minutes from the time that the steam generator water level falls below the feedwater sparger, feedwater flow shall be limited to 168 gpm."

This condition was imposed in 1977 to provide adequate measures against water hammer while the NRC staff and the licensee further assessed the significance of water hammer considerations. The purpose of this condition was to limit the flow of the subcooled water in the feedwater piping and feedring when the subcooled water is in contact with steam in the feedwater piping and feedring. This proposed change is evaluated in this Safety Evaluation.

2. Discussion and Evaluation

Our consultant, EG&G Idaho, Inc., prepared the attached evaluation of steam generator water hammer at Millstone, Unit No. 2 as part of our technical assistance program (Letter from J. A. Dearien, EG&G, to R. E. Tiller, DOE, dated December 18, 1979). We have reviewed this report together with the NNECO submittals dated August 1, 1977, January 11 and March 21, 1978 and November 30, 1979.

Our consultant concluded that the modifications that were made to the feedwater sparger and piping reduced the potential for water hammer, that manual initiation and control of auxiliary feedwater may not be adequate under all conditions, and that tests performed at St. Lucie, Unit No. 1 provide an adequate basis for omission of a limit on auxiliary feedwater flow at Millstone Unit No. 2. Based on these conclusions our consultant recommended:

(1) To reduce the potential for operator error which could lead to steam generator water hammer, the licensee should install a system to automatically initiate the auxiliary feedwater system flow;

(2) Existing feedwater flow limitations should be abolished; and

(3) Manual auxiliary feedwater system start and control capability should be retained with manual start serving as backup to automatic auxiliary feedwater system initiation.

We concur with our consultant's conclusions and recommendations. However, although it may be advantageous to automate the initiation of auxiliary feedwater flow with regard to steam generator water hammer, the total impact on reactor safety is currently being evaluated by the NRC. The licensee's letter of November 30, 1979, pointed out some advantages of completely manual operation of the auxiliary feedwater system and stated that the reactor operators responded typically within 30 seconds to plant transients involving a need for auxiliary feedwater. We have independently determined that for plants with top discharge feedrings the initiation of auxiliary feedwater flow within 5 minutes of a plant trip will ensure sufficiently full feedrings to preclude the occurrence of steam generator water hammer. We have therefore concluded that prompt manual initiation of auxiliary feedwater is adequate to reduce the likelihood of occurrence of steam generator water hammer.

Based on our knowledge of water hammer phenomena, and our review of the licensee's responses and the attached evaluation report by EG&G, we have concluded that the means for reducing the potential for steam generator water hammer at this facility are adequate.

In their March 21, 1978 application, NNECO proposed to amend its operating license by deleting Section 2.C.(3) which places restrictions on steam generator feedwater flow. Our evaluation now shows that such restrictions are not necessary. Because this license condition could cause the licensee to restrict the flow of feedwater unnecessarily when additional flow might be needed to cool the reactor system, we find that lifting the restrictions on feedwater flow is the appropriate action to take. Therefore, License Condition 2.C.(3) should be deleted from Facility Operating License No. DPR-65.

There may be situations, however, when failure to initiate the auxiliary feedwater system in a timely manner could lead to the introduction of subcooled water into the steam-filled feedwater ring and piping. Therefore, procedures for refilling a steam generator should be modified to include precautions to restrict feedwater flow when, coincidentally, all water flow to the feedring has been interrupted for five minutes or more and the water level in the steam generator is below the top of the feedring. Such a procedure should not require restrictions of main or auxiliary feedwater flow, in the event of a plant trip or a loss of feedwater event, if the above conditions that could lead to water hammer do not exist. After a plant trip, the operator should manually throttle feedwater flow to prevent overcooling of the reactor coolant system or overfilling of the steam generator. If for some reason, the operator is confronted with an overheating situation, maximum feedwater flow will take precedence over water hammer considerations. The licensee has agreed to modify the operating and emergency procedures, considering the above comments, as necessary to provide additional assurance that a damaging water hammer event is prevented at Millstone, Unit No. 2.

3. Environmental Considerations

We have determined that the amendment does not authorize a change in effluent types or total amounts nor an increase in power level and will not result in any significant environmental impact. Having made this determination, we have further concluded that the amendment involves an action which is insignificant from the standpoint of environmental impact and pursuant to 10 CFR 51.5(d)(4), that an environmental impact statement or negative declaration and environmental impact appraisal need not be prepared in connection with the issuance of this amendment.

4. Conclusion

We have concluded, based on the considerations discussed above, that: (1) because the amendment does not involve a significant increase in the probability or consequences of accidents previously considered and does not involve a significant decrease in a safety margin, the amendment does not involve a significant hazards consideration, (2) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, and (3) such activities will be conducted in compliance with the Commission's regulations and the issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public.

Dated: May 7, 1980

EG&G Idaho, Inc.

P. O. Box 1625
Idaho Falls, Idaho 83401

December 18, 1979

Mr. R. E. Tiller, Director
Reactor Operations and Programs Division
Idaho Operations Office - DOE
Idaho Falls, ID 83401

STEAM GENERATOR WATER HAMMER TECHNICAL EVALUATION FOR MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2 (A6257) - JAD-248-79

Ref: J. A. Dearien Ltr to R. E. Tiller, PWR Steam Generator Water Hammer Reviews (A6257) - JAD-225-79, November 8, 1979

Dear Mr. Tiller:

The attachment completes the review of the effectiveness of the existing means to reduce the potential for steam generator water hammer at Millstone Nuclear Power Station, Unit No. 2.

The review has shown that Millstone Nuclear Power Station, Unit No. 2, incorporates those features currently recommended as a means to reduce the potential for steam generator water hammer. However, it was concluded that certain conditions can exist which question the assurance of proper operator evaluation and response. Normal initiation and control of auxiliary feedwater (AFW) may not be adequate to avoid steam generator water hammer under those normal, transient, and accident operating conditions reviewed. Automatic initiation of AFW can obviate the need for existing feedwater administrative controls because prompt positive initiation and increased volumetric flow assists in maintaining the feedwater sparger and piping full of water. Tests undertaken at St. Lucie Unit No. 1 constitute an appropriate basis for the omission of AFW flow limits for Millstone Unit No. 2.

Recommendations from this review pertinent to reducing the potential for steam generator water hammer at Millstone Unit No. 2 are as follows: 1) to reduce the potential for operator error which could lead to steam generator water hammer, the licensee should install a system to automatically initiate the AFW flow, 2) existing feedwater flow limitations should be abolished, and 3) manual auxiliary feedwater system (AFWS) start and control capability should be retained with manual start serving as backup to automatic AFWS initiation.

This transmittal constitutes completion of the Millstone plant SER, Task A6257, of the cited reference.

Very truly yours,

J. A. Dearien, Manager
Code Assessment and
Applications Program

OMH:tn

Attachment:
As stated

cc: S. D. MacKay, NRC-DOR
R. W. Kiehn, w/o attach.

STEAM GENERATOR WATER HAMMER TECHNICAL EVALUATION
MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2

December 1979

EG&G Idaho, Inc.

CONTENTS

STEAM GENERATOR WATER HAMMER TECHNICAL EVALUATION
MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2

I. INTRODUCTION

An evaluation was performed for the Millstone Nuclear Power Station, Unit No. 2, feedwater system. The purpose was to assess the effectiveness of the existing means to reduce the potential for steam generator water hammer in the feedwater systems during normal, transient and accident operating conditions. The steam-water slugging in the steam generator feedrings and adjacent feedwater piping was considered in this review. One nondamaging steam generator water hammer was reported in 1975 during pre-operational testing. Subsequent modifications have been made to feedwater piping inside the containment and to the feedwater sparger inside the steam generator to reduce the potential for water hammer consistent with recommendations of Creare[1] and Westinghouse.[2]

The potential for steam generator water hammer is avoided if the feedwater system is maintained full of water. Hence, this evaluation was based on the effectiveness of the means utilized to maintain the feedwater system full of water during normal, transient and accident operating conditions at Millstone Nuclear Power Station, Unit No. 2.

The information for this evaluation was obtained from: 1)discussion with the licensee, 2) NRC correspondence and reports[1,3,4], 3) licensee submittals[5,6,7,8], 4) the "Millstone Point Nuclear Power Station Final Safety Analysis Report,"[9] and 5) Westinghouse Technical Bulletin, NSD-TB-75-7.[2]

A description of the feedwater system and its general operation is presented in Section II. The means to reduce the potential for steam generator water hammer are presented in Section III, including a discussion of their effectiveness during operating conditions conducive to water hammer. Finally, conclusions and recommendations are presented in Section IV concerning the adequacy of the existing means to reduce the potential for steam generator water hammer at this facility.

II. FEEDWATER SYSTEM

1. DESCRIPTION

The feedwater system for Millstone Nuclear Power Station, Unit No. 2, was designed to provide an adequate supply of feedwater to the secondary side of the two steam generators during all operational conditions. The main feedwater source is condensate which is pumped from the main condenser hot well by electric motor driven condensate pumps in series with two turbine-driven main feedwater pumps. From the condensate pumps, flow enters a 24-inch header and goes through a steam packing exhauster to a common header where the flow is split into two separate flow trains. Each train contains a steam jet air ejector, a drain cooler, five low-pressure feedwater heaters, and a steam turbine-driven main feedwater pump. Both main feedwater pumps take suction from a common 20-inch header and discharge to a common 24-inch header. From the discharge header, two 18-inch lines branch off with each line containing a high pressure feedwater heater. After passing through the high-pressure heaters, the flow is discharged into a 24-inch header from which branch two 18-inch Schedule 80, carbon steel lines with one line to each steam generator. Inside the steam generator, flow enters the feedring or sparger and is discharged through 36 inverted "L"-shaped tubes located on top of each feedring.

Two, double suction diffusion type, single stage, vertically split, horizontal centrifugal, 55 percent capacity main feedwater pumps, each rated at 15,000 gpm at 2100 feet of total developed head (TDH), operate in series with the condensate pumps. There are three 55 percent capacity condensate pumps which are electrical motor driven, multistage, vertical, canned suction type, centrifugal units. The third (standby) pump starts automatically on the low-pressure signal from the condensate discharger header.

The auxiliary feedwater system (AFWS) is designed to provide feedwater for the removal of sensible and decay heat to cool down the primary system to 300^{0}F for both normal cooldown and when the condensate and main feedwater system (MFWS) pumps are inoperative. The AFWS is also used for plant startups. The AFWS supplies water from the condensate storage tank (CST) to the steam generators via a direct connection to each 18-inch main feedwater line. A 6-inch AFWS line tees into the MFWS line just outside the containment building penetration.

Two completely redundant AFWS are provided. Each system is capable of providing the required amount of feedwater for cold shutdown of the reactor coolant system. One system contains a full-capacity steam turbine-driven pump and is normally aligned to supply No. 2 steam generator. The other system contains two half-capacity motor-driven pumps which are normally aligned to supply No. 1 steam generator. Power for the motor-driven pumps is supplied from the emergency buses, which are automatically supplied by the diesel generators in the event of loss of offsite power supplies. The turbine-driven pump has a capacity of 600 gpm at 2437 feet TDH and two motor-driven pumps have a 300 gpm capacity each at 2437 feet TDH. The turbine steam is supplied from a common line connected to lines coming from each steam generator and include a flow admission valve and a flow (speed) regulating valve. The turbine driven pump operates reliably as long as there is steam pressure in excess of 50 psig in one of the steam generators. The steam generator auxiliary feedwater system is initiated by remote manual control. The control of AFWS flow and steam generator level is by remote manual control from the control room or from the hot shutdown standby control panel. All AFWS motor operated valves are powered from the emergency 480-VAC buses and fail-as-is.

The 250,000-gallon capacity CST is the primary water source for AFWS and the primary water storage tank (PWST) is the secondary source. Backup sources consist of two 250,000-gallon fire protection system water storage tanks. In addition, a connection to the city water exists which can be used to provide a water supply for an extended period of time if needed.

2. GENERAL OPERATION

During normal power operation of the reactor, the main feedwater system supplies heated feedwater and maintains the required water quality and inventory to the secondary side of the steam generators to assure a heat sink for the primary coolant system when it is above 300^{o}F. The feedwater flow can be regulated by individual regulating valves in the main feedwater lines to each steam generator. The positions of the valves are controlled based upon steam generator level, steam flow, and feedwater flow with both manual and automatic control available. The MFWS is normally utilized above 2% power and, above 15% power, can be placed in the automatic control mode. The MFWS flow response is normally adjusted by pump speed control via the steam turbine drivers.

The auxiliary feedwater pumps, one 100-percent capacity steam-driven and two 50 percent capacity motor-driven, normally take suction from the CST. The typical temperature range of the CST water is from 50^{o}F to 80^{o}F and is not preheated before it enters the steam generator. During a normal startup, auxiliary feedwater is used from the time primary system temperature reaches 532^{o}F until approximately two-percent power, at which time the main feed pumps are utilized. Typically, the period of time involved is eight hours. During a normal shutdown, one main feed pump remains in service until primary system temperature decreases to approximately 425^{o}F, at which time the auxiliary feed pumps are used. The exceptions to this guideline involve minimal decay heat or unavailability of the condenser, when auxiliary feed pumps are utilized as soon as primary system temperature decreases to 532^{o}F. The auxiliary feedwater is manually controlled to maintain proper water levels in the steam generators.

III. MEANS TO REDUCE THE POTENTIAL FOR WATER HAMMER

1. DESCRIPTION AND EXISTING CONDITIONS

The following items describe the means currently employed at Millstone, Unit 2, to reduce the potential for steam generator water hammer:

1. Inverted "L"-shaped discharge tubes are installed atop all steam generator feedrings, and all bottom discharge holes are plugged.

2. The feedwater piping inside the containment contains a loop seal and the length of the horizontal pipe from the steam generator nozzle to the downward elbow is 4.5-feet.

3. Administrative Controls were used to establish feedwater flow limits during steam generator water addition and recovery for conditions not bounded by tests at the Millstone plant.

The "L" tubes and loop seals were installed to prevent or mitigate water hammer as recommended and performed by the nuclear steam supply system (NSSS) vendor, Combustion Engineering (CE). The new design included removal of the standpipes from inside the feedring and installation of 36 3-1/2-inch elbows or inverted "L" tubes spaced around the top of the feedrings. Caps were welded in place of the holes left on the underside of the feedring from the removal of the standpipes. This modification has been successfully completed at other operating CE plants, and has also been incorporated into the current CE steam generator design.

The "L"-shaped discharge tubes were installed on the top side of the feedrings to provide for top discharge of water rather than bottom discharge. When the feedrings had bottom discharge holes, the maximum auxiliary feedwater flow with both sub-systems operating (about 600 gpm per steam generator) was not sufficient to maintain the feedrings and feedwater piping full of water when the feedring was uncovered. The feedrings equipped with "L"-shaped discharge tubes, however, permit relatively low feedwater flow rates to keep the feedrings and feedwater piping full of water until feedring recovery occurs. This allows time to re-establish steam generator water level during startup and low power operating conditions, during which the water level drops below the feedrings in one or both steam generators. The AFWS is normally initiated in less than 5 minutes. The potential for water hammer is thus avoided if the feedrings and feedwater piping are kept full of water. With top discharge, the basic mechanisms for water loss in the feedwater piping and sparger are 1) boil-off due to depressurization, and 2) leakage at the feedwater nozzle at the sparger inlet. The second condition is normally the more significant.

The loop seals in the main feedwater piping system have been completed to further minimize water hammer potential[1,6]. The loop seals limit the volume voided (in which steam formation occurs) and the attendant water-steam contact area, on drainage. The Millstone, Unit No. 2, pipe horizontal run length is about 4.5-feet, which is less than the maximum of 8 feet recommended[2].

During the initial startup following the feedwater sparger and pipe modification, a Special Test (T-76-39) was performed to verify the absence of water hammer when initiating feedwater flow to the steam generator[5]. The steam generator water level was held below the feedring for 15 minutes without any feedwater pumps running before flow was initiated. The test was run with the reactor in the hot-standby mode at AFWS flow increments up to 600 gpm. During the conduct of the test, no indications of water hammer were noted. Monitoring of steam generator response during the test was accomplished visually, audibly, and through the use of transducers.

The test efforts just described resulted in administrative controls,[4] which currently remain in effect, that includes a license condition which precludes the addition of feedwater for conditions not bounded by the test conducted and states:

> "When the steam generator water temperature is above 212^{o}F and the steam generator water level falls below the feedwater sparger, feedwater flow shall be limited to 600 gpm. If feedwater is not established within 15 minutes from the time that the steam generator water level falls below the feedwater sparger, feedwater flow shall be limited to 168 gpm."

The flow limitations of feedwater addition do not specifically distinguish between using MFWS or AFWS for recovery of water levels in the steam generators. The licensee has indicated[7] that a condition could exist, when limiting MFWS to 600 gpm, which implies that MFWS pumps should be tripped and a switch to AFWS be made. If the feedwater sparger and piping are being maintained full of water there is no reason to limit feedwater flow rates.

The basis of the 168 gpm AFWS flow limitation was derived from tests[1] undertaken at Calvert Cliffs 1 and 2 when bottom discharge was being used and as such does not specifically relate to feedwater spargers with top discharge. Administrative controls on feedwater addition at Millstone Unit No. 2 were thus established[4] using available information to cover 'threshold' water hammer conditions[1] not firmly established by plant specific tests.

Later tests at St. Lucie Unit No. 1 (with stand-pipes) were run for a sparger drain periods of two hours with recovery AFWS flow rates of 300 and 785 gpm without water hammer occurring.[8] These tests are considered more applicable to Millstone Unit No. 2 than those of Calvert Cliffs. The AFWS and its means and location of water injection are quite similar for both Millstone Unit No. 2 and St. Lucie Unit No. 1. As such, this would appear to be a a reasonable basis for eliminating existing administrative controls on feedwater addition.

2. EFFECTIVENESS DURING TRANSIENTS AND CONDITIONS CONDUCIVE TO WATER HAMMER

The normal and hypothetical transients and conditions conducive to steam generator water hammer are discussed in this section. With the exception of subsection 2.4 entitled "Operator Error", each subsection describes a transient resulting from a single initiating event or failure with the unit in normal power operation.

A single criterion was the basis for evaluating the effectiveness of the means to adequately reduce the potential for steam generator water hammer. The criterion is to maintain the feedwater system full of water during the time from the initiating event resulting in feedring uncovery to subsequent feedring recovery and stabilized steam generator water inventory.

2.1 Reactor Trip

A reactor trip with the plant in normal power operation would result in a turbine trip and cause the water level in all steam generators to collapse to a level below the feedrings. Following the turbine trip, the MFWS is automatically ramped down to 5% of full flow within 60 seconds. One MFWS pump is normally tripped, and transfer to the MFWS low-flow bypass is made depending on power requirements. Main feedwater is then maintained (or) auxiliary feedwater can then be manually initiated and controlled to restore the water levels in the steam generators and maintain the levels above the feedrings.

With proper operator response the potential for water hammer occurring in the feedring or feedwater piping after a reactor trip is avoided because the main and auxiliary feedwater keeps the feedrings and feedwater piping full of water.

2.2 Loss of Main Feedwater Flow

The main feedwater supply could be interrupted by feedwater pump turbine drive malfunction, various pump trip signals, line blockage (inadvertent valve closure, clogged lines, etc.) loss of condenser vacuum, loss of condenser circulating water and loss of feedwater heaters with failure to by-pass. MFWS pump trip signals include low suction pressure, low oil pressure, low flow, higher discharge pressure, thrust bearing wear, low vacuum and, manual trip. A reactor trip would occurr on low steam generator water level and a turbine trip would follow.

The reactor trip would cause the water levels in the steam generators to collapse to a level below the feedrings. The turbine and the motor driven AFWS pumps would be manually started and the AFWS would then be used for refill and to recover the feedrings. When a loss of feedwater occurs at full power, the AFWS must be initiated after the reactor trips to prevent a boil-dry condition in the steam generators. With the "L" tubes installed providing top discharge, the total loss of main feedwater and the likely uncovery of the feedrings would not result in substantial feedring and feedwater piping drainage provided the AFWS is initiated promptly by the operator, or automatically.

2.3 Loss of Offsite Power

The complete interruption of off-site power would result in a reactor trip, a turbine trip, and automatic startup of the emergency diesel generators. The electric motor-driven main condensate pumps would trip on loss of power causing a low suction pressure trip of the main feedwater pumps. Manual initiation of the motor-driven and turbine-driven auxiliary feedwater systems would occur to supply feedwater to the steam generators. The redundant auxiliary feedwater systems are fully functional without off-site power since the diesel generators and DC batteries can supply all necessary electrical power to both systems.

As was the case for the loss of main feedwater flow, auxiliary feedwater flow would maintain the feedrings and feedwater piping full of water until feedring recovery occurs and again the potential for water hammer would be very low.

2.4 Operator Error

The potential for water hammer in the feedwater system increases if, t' ough an operator error, uncovered feedrings are allowed to drain substantially after an event causes the steam generator water levels to drop below the feedrings. Admission of feedwater into the drained feedrings and horizontal feedwater piping could then result in conditions conducive to water hammer.

The uncovery of one or both feedrings is most likely when the plant is operating at low power or during startup since feedwater is being regulated manually and recovery flow tends to be low. The primary concern, therefore, is the failure of the operator to inititate and administer feedwater as required under existing ' WS manual initiation capability and existing administrative controls.

Automatic initiation of the AFWS would provide a prompt, positive means of providing feedwater to the steam generators when main feedwater is unavailable (or) in the transition from main to auxiliary feedwater supply. With regard to water hammer, there is no reason to resrict feedwater flows while the feedwater spargers and pipes are being maintained full of water. Automatic AFWS flow initiation and elimination of existing administrative controls on feedwater admission would reduce the potential for steam generator water hammer due to operator error.

2.5 Steam Line Rupture

The potential for steam generator water hammer resulting from or concurrent with steam line rupture inside the containment was evaluated. The sequence of events following such an incident was considered to determine if rupture of a main steam line could result in 1) blowdown of the intact loop and steam generator or 2) the inability to supply auxiliary feedwater to the unaffected steam generator.

The rupture of a main steam line would cause a reactor trip due to low steam pressure, a turbine trip, and result in a safety injection signal (SIS) on low pressurizer pressure. Back-up reactor trips include thermal margin, high power level, high rate-of-change of power, and high containment pressure. For the full load condition, the MFWS is automatically ramped down to 5% of full flow in 60 seconds. On MFWS isolation, manual transfer to and initiation of AFWS would occur to maintain or recover the water levels in the steam generator in the intact loop. Automatic initiation would ensure prompt delivery of auxiliary feedwater to the unaffected steam generator to keep the feedring full of water.

The blowdown of a steam generator would not deprive the turbine driven auxiliary feedwater pump of driving steam. A check valve in each steam supply line would prevent "crossover" blowdown through the supply lines from the unaffected steam generators to the associated blowndown steam generator.

The potential for water hammer is considered low after a steam line break with proper operator response, i.e., delivery of auxiliary feedwater in conjunction with the "L" shaped discharge tubes which assist to maintain full feedrings and feedwater piping in the unaffected steam generator.

2.6 Loss-of-Coolant Accident

The potential for feedwater water hammer during a postulated loss-of-coolant accident (LOCA) in either unit was examined because 1) an additional pipe rupture due to a water hammer could increase the consequences of a LOCA and 2) the plant protective actions during a LOCA could result in conditions which are conducive to water hammer if the feedwater system is not kept full of water.

A LOCA would result in an SIS, a reactor trip, a turbine t ip, and subsequent isolation of the main feedwater system. The subsequent startup of the motor-driven and turbine-driven auxiliary feedwater pumps would result, and feedwater would be supplied to the steam generators. Refill of the steam generators and recovery of the feedrings would occur in a manner typical of a reactor trip or the loss of offsite power.

The conditions conducive to water hammer in the feedrings and feedwater piping resulting from a LOCA would be very similar to those resulting from a reactor trip. Therefore, the means to reduce the potential for water hammer are expected to be fully effective during a LOCA.

IV. CONCLUSIONS AND RECOMMENDATIONS

The assessment of the capability of existing means to reduce the potential for steam generator water hammer during normal, transient and accident operating conditions was discussed in Section III. Based on information in References 1 through 9, this review of Millstone Unit No. 2 has concluded that:

1. Tests were run to verify the absence of water hammer,

2. The modifications made to the feedwater sparger and piping reduced the potential for water hammer,

3. Certain conditions exist which question the assurance of proper operator evaluation and response. Manual initiation and control of AFWS may not be adequate to avoid water hammer under all conditions. Automatic initiation can obviate the need for administrative controls relative to AFWS water addition because prompt, positive initiation and increased volumetric flow assists in maintaining the feedwater sparger and piping full of water. Although tests have not been performed at Millstone to confirm the absence of steam generator water hammer for sparger drainage and uncovery periods in excess of 15 minutes, those tests[8] undertaken at St. Lucie Unit No. 1 consitute an appropriate basis for the omission of AFWS flow limit for Millstone Unit No. 2.

The following recommendations are made for Millstone Unit No. 2 as a result of this review:

1. To reduce the potential for operator error which could lead to steam generator water hammer, the

licensee should install a system to automatically initiate the AFWS flow.

2. Existing[4] feedwater flow limitations should be abolished.

3. Manual AFWS start and control capability should be retained with manual start serving as backup to automatic AFWS initiation.

V. REFERENCES

1. Block, J. A., et al, An Evaluation of PWR Steam Generator Water Hammer, NUREG-0291, NRC-1 (June 1977).

2. Bennett, W. E., Water Hammer in Steam Generator Feedwater Lines, Westinghouse Technical Bulletin, NSD-TB-75-7 (June 10, 1975).

3. NRC Staff, Water Hammer in Nuclear Power Plants, NUREG-0582 (July 1979).

4. Lear, G., "Millstone Nuclear Power Station, Unit 2, (NRC) Docket No. 50-336, Amendment No. 32 to Operating License No. DPR-65," (October 27, 1977).

5. Switzer (NNECO), D. C., "Millstone Nuclear Power Station, Unit No. 2, Proposed Revisions to Technical Specifications," letter to G. Lear (NRC), (August 1, 1977).

6. Switzer (NNECO), D. C., "Millstone Nuclear Power Station, Unit No. 2, Feedwater System Piping," letter to R. Reed (NRC), (August 22, 1979).

7. Switzer (NNECO), D. C., "Millstone Nuclear Power Station, Unit No. 2, Proposed License Amendment Regarding Steam Generator Feedwater Flow," letter to R. Reed (NRC), (March 21, 1978).

8. Uhrig, R. E., (Florida Power and Light Company), "St. Lucie Unit No. 1, Docket No.50-335, License Condition C," letter to Mr. Zieman (NRC), (February 25, 1977).

9. Millstone Point Company, Final Safety Analysis Report, Millstone Point Nuclear Power Station, Unit No. 2, (August 10, 1972).