STEAM GENERATOR WATER HAMMER
TECHNICAL EVALUATION
GINNA POWER STATION

OCTOBER 1979

EG&G IDAHO, INC.

7912190 066

CONTENTS

I. INTRODUCTION

An evaluation was performed for the Ginna feedwater system. The purpose of this evaluation was to assess the effectiveness of the existing means to reduce the potential for steam generator water hammer in the feedwater system during normal and hypothetical operating conditions. The steam-water slugging in the feedwater systems (specifically, the steam generator feedwater sparger rings and adjacent feedwater piping) was considered in this review. No known water hammer event directly attributable to feedwater ring draining has occurred at Ginna. Two water hammer transients caused by feedwater control valve malfunction did happen, however.

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 at Ginna to maintain the feedwater system full of water during normal and hypothetical operating conditions.

The information for this evaluation was obtained from: 1) discussions with the licensee, 2) licensee submittals of August 1, 1973[1], July 17, 1975[2], October 31, 1975[3], January 30, 1976[4], and June 15, 1978[5], 3) the "Ginna Nuclear Plant Final Safety Analysis Report"[6], 4) "An Evaluation of PWR Steam Generator Water Hammer," NUREG-0291[7], and 5) Westinghouse Technical Bulletin, NSD-TB-75-7[8].

A description of the feedwater system at Ginna 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 Ginna was designed to provide an adequate supply of feedwater to the secondary side of the two steam generators during all operational conditions. Feedwater is supplied to the main feedwater pumps by the heater drain pumps and by the condensate pumps via the low pressure heaters. Feedwater from the main feedwater pumps is supplied to a main header via the high pressure heaters. The main header splits into two 14-inch feedwater lines to supply a 10.75-inch diameter, half-inch wall thickness feedring inside each steam generator. Feedwater is discharged downward through inverted "J" shaped tubes uniformly distributed on top of each feedring.

The two main feedwater pumps are single stage, double flow, centrifugal type, each rated for a flow rate of 14,000 gpm at 853 psig. The two pumps, each driven by a 5000 hp electric motor, share common suction and discharge headers. The pump motors are normally supplied with power via the main auxiliary transformer. In the event of a turbine trip, offsite power supplies the pump motors via the reserve auxiliary transformer.

The auxiliary feedwater system (AFWS) provides feedwater to the steam generators for residual heat removal during reactor startup and shutdown, low power operation, and in the event of loss of main feedwater flow. The AFWS consists of a main (M)AFWS and a standby (SB)AFWS.

The (M)AFWS consists of 2 motor-driven pumps, each 200 gpm capacity and 1 turbine-driven, 400 gpm capacity. Each motor-driven pump can supply either one or both steam generators. The turbine-driven pump normally supplies both steam generators. The primary source of water is two 30,000 gallon condensate storage tanks which are cross-connected through locked-open manually operated valves, while the backup supply is available from the service water system. The turbine-driven pump is supplied with steam from the main headers.

The (SB)AFWS consists of 2 motor-driven pumps, each 200 gpm capacity. This system was installed in a separate plant area from the (M)AFWS during August 1979, to provide independent AFWS capability following a steam or feedwater line break in the immediate vicinity of the (M)AFWS pumps. The primary water source is the service water system.

The two AFWS are each powered from 2 redundant and independent AC emergency buses from plant emergency diesel generators. They are interlocked so that both are not simultaneously loaded onto the vital AC buses.

The (M)AFWS supplies feedwater to each steam generator via 2 three-inch lines connected to each main feedwater line just outside the containment building. The (SB)AFWS connections to each main feedwater line are placed within the containment building via one line per steam generator. They are capable of being cross-connected by the operation of manual valves. All valves between the pumps and the steam generators are locked open.

2. GENERAL OPERATION

During normal power operation of the reactor, the main feedwater system supplies feedwater to the secondary side of the steam generators for heat removal from the reactor coolant system. The feedwater flow is regulated by individual regulating valves in the main feedwater lines to each steam generator. The positions of the valves are automatically controlled based upon steam generator level, steam flow, and feedwater flow.

During plant shutdown, startup, and for feedwater requirements up to about 3% of full reactor power, feedwater is normally supplied by the main auxiliary feedwater system. Feedwater flow is manually regulated to maintain adequate water levels in the steam generators.

As power is increased and sufficient high pressure steam is available, a main feedwater pump is started and the auxiliary feedwater system is shut down. For feedwater requirements of about 3% to 15% of full power, feedwater is manually controlled and supplied via low flow bypass lines which bypass the main feedwater regulating valve in each main feedwater line. The bypass regulating valve in each bypass line allows more accurate and responsive feedwater flow control than would be possible with the larger main regulating valves during low power (and low feedwater flow) operation.

Above feedwater requirements of about 15% of full reactor power, feedwater control is shifted to the main regulating valves. As power is increased to 50-60% of full power, the second main feedwater pump is started and feedwater flow is placed under automatic control.

After the loss of main feedwater flow to one or both steam generators, automatic initiation of the main auxiliary feedwater flow will result upon receipt of one or more auxiliary feedwater pump startup signals. The motor driven auxiliary feedwater pumps start on: 1) the coincidence of two out of three steam generator low-low water level (15% of narrow range, or 1.3 inches above the bottom surface of the feedring) signals from either steam generator, 2) the tripping of both main feedwater pumps, or 3) a safety injection signal (SIS). The turbine driven auxiliary feedwater pump starts on: 1) the coincidence of two out of three steam generator low-low water level signals from both steam generators or 2) the coincidence of a turbine-generator trip and loss of offsite power. The auxiliary feedwater is subsequently manually controlled to maintain proper water levels in all steam generators. The motor driven and turbine driven auxiliary feedwater pumps can also be started manually (local or remote). The (SB)AFWS is manually initiated.

Plant design specifications allow for a maximum delay of one minute from receipt of any auxiliary feedwater pump startup signals to delivery of main auxiliary feedwater to the steam generators. A limit of ten minutes is allowed to get the (SB)AFWS on stream.

Operating procedures to administratively limit auxiliary feedwater flow during recovery of the steam generator feedrings from normal and abnormal transients have been implemented at Ginna. In these situations, the auxiliary feedwater flow rate to either steam generator is to be manually limited to a maximum of 150 gpm. This limitation is to apply whenever steam generator level is below the low-low level set point, 15% of narrow range, and until the level is recovered to 25% (1 inch above the top of the ring). This limitation is not applicable in the event of safety injection involving water levels far below the feedring.

Both the main and standby auxiliary feedwater systems flow paths to the steam generators are not isolated automatically as a result of a steam or feedwater (main or auxiliary) line break. The isolation is accomplished manually.

III. MEANS TO REDUCE THE POTENTIAL FOR WATER HAMMER

1. DESCRIPTION

The following are means currently employed at Ginna to reduce the potential for steam generator water hammer:

1. "J" shaped discharge tubes[7] on all steam generator feedrings in conjunction with the prompt automatic initiation of auxiliary feedwater flow upon loss of main feedwater flow and/or steam generator feedring uncovery.
2. Administrative controls[7] to limit auxiliary feedwater flow to less than 150 gpm per steam generator during periods of steam generator feedring uncovery.
3. The reduction of the effecitve horizontal section of main feedwater piping at the entrance to all steam generators to less than eight feet[8].

The "J" shaped discharge tubes were installed on top of the feedrings and the bottom holes were plugged to provide for top discharge of water rather than bottom discharge. During periods of feedring uncovery, this arrangement increases the time for complete drainage of the feedrings and associated horizontal feedwater piping from less than one minute to about 30 minutes. Also, the maximum main auxiliary feedwater flow (about 400 gpm per steam generator) was not sufficient to maintain the feedrings and feedwater piping full of water when the feedrings had bottom discharge holes. The feedrings equipped with "J" shaped discharge tubes, however, permit feedwater flow rates as low as about 10 gpm per steam generator to keep the feedrings and feedwater piping full of water until feedring recovery occurs. Substantial drainage of the feedrings and piping via the feedring fitting clearance does not occur for about five minutes which allows time for automatic actuation of the main auxiliary feedwater system after the loss of main feedwater flow. The potential for water hammer is avoided if the feedrings and feedwater piping are kept full of water.

The prompt automatic startup of any one main auxiliary feedwater pump after the loss of main feedwater flow provides feedwater flow to keep the feedrings and feedwater piping full of water. Because the "J" shaped discharge tubes reduce the leakage from the feedring, the auxiliary feedwater flow from either of the motor driven pumps or the turbine driven pump is more than sufficient to keep the feedwater system full of water.

The present Ginna main feedwater piping geometry adjacent to each steam generator consists of a horizontal run from the steam generator to the first downward turning elbow in each line. The horizontal runs are 2 feet 3 inches from the nozzle to the center line of the downward leg of the elbow, well within the vendor's recommendations to minimize water hammer damage to the feedwater piping system.

Prior to the decision to install "J" tubes an analysis of the Ginna main feedwater piping using a preliminary, Westinghouse-derived dynamic forcing function[3] was performed. Assumptions were that the steam-water slug initiated at the steam generators; that auxiliary feedwater was in use; and that the main feedwater check valves were closed. The time dependent mathematical function was modified for the Ginna piping configuration. The time history of the acoustic shock wave generated by the steam-water slug was evaluated with respect to stress criteria based on allowable stress obtained from the original construction code. The results showed that there were several locations in both feedwater piping systems which exceeded the stress criteria. "J" tubes subsequently were installed to reduce the potential for water hammer.

No test programs have been performed at Ginna to determine whether any water hammer transient would occur as a result of uncovering of the steam generator feedrings. However, both feedwater lines inside of containment were instrumented following the 1975 transient to provide the control room operator with piping vibration information during plant startup.

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. Potential component or system failures as a direct result of a hypothetical steam generator water hammer are accounted for in the analysis.

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. Within 60 seconds of the resulting steam generator low-low water level signals, the motor driven and turbine driven main auxiliary feedwater pumps would automatically start and supply auxiliary feedwater to the steam generators. If the initiating event for the reactor trip did not close the main feedwater regulating valves, the valves would close upon receipt of: 1) low primary coolant average temperature signals, 2) steam generator high-high water level signals, or 3) an SIS. Auxiliary feedwater would then be manually controlled to restore the water levels in the steam generators and maintain the levels above the feedrings.

The potential for water hammer occurring in the feedring or feedwater piping after a reactor trip is very low 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 due to the 1) loss of offsite power, 2) malfunction or tripping of the main feedwater pumps,

3) loss of suction to the main feedwater pumps, or 4) closure of the main·feedwater regulating and/or isolation valves. A reactor trip would occur upon receipt of the resulting steam/feedwater flow mismatch signals and low steam generator water level signals. The reactor trip would cuase the water levels in all steam generators to collapse to a level below the feedrings. The motor driven and turbine driven main auxiliary feedwater pumps would start upon receipt of the subsequent low-low steam generator water level signals. Auxiliary feedwater would then be used to refill the steam generators and recover the feedrings.

The loss of main feedwater flow and the likely uncovery of the feedrings would not result in substantial feedring and feedwater piping drainage since the main auxiliary feedwater pumps would start promptly to supply feedwater to the steam generators. Therefore, the potential for water hammer is significantly reduced.

2.3 Loss of Offsite Power

The complete interruption of offsite power would result in a reactor trip and automatic startup of the emergency diesel generators. Automatic initiation of the motor driven and turbine driven main auxiliary feedwater systems would occur to supply feedwater to the steam generators. The redundant auxiliary feedwater systems are fully functional without offsite 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 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 water slugging and subsequent water hammer. The uncovery of one or both feedrings is possible through operator error when the plant is

operating at low power or during startup or while shutting down since feedwater is being regulated manually, rather than automatically. For this situation, an administrative limit of 150 gpm on auxiliary feedwater flow has been implemented in the operating procedures. This limitation was recommended in Reference 7 based on tests at Indian Point.

2.5 Steam Line Break

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

The rupture of a steam line would automatically result in an SIS causing a reactor trip, a turbine trip, and isolation of all main feedwater lines. The loss of main feedwater flow to the steam generators would result in the automatic startup of the motor driven and turbine driven main auxiliary feedwater pumps upon receipt of low-low steam generator water level signals. Auxiliary feedwater would continue to be supplied for subsequent refill of the unaffected steam generator and recovery of the feedring.

However, if the rupture occurs in the immediate vicinity of the main auxiliary feedwater pumps and renders them inoperable, the operating procedures allow ten minutes for the operation of switches in the control room that will isolate the (M)AFWS and get the (SB)AFWS on stream. Although the feedring might drain significantly in that time, the administrative limit of 150 gpm of auxiliary feedwater flow will reduce the potential of water hammer occurrence. This limitation is considered applicable at Ginna based on the best available information obtained in tests at Indian Point.

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 generator to the associated blowndown steam generator.

The potential for water hammer is low after a steam line break since prompt delivery of auxiliary feedwater in conjunction with the "J" shaped discharge tubes 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) 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 trip, and subsequent isolation of the feedwater system. The startup of the motor driven and turbine driven main auxiliary feedwater pumps would result and feedwater would be supplied to the steam generators within 60 seconds of the reactor trip. 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 would 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 and hypothetical operating conditions was discussed in Section III. This assessment has shown that under conditions which are most conducive to water hammer in the feedwater systems (specifically, uncovered and draining feedrings and feedwater piping subjected to admission of cold auxiliary feedwater), the means available to reduce the potential for water hammer at Ginna are adequate to maintain sufficiently full feedrings and feedwater piping. Keeping the feedrings and feedwater piping full of water avoids the potential for water hammer. Therefore, we conclude that the means to reduce the potential for steam generator water hammer at this facility are adequate and we recommend acceptance by the NRC staff.

REFERENCES

1. G. E. Green, Rochester Gas and Electric Corp. (RGE), ltr to J. P. O'Reilly, NRC, "R. E. Ginna Nuclear Power Plant, Unit No. 1, Failure of Sensing Line on 'B' Auxiliary Feedwater Pump, Abnormal Occurrence 73-6 and 73-7," August 1, 1973.

2. K. W. Amish, RGE, ltr to R. T. Colson, NRC, "Feedwater Piping Transient Evaluation," July 17, 1975.

3. L. D. White, Jr., RGE, ltr to R. A. Purple, NRC, "Secondary System Fluid Flow Instability, R. E. Ginna Nuclear Power Plant Unit No. 1," October 31, 1975.

4. K. W. Amish, RGE, ltr to R. A. Purple, NRC, "Specific Changes Made at Ginna Relative to Water Hammer," January 30, 1976.

5. L. D. White, Jr., RGE, ltr to D. Ziemann, NRC, "Steam Generator Water Hammer Prevention," June 15, 1978.

6. Ginna Nuclear Power Plant Unit No. 1 Updated Final Facility Description and Safety Analysis Report, RGE, NRC Docket No. 50-244.

7. J. B. Block, et al, An Evaluation of PWR Steam Generator Water Hammer, Creare, Inc. NUREG-0291 (December 1976).

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

50-244

Standard Form 1047
September 1973
4 Treasury FRM 2000
1047-106

PUBLIC VOUCHER FOR REFUNDS

50-244

Voucher No. ....

Schedule No. C0462-05

U. S. NUCLEAR REGULATORY COMMISSION
(Department or Establishment, Bureau or Office)

Location: WASHINGTON D C 20555

Appropriation or Fund: 31X6875

To Address:
ROCHESTER GAS & ELEC CORP
89 E AVE
ROCHESTER NY 14649
*ATTN L D WHITE JR

PAID BY
12-26-79

Deposit received from the above-named depositor on ...., 19......

for ....

has been applied as herein stated and the balance indicated is returned herewith:

Amount of deposit .... $..................

Applied as explained in "Remarks" below ....

Balance authorized to be refunded .... $ 4,000.00

Remarks:

THE NOV 14, 1979 APPLICATION WAS REVIEWED AND FOUND NOT TO BE SUBJECT TO FEES BECAUSE THE NRC IS WAIVING FEES FOR CERTAIN TYPES OF FIRE PROTECTION AMENDMENTS.

Ginna 1

(50-244)

12/31/79
cc: Docket File
Refund File
Reactor File
Activity File

(Sign original only) ....

Title ....

Refund by
- *Check No.* ....
- *Cash, $* .... *on* .... *(Signature of payee)* .... (Sign original only)
- *Other method, $* ...., ... (Describe)

★ U.S. GOVERNMENT PRINTING OFFICE : 1974 O—548-300

My