NSP

Northern States Power Company
Prairie Island Nuclear Generating Plant
1717 Wakonade Dr. East
Welch, Minnesota 55089

October 22, 1998

Generic Letter 96-06

U S Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Docket Nos.50-282 License Nos. DPR-42
50-306 DPR-60

Response to Request for Additional Information Related to Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions" (TAC Nos. M96854 and M96855)

The purpose of this letter is to respond to the NRC request for additional information, dated April 10, 1998. Our response is attached to this letter.

With this letter we are making one new NRC commitment:

NSP is participating in the NEI/EPRI Collaborative Project to Support Resolution of GL 96-06 Waterhammer RAIs and intends to resolve related NRC concerns through that effort and will inform the NRC of the results from these analyses when they are complete.

Please contact Jack Leveille (651-388-1121, Ext. 4142) if you have any questions related to this letter.

Joel P. Sorensen
Plant Manager
Prairie Island Nuclear Generating Plant

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c: (see next page)

c: Regional Administrator - Region III, NRC
Senior Resident Inspector, NRC
NRR Project Manager, NRC
J E Silberg

Attachments:

1. Affidavit
2. Response to GL 96-06 RAI, dated April 10, 1998

GL9606_4.DOC

UNITED STATES NUCLEAR REGULATORY COMMISSION

NORTHERN STATES POWER COMPANY

PRAIRIE ISLAND NUCLEAR GENERATING PLANT DOCKET NO. 50-282
50-306

GENERIC LETTER 96-06, Assurance of Equipment Operability
and Containment Integrity During Design-Basis Accident Conditions

Northern States Power Company, a Minnesota corporation, with this letter is submitting information in response to an NRC request for additional information related to NRC Generic Letter 96-06.

This letter contains no restricted or other defense information.

NORTHERN STATES POWER COMPANY

BY Joel P. Sorensen

Joel P. Sorensen
Plant Manager
Prairie Island Nuclear Generating Plant

On this 22nd day of October 1998 before me a notary public in and for said County, personally appeared Joel P. Sorensen, Plant Manager, Prairie Island Nuclear Generating Plant; and being first duly sworn acknowledged that he is authorized to execute this document on behalf of Northern States Power Company, that he knows the contents thereof, and that to the best of his knowledge, information, and belief the statements made in it are true and that it is not interposed for delay.

Dale M. Vincent

DALE M. VINCENT
NOTARY PUBLIC-MINNESOTA
DAKOTA COUNTY
My Commission Expires Jan. 31, 2000

Response to GL 96-06 RAI, dated April 10, 1998

The NRC issued a request for additional information (RAI) related to Generic Letter 96-06, "Assurance of Equipment Operability and Containment integrity During Design-Basis Accident Conditions," on April 10, 1998 (received by NSP on April 20, 1998). On April 29, 1998, a conference call was held between representatives from the NRC and NSP to discuss the RAI comments in order that NSP could obtain clarification and more detail regarding the comments. Subsequently, NSP documented its understanding from the conference call in a letter to the NRC, dated May 15, 1998. In that letter, NSP requested feedback from the NRC if our understanding of the comments was not completely accurate. NSP is proceeding with the resolution to NRC concerns as documented in that correspondence.

NSP is participating in the NEI/EPRI Collaborative Project to Support Resolution of GL 96-06 Waterhammer RAIs and intends to resolve several of the NRC concerns through this effort. Resolution to the comments which are not being addressed through this project are discussed below.

Comment No. 1

The licensee has concluded that column separation and rejoining is the bounding scenario for the waterhammer issue. While analysis that was performed for the column separation and rejoining scenario is adequate for a "nominal" treatment of this event, the licensee has not established that the assumptions that were used are appropriate for the worst-case scenario. For example, the value for the speed of sound that was used in the analysis has not been adequately justified and the effects of potential single failures have not been addressed.

Response:

Northern States Power considers that the analysis of the water column separation and rejoining scenario produces very conservative results. The value for the speed of sound used in the analysis is 3800 feet per second. This is based on elastic pipe and a very small amount of air entrainment. The speed of sound in water with no air entrainment in elastic pipe (8 inch nominal diameter) is approximately 4300 feet per second. Thus, an approximate 11.6% reduction was taken based on an assumed small amount of air entrainment in the water. The Prairie Island Cooling Water System is an open system with water being drawn from the Mississippi river. For cooling water systems in which the water is drawn from a lake, a river, a cooling pond, etc., the incoming water would be saturated with air at atmospheric pressure. Thus, dissolved gases always exist in cooling systems where the water is exposed to air and no specific actions are taken to remove the air. This amount of dissolved gas can be determined using Henry's law. With the interruption of cooling water pumping power, the water would stagnate and column separation could occur. As this separation occurs, the water is exposed to subatmospheric pressures. Given the subject pressures, this would be sufficient to force noncondensible gases to exit from solution.

EPRI TR-106438, "Water Hammer Handbook for Nuclear Plant Engineers and Operators," dated May 1996, provides information and methodologies which are very useful to the evaluation of, and design for, potential water hammer scenarios. Section 3.1 addresses the effects of air entrainment; noting that with very small amounts of entrained air the wave speed is reduced significantly; for example, with only 0.1 percent by volume of entrained air at 47 psi the wave speed is reduced from 4000 to 2000 feet per second. From Henry's law, the smallest amount of air entrainment would exist at the coldest river water temperature (32°F). At this temperature, the percentage by volume of entrained air in the river water would be higher than 0.1 percent. Thus, a reduction in the wave speed to 2000 feet per second could be used and still be conservative. This is consistent with information presented in report FAI/96-89 (provided to the NRC in response to the Request for Additional Information, dated September 15, 1997). Additional sources (for example, NUREG/CR-6519) note that a value for the speed of sound of 2000 feet per second is more appropriate. NSP is participating in the NEI/EPRI Collaborative Project to Support Resolution of GL 96-06 Waterhammer RAIs and intends to resolve NRC concerns relative to the use of air entrainment through that effort.

In addition, there are many other conservatisms in the analysis. For example, as a pressure wave propagates through a piping system, losses will occur at elbows and bends in the piping. Per EPRI TR-106438, traversing through a 90° elbow will result in a loss of more than 10 percent. This effect is (conservatively) ignored in the column rejoining analysis and piping stress analysis.

In the initial response to GL 96-06, dated January 28, 1997, NSP discussed potential single active failures such as loss of a pump or loss of a complete train of safeguards equipment. These single active failures are limiting from a containment heat removal performance perspective. In light of the NRC comments related to the consideration of single active failures, NSP has reviewed this evaluation specifically for it's potential effect on the water hammer analysis. This review was performed to ensure that there were no possible single active failures which, from a water hammer perspective, could adversely effect containment integrity, containment heat removal capability, or cooling water system performance. In addition to the design bases single failures mentioned above (loss of a pump or failure of a complete train of safeguards), this review looked at other component failures which could increase the severity of a waterhammer event. This included such items as inadvertent valve closure which would cause a water column closure against a hard surface, two pumps starting on the same header, etc. This review concluded that there are no single active failures which could result in a loss of containment integrity or a reduction in the containment cooling below that assumed in the containment pressure analyses.

Comment No. 2:

Except for evaluation of the column separation and rejoining scenario, the licensee has not completed a rigorous analysis of the various types of waterhammer that can be encountered. The licensee credits experimentation that has been done to show that the column separation and rejoining scenario is the bounding case, but the experiments are very limiting and much more work is needed to establish the worst-case scenario for the licensee's plant-specific application. Also, the licensee's assumption that a Froude (Fr) Number of 0.5 is sufficient to demonstrate that piping lines run full during refill is not consistent with Fr ≥ 1.0 as suggested in NUREG/CR-5220 ["Diagnosis of Condensation Induced Waterhammer"] and must be justified.

Response:

NUREG/CR-5220 recommends a minimum Froude number of 1.0 to ensure that a horizontal pipe will run water solid during the refill. NUREG/CR-6519 also recommends a minimum Froude number of 1.0, but it does note that this is a conservative number. EPRI TR-106438 states that a minimum Froude number of 0.5 will ensure that the pipe runs full. This is based on a paper by Wallis, G.B.; Crowley, C.J.; and Hagi, Y, "Conditions for a Pipe to Run Full When Discharging Liquid Into a Space Filled with Gas," ASME Transactions Journal Fluids Engineering, Vol. 99, pp. 405-413, 1977. This minimum criterion of a Froude number ≥ 0.5 is also used by Bjorge and Griffith in "Initiation of Waterhammer in Horizontal and Nearly Horizontal Pipes Containing Steam and Subcooled Water," ASME Journal of Heat Transfer, Vol. 106, 1984. It should be noted that these two references are based on experimental data. The first paper (Wallis, et al) was based on air-water experiments. The second paper (Bjorge and Griffith) was based on steam-subcooled water experiments. Each set of data was analyzed and correlated with simple limiting theories which facilitate evaluation of the susceptibility of piping systems to water hammer. This was also discussed in report FAI 96-89; provided with the response to the NRC RAI related to GL 96-06, dated August 14, 1997. Therefore, there appears to be adequate technical justification of use of a minimum Froude number of 0.5 to ensure that the horizontal piping lines run full.

NSP is participating in the NEI/EPRI Collaborative Project to Support Resolution of GL 96-06 Waterhammer RAIs and intends to resolve NRC concerns relative to this comment through that effort.

Comments No. 3:

The licensee's evaluation indicated that the pipe and pipe supports were evaluated by inputting the expected dynamic loads due to waterhammer into the pipe stress program PIPEPLUS. However, the licensee did not describe the method used to bench mark the computer code for this type of loading condition (see Standard Review Plan Section 3.9.1).

Response:

Software utilized by our consultant for the analysis of piping and supports due to dynamic waterhammer loads is PIPEPLUS, Version 5.08 developed by Algor, Inc. This version was verified and benchmarked against the seven example problems given in NUREG-1677 as part of the consultant's Quality Assurance Program. The results compared well within 5% of the results published in the above report for all problems except for Benchmark Problem number 3. In Problem 3, the coordinates in the Z-direction for nodes 27 and 28 were switched in the generated input data given in the NUREG. When the switched data is used, the frequencies for the 10 modes compared very well (well within 5%) with the published data.

In addition, as part of the consultant's QA program, other examples with available output from validated software have been used to compare the results from the PIPEPLUS version. All of these compared within 5% accuracy.

Specifically, for the stress analysis associated with Generic Letter 96-06 waterhammer analysis, the consultant verified the time-history force response evaluation feature of the software for an 8" diameter, Schedule 40, undamped, simply supported straight pipe (beam) 16 feet long subjected to a trapezoidal (nearly rectangular) load with a 10 ms duration of constant load and a ramp up and down of 1 ms. The resulting maximum deflection at the center of the pipe was compared against the corresponding value for an equal magnitude static load applied at the center. The ratio of the dynamic deflection to the static deflection is termed as the dynamic load factor (DLF). The DLF derived from the PIPEPLUS software compared very closely to the DLF obtained for a rectangular pulse at the corresponding duration and period of vibration (DLF = 0.348 by time-history analysis vs. 0.34 from "Introduction to Structural Dynamics," by John M. Biggs, McGraw-Hill Book Company, 1964). This provided a verification of the methodology utilized in the time history method.

Comment No. 4:

The licensee's evaluation of the hydrodynamic loads due to two-phase flow discharge from the fan coil units is qualitative and does not include analysis of the effects of two-phase flow on components and piping (e.g., flow-induced vibration, erosion, and cavitation effects). Also the licensee's two-phase hydraulic analysis with initial pressure and flow corresponding to the cooling water pump operating at 93% of the inservice testing (IST) pump curve has not yet been completed.

Response:

With regards to other effects due to two phase flow (e.g., erosion, cavitation effects, vibration, etc.), NSP believes that these are long term type effects and that, due to the short duration of the two phase flow (under the bounding analysis), these are not significant concerns. The period of time that the two phase flow condition could exist downstream of the containment fan coil units is small; less than approximately 10 hours. EPRI NP-3944, "Erosion/Corrosion in Nuclear Plant Steam Piping: Causes and inspection Program Guidelines," provides a methodology to estimate the amount of accelerated pipe wall erosion due to two phase flow. Based on very conservative inputs (bounding values for temperature, steam wetness, and geometry) using these methods indicate that the pipe wall erosion rate during this time period is minimal. These sections of the system are monitored as part of the pipe wall thinning inspection program at Prairie Island. This program provides assurance that adequate wall thickness exists in these systems during normal operation. EPRI also indicates that raw water systems (such as Cooling Water) are generally immune to flow accelerated corrosion due to the presence of significant amounts of dissolved oxygen coupled with the low flow velocities in the cooling water system. For similar reasons pipe wall losses due to cavitation would also be minimal. This is primarily due to the short duration of the two phase flow condition and the cavitation mechanism which would occur in this system. As opposed to pressure recovery, the cavitation mechanism which would occur during the two phase flow condition would be condensation back into the liquid stage primarily by cooling. Per NUREG/CR-6031, "Cavitation Guide for Control Valves," this type of cavitation does not cause a violent collapse of the cavities and generally no classical cavitation erosion damage occurs (pg. 45). Other potential effects will be investigated as part of the EPRI project and the results reported to the NRC.

Using the two phase hydraulic model, NSP is in the process of performing sensitivity studies to ensure that the limiting cases are identified and evaluated. These are being done to ensure that the case of one cooling water pump operating at 93% of the inservice testing (IST) pump curve is bounded. NSP will inform the NRC of the results from these analyses when they are complete.