NSP

Northern States Power Company

Prairie Island Nuclear Generating Plant

1717 Wakonade Dr. East
Welch, Minnesota 55089

January 28, 1997 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 Generic Letter 96-06, Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions

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The purpose of this letter is to provide the 120-day response to NRC Generic Letter 96-06 for the Prairie Island Nuclear Generating Plant, the response is attached to this letter.

The operability of affected systems has been assessed. These assessments have determined that all affected equipment is operable.

In this letter we have made new NRC commitments, indicated as the italicized statements in the summary section of the attachment, " Response to Generic Letter 96-06." Please contact Jack Leveille (612-388-1121, Ext. 4662) if you have any questions related to this letter.

Michael D Wadley
Plant Manager
Prairie Island Nuclear Generating Plant

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c: (see next page)

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

Attachments:

1. Affidavit
2. Response to Generic Letter 96-06

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 requested by NRC Generic Letter 96-06.

This letter contains no restricted or other defense information.

NORTHERN STATES POWER COMPANY

BY Michael D Wadley
Michael D Wadley
Plant Manager
Prairie Island Nuclear Generating Plant

On this 28th day of January 1997 before me a notary public in and for said County, personally appeared Michael D Wadley, 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.

Marcia K LaCore

MARCIA K. LaCORE
NOTARY PUBLIC-MINNESOTA
HENNEPIN COUNTY
My Commission Expires Jan. 31, 2000

Response to Generic Letter 96-06

This summary report is submitted in response to NRC Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity during Design Basis Accident Conditions." This report includes a description of the analyses completed to date, the results of these analyses, conclusions based on these results, basis for continued operability (where applicable), and corrective actions that are being implemented or considered.

Generic Letter 96-06 addresses two potential issues:

1. Containment air cooler cooling water systems may be susceptible to either water hammer or two-phase flow conditions during postulated accident conditions;

2. Piping systems that penetrate containment may be susceptible to thermal expansion of fluid resulting in piping overpressurization.

This report summarizes work performed, to date, and actions in progress to completely address these concerns.

PART 1 - Determination of Susceptibility to either Water Hammer or Two Phase Flow Conditions during postulated Accident Conditions

I. System Description

A. Cooling Water System

The design basis for the Cooling Water System is to remove heat from various safeguards and non-safeguards loads and transfer the heat to the ultimate heat sink. During accident mitigation, the following safeguards loads are cooled or supplied by the Cooling Water System:

Component Cooling Heat Exchangers
Unit 1 Emergency Diesel Generators
Containment Fan Coil Units
Control Room Chillers
Backup Water Supply to Auxiliary Feedwater Pumps

B. Cooling Water Pumps

The Cooling Water System has five pumps, two non-safeguards and three safeguards. The two non-safeguards pumps are operated during normal power operation, with the three safeguards pumps in standby. During certain times of the year, as intake water temperature increases, it is necessary to operate a third pump to support unit operation (the motor

driven safeguards pumps). The non-safeguards pumps are powered from non safety related buses and would be de-energized on a loss of off site power (LOOP).

Two of the three safeguards pumps have their own independent diesel engine drivers (referred to as DDCLPs). The third safeguards pump is motor driven (121 MDCLP) with the safeguards Unit 2 Emergency Diesel Generator back-up power supply. All three safeguards pumps automatically start on the SI signal generated by the accident condition. When both DDCLPs start the 121 MDCLP is tripped if running or blocked from starting if idle.

If one of the DDCLPs fails to automatically start, the 121 MDCLP starts and is automatically aligned to the header associated with the accident unit; which could be the header with the failed or the operating DDCLP. In addition, per Technical Specifications, it is permissible to pre-align the MDCLP in place of a DDCLP without entering a LCO. In this instance, valves are positioned such that the MDCLP and the operable DDCLP each would supply separate headers.

C. Containment Fan Coil Units

There are two trains of safeguards fan coil units (FCUs) in each containment. Each train has two FCUs. The FCUs are air-to-water heat exchangers which serve post-accident mitigation function. The FCUs remove heat from the containment atmosphere by heat transfer to the cooling water on the tube side of the heat exchanger and condensation. In conjunction with Containment Spray, heat removal by the FCUs reduces the containment pressure and temperature profiles to limit off-site releases during the accident. The Cooling Water System pressure boundary of the FCU heat exchanger and associated piping serve as a containment boundary to prevent release of the containment atmosphere to the outside environment. The FCU tubes and associated Cooling Water piping are a closed system within containment. In the event of a leak from this system into containment during accident mitigation, the plant operator would close the FCU supply MOV and both return MOVs from the Control Room. A manual valve in a one inch line from the supply header would then be opened to pressurize the volume between the two MOVs in the return header. This line provides a pressure seal to ensure that containment atmosphere will not leak into the Cooling Water System return header.

D. Plant Response

The event considered for this evaluation is a LOCA with a concurrent LOOP. The LOCA/LOOP event occurs at time zero. The following are the expected key time parameters during the initial period following the accident:

ECCS Time Sequence

Time	Description
0 sec	LOCA + LOOP
2.4 sec	SI Signal (USAR, Table 14.6-3)
4 -5 sec	DDCLP start (typical)
SI + 10 sec	EDG Up To Speed and Voltage
	SI Pump start
	480 VAC loads energized
SI + 15 sec	RHR Pump start
	CS Pump start
SI + 20 sec	121 MDCLP start
SI + 25 sec	CC Pump start
	FCUs start
SI + 30 sec	AFW Pump start
	Air Compressor start
SI + 35 sec	Pzr Heaters energized
	Unit 2 Diesel Generator Room Cooling Fans start
SI + 40 sec	Control Room Chiller start

Containment Temperature Transient

Time	Description
0 sec	LOCA + LOOP
~ 10 sec	Containment temperature at 250F
~ 15 sec	Containment temperature at peak value of 270F
~ 700 sec	Containment temperature at 250F
~ 3500 sec	Containment temperature at 237F

This containment temperature profile is based on one Containment Spray Pump during the injection phase only and the heat removal equivalent to one FCU for the duration of the event analysis.

The Motor Driven Cooling Water (non-safeguards) pumps and Fan Coil Unit (FCU) fans lose power on the LOOP. Safeguards Cooling Water Pumps start and the FCU fans are restored as shown above. When power is lost, the FCU fans coast down at a much slower rate than the cooling water pumps. During this coast down time period, it is postulated

that the fans continue to pull steam laden air across the fan cooler heat exchanger tubes. When both DDCLPs start, flow is re-established to the FCUs before any voiding occurs, precluding any water hammer due to void collapse during refill. As discussed above, either due to a DDCLP out of service or a failure of a DDCLP to start, 121 MDCLP could be providing the CL flow; this would occur at approximately 23 seconds into this transient. This allows sufficient time for the water in the FCU to stagnate and start to void due to column separation. As the steam/air mixture is pulled across the stagnant water in the heat exchanger by the fan during coastdown, the water in the tubes will boil and rapidly void the fan coil unit heat exchangers.

When Cooling Water flow is re-established, the water refills the supply lines, the fan coil units, and the return lines. For a loss of off site power event, only, the water exiting the FCUs will be subcooled. Hydrodynamic loads could be experienced due to collapse of voids resulting from the column separation. For a LOCA event, significant heat will be added to the cooling water through the FCUs. This will result in two phase conditions at the exit of several of the FCUs. Hydrodynamic loads may be experienced due to void collapse (e.g., steam bubble collapse). The magnitude and location of the two phase flow condition depends on the system pressure at the FCU and downstream piping, and the elevation of the specific FCU. For a LOCA/LOOP event, significant heat will be added to the cooling water through the FCUs. This will result in two phase conditions at the exit of several of the FCUs. Similar to the LOCA without a LOOP case, hydrodynamic loads may be experienced due to void collapse.

The potential for water hammer due to column separation is discussed in Section III of this report. The potential water hammer due to two phase flow discharge from the FCU is discussed in Section IV of this report.

Following the establishment of Cooling Water flow through the FCUs, a steady state condition will be reached. Depending on the Cooling Water System pressure at the FCUs, a two phase flow condition may be present. This is discussed in Section IV of this report.

II. Engineering Considerations

A. Initial Engineering Judgment

The issue of water hammer during system refill relates to component and system performance during the initial seconds of post-accident mitigation. This time frame was not specifically analyzed during the design and licensing of Prairie Island; however, it was considered acceptable based

on engineering judgment. This engineering judgment was based on the robust design of the systems and the extreme conservatisms in the analysis. More recently developed tools (for example; Leak before Break and Probabilistic Risk Assessment) would indicate that these design basis events are not credible.

In response to this Generic Letter, detailed engineering analysis has been performed, and more is in progress. These analyses substantiate the engineering judgment of the plant designers. It should be noted that this issue pertains to the original design of the system, and is not the result of any changes to the configuration or operation of the system.

B. LOCA Scenario

A LOCA scenario is the bounding scenario for evaluating the response of the FCUs. MSLB containment pressure and temperature analyses demonstrate that heat removal by the FCUs is not required to maintain containment pressure and temperature below the design limits. The only active heat removal source credited in the MSLB containment pressure and temperature analysis is one Containment Spray Pump during the injection phase only. Following the injection phase, the MSLB containment atmosphere is depressurized and cooled through the passive heat sinks. The post-MSLB steam mixture environment is less severe than for the LOCA. Thus, the heat transfer to the FCUs would be less for the MSLB, resulting in a less severe two phase flow condition.

C. Loss of Off Site Power

A LOCA both with and without a loss of off site power were initially considered for this evaluation. During a non-LOOP event, the Cooling Water Pumps remain in operation and the initial voiding scenario does not occur. Thus, in this instance, a LOOP scenario is potentially more severe.

The potential for steady state two phase flow is not significantly effected by the presence or absence of off site power. That is, in either scenario, each header will be supplied by one pump; which will be unable to maintain sufficient pressure to prevent boiling at peak containment post-accident conditions.

Therefore, a LOOP scenario will bound a non-LOOP event, and is evaluated in the subsequent discussions.

III. Water Hammer During System Refill (Subcooled Discharge from the FCUs)

A. Analysis

This section of the report discusses a subcooled refill condition; a two phase discharge from the FCUs is discussed in Section IV. Due to their complex nature, these analyses are time consuming. To simplify the analyses and ensure any potential operability concerns were identified early, it was decided to identify and analyze the most limiting FCU physical configuration. The most limiting FCU was identified based on flow rates and pressures from the single phase hydraulic model, and the FCU locations. These results are presented in this report. The remainder of the FCU configurations will be analyzed to confirm the selection of these bounding configurations.

The potential hydrodynamic loads are determined based on water impacting water (water column rejoining) using the Joukowsky equation and water properties. Hydrodynamic loads for this scenario were calculated in Fauske & Associates, Inc. (FAI) Calculation No. 96-77, "Assessment of Prairie Island Fan Cooler Piping Loads." This calculation reviewed the piping configurations to evaluate the possibility of void formation, and assessed the nature of the piping and fan cooler refill to determine the potential for producing a stratified condition of steam and subcooled water. The water velocity in the pipes was based on the design conditions for the FCU. Based on this review, the bounding pressure pulse was determined. The calculation showed that the piping refill velocities would be more than sufficient to ensure that horizontal pipes run full. Furthermore, experiments in a two inch scaled model pipe shows that the vertical pipe would also flow in a one-dimensional manner. Horizontal and vertical pipes running full precludes a stratified condition. If the downward flowing vertical lines did not run full, hydrodynamic loads could occur due to void collapse at the top of the vertical run as the void moved up and reached the top of the line. This implies that the worst case water hammer in these lines would be due to column rejoining. Thus, the loads calculated based on the column rejoining are bounding for this scenario.

The piping and supports were evaluated by inputting the expected dynamic load due to the water hammer (from the above referenced calculation) into the pipe stress program PIPEPLUS ("Evaluation of FCU Piping Systems for Water Hammer Loads"). The stresses in the piping and loads on the supports were evaluated using a time history methodology. The load time history is applied at each elbow sequentially as independent loading runs. These analyses, to date, indicate that the loads on the piping and supports is within the USAR acceptance criteria.

The hydrodynamic loadings are conservatively evaluated. That is, minimal credit was taken for reductions due to cushioning by uncondensed steam or non-condensable gas, compliance of piping, hangers and mounts, and oblique impact. Per NUREG-5220, these factors usually result in actual loads being less than the evaluated loads by a factor of 2 to 10.

Experiments were run using scale models of a representative bounding FCU piping configuration (FAI Report Numbers 96-89 and 96-107). The scale models were constructed to create a situation where the following conditions could be simulated:

1) column separation could occur once the imposed flow rate was removed,
2) steam generation would be added to the piping configuration,
3) a significant loop seal exists in the simulated fan cooler,
4) a significant size loop seal exists at the bottom of the piping,
5) the supply piping can experience column separation as well as some drainage, and
6) water refill rates would be imposed on the system for Froude numbers typical of those of interest in the Prairie Island Cooling Water System.

Using the scale models, input parameters (steam flow rate, water refill rate, voiding time, pipe size) were varied to determine the relative sensitivity to the resultant water hammer. Water hammer activity was exhibited by the experimental results; however, these results demonstrated that the calculated hydrodynamic loads used in the piping support analyses are high by a factor of 3 to 20 compared to the experimental results. This is consistent with the above noted statements from NUREG-5220.

Furthermore, the water hammers with the highest magnitude observed during the experiments occurred during the voiding phase, not during the refill. During voiding, water hammer loads would not be propagated to the FCUs due to the significant compliance of the steam void.

B. Basis for Continued Operability

This issue was initially identified in NRC Information Notice 96-45, "Potential Common Mode Post-Accident Failure of Containment Coolers." At that time, NSP prepared an operability assessment to support continued operation for the interim time period until more detailed analyses was available. As further analyses were performed the operability assessment was revisited. At no time during this period did any additional information raise any doubt regarding the adequacy of this assessment. Based on the

above discussed analyses, the piping and supports are shown to be within their design bases.

C. Corrective Actions

Further confirmatory evaluations are in progress for the piping associated with all the FCUs to ensure that the bounding cases remain valid. System operability will continually be evaluated as more results become available,

IV. Two Phase Flow Conditions During Accident Conditions

During the initiation of flow (following the LOCA /LOOP scenario), the discharge from the FCUs could be in a two phase flow condition. This is primarily due to lower pressures in the FCU return piping. The analysis (to date), operability evaluations, and corrective actions for this scenario are discussed below.

A. Analysis

1. Flow and Heat Removal

Evaluation of the Cooling Water flow through the FCUs has been analyzed using a thermal hydraulic model. The hydraulic model balances the pressures at various node junctions to determine the flows existing in various branches in the complex network. The model is used to analyze Cooling Water System performance under various normal and abnormal operating configurations. To evaluate a bounding case with respect to the potential for two phase flow at the FCUs, the following inputs were used:

- LOCA at peak conditions (maximum heat input to the FCUs)
- Loss of Off-Site Power
- FCU fouling factor of 0.0000 (maximum heat transfer capability)
- One Cooling Water Pump per header (headers separated)
- Cooling Water Pump at the minimum performance limit (93% of pump Inservice Testing curve)
- Loss of Instrument Air System (results in maximum flow demand on the system)

At present there are no flow limiting devices (orifice, throttle valve, etc.) used during post-accident mitigation to provide back pressure for the water flow through the FCUs. Orifices are installed in the return lines from the FCUs. However, during an accident, an air operated bypass valve provides a flow path around the orifice. This

bypass valve opens on the SI signal to maximize flow through the FCUs. Under the conditions above, the hydraulic model predicts that saturated conditions will be present at the outlet of several of the FCUs. This hydraulic model can identify saturated conditions, but it does not model two phase flow.

In order to evaluate the effects of two phase flow conditions, a new transient thermal hydraulic model was developed which is capable of modeling the increased resistance due to the two phase flow condition. This model incorporates the momentum transfer process which cause waterhammer, the transient heat transfer, and steam generation in the fan cooler coils. The model evaluates displacement of water due to steam generation in the FCUs and associated piping, the energy transfer to the supply and return piping and the influence of two-phase frictional and momentum pressure drop including those which could lead to two-phase critical flow. The model is benchmarked with relevant data in these areas, including water hammer events.

Two trains of FCUs, consisting of two FCUs each, are located within each containment. To simplify the analysis the train of FCUs with the most significant two phase flow conditions are modeled. These FCUs were identified based on flow rates and pressures from the single phase hydraulic model and the FCU locations. The most significant two phase flow condition is predicted at FCU 24 due to it's elevated location in containment. To ensure that the analysis is bounding, a train consisting of two FCUs are considered as one unit located at the elevation equivalent to FCU 24. This is conservative as FCU 22 is located at a much lower elevation than FCU 24; i.e., the two phase flow condition would be much less significant at the lower elevation. Further evaluation of the other FCUs is in progress to ensure that this evaluation is bounding. That is, assurance will be provided that there would be no other potential affects which could degrade FCU performance.

The model is being used to evaluate the system hydraulic response during the transient from flow cessation (due to the LOOP), to flow reinitiation, then to steady state conditions. The time period from pump stop on the loss of power to flow reinitiation is varied from 5 to 30 seconds. The time period for flow reinitiation is varied to evaluate the different possible pump combinations; i.e., typical starting time for the DDCLPs is on the order of 5 seconds, and 121 MDCLP will be up to speed within 30 seconds.

The results of the model, to date, show that the heat removal by the two FCUs is on the order of approximately 85 million Btu/hr. This is lower than the heat removal capability indicated in the USAR (100 million Btu/hr). The design bases for the FCUs is to limit the containment pressure to less than design. Due to the reduced FCU heat removal capability, the affect on containment pressure and temperature profiles was evaluated.

In 1995, new containment pressure and temperature analyses were performed using CONTEMPT to evaluate the effects of varying the heat removal inputs and safeguards equipment operating configurations. The initial runs of the model were performed using the inputs from the USAR. The results were then compared to the results in the USAR to validate the model. Following the model validation, several sensitivity studies were performed with different combinations of Containment Spray Pumps and Fan Coil Units. The results of these analyses show that with one Containment Spray Pump in operation during the injection phase of the post-LOCA mitigation and the heat removal equivalent to one FCU at design conditions (50 million Btu/hr) containment pressure and temperature are maintained within the design basis. The containment pressure profiles are also well within the profiles assumed for Off Site and Control Room personnel dose analyses. Environmental qualification of equipment inside of containment was reviewed to ensure the necessary components would function when needed.

The new post-LOCA containment analysis also included a review of the Containment Sump water temperature transient. These results were used to ensure that sufficient net positive suction head (NPSH) was available to the RHR Pump(s) to prevent cavitation.

Results of the transient hydraulic model indicate that the heat removal capability of the FCUs is significantly higher than that necessary to maintain containment pressure and temperature within the design limits. Further analyses were performed using the transient hydraulic model to evaluate the FCU heat removal capabilities at heat exchanger fouling factors of 0.001 and 0.002 (0.002 is the design fouling factor). These sensitivity studies indicate that the heat removal capability of the FCUs will still be above that assumed in the containment pressure and temperature analysis.

There are several other factors which need to be considered with the predicted presence of two-phase flow in the Cooling Water return lines from the Fan Coil Units. These are discussed below.

2. Hydrodynamic loads

The presence of the steam in the FCUs and associated piping could generate hydrodynamic loads during refill and steam bubble collapse. Loads resulting from refill are discussed above. The bounding case, due to the refill rates is the water column rejoining mechanism. These results are then used in the piping analysis. Furthermore, from experimental evidence, these loads are demonstrated to be conservative. This part of the report discusses potential hydrodynamic loads resulting from other mechanisms. These evaluations are qualitative at this time. Thus far, these evaluations indicate that the potential hydrodynamic loads from the water column rejoining event are bounding.

a. Piping taps off of CL header to FCU

During normal operation, cooling water is provided to non-safety related shroud coolers inside of containment. The water supply to the shroud coolers comes from a four inch tap into the eight inch supply line to one of the FCUs inside of containment. The return is into the eight inch return line inside of containment. Isolation valves automatically close on the Safety Injection signal to isolate the non-safety related four inch piping from the safety related eight inch piping. The four inch piping from the eight inch header to and including the isolation valve is safety related.

During the loss of flow, the FCU voids and steam is pushed into the supply and return piping. This steam could migrate into the eight inch supply pipe past the four inch tap. Thus, steam may intrude into and accumulate in the four inch line to the isolation valve. With flow reinitiation the possibility exists for the steam to be trapped by the cooler water. This could result in a water hammer event. These loads would then be transmitted back into the eight inch header. Preliminary evaluation indicates that the resulting water hammer loads would be less than those calculated for the water column rejoining in the eight inch header. The experimental evidence shows that this is a very conservative evaluation.

b. Piping Horizontal Runs

Following flow initiation, a steady state two phase flow condition would be established (as indicated by the transient hydraulic analysis. Outside of containment, horizontal runs of pipe exist prior to the flow entering the return header. If subcooled water existed in these horizontal runs, steam flow into the piping run can generate surface waves which could grow and sweep up the liquid into a coherent water slug which fills the entire flow cross sectional area. Loads are generated when the slug passes through pipe bends and if it is abruptly stopped. In the scenario here, the resultant force can be approximated. The differential pressure developed across a water slug formed in this area of the system is the difference between the steam pressure from the FCU and the downstream return header. The force generated from these very low pressure differentials would be much less than the force, calculated for the column rejoining, used in the piping and support analyses. Therefore, water hammer from this phenomena is expected to be bounded by the column rejoining.

c. Return Header

Interaction and mixing of a two phase flow mixture with the subcooled water in the return header was also considered. Comparing the transient plant conditions to such mixing data from published literature shows that quenching would occur within one to two diameters of the mixing location and that the mixing zone would behave as a quasi-steady sate condition. Thus, while some cavitation-like small pressure pulses could be expected, these are very small compared to that calculated for the column rejoining event.

3. Interactions with other portions of the CL system

a. Supply Header

The two phase flow condition increases the flow resistance through the FCUs. This causes an increase in the backpressure to these components and an increase in the pressure at the tap off the main supply header to the FCUs. These taps to the FCUs off the supply header are the last tap prior to the isolation valves which separate the headers. An increase in the pressure at this point will result in a slight flow increase to the other components supplied by the Cooling Water System. This slight flow increase is not detrimental to these other components.

b. Return Header

The Cooling Water return from the FCUs is the first tap into the return header. Potential hydrodynamic loads generated at this point are discussed above. The other significant returns into the header are from the return from the other opposite Unit (same train) FCUs, Component Cooling Heat Exchangers, the Unit 1 Emergency Diesel Generators, and other miscellaneous smaller loads. The return water from these various heat exchangers is significantly subcooled. Two phase flow from the FCUs would be quenched by the subcooled water in the header such it would not migrate to other areas in the system. Thus, flows from other components would not be effected by steam accumulation, and potential water hammer due to steam void collapse would not occur in areas other than those discussed above.

c. Therefore, there are no detrimental effects to other areas of the system due to the two phase flow condition.

4. Erosion

Cooling Water System piping is monitored for pipe wall thinning through the Pipe Thinning Inspection Program (Operations and Maintenance Support Procedure No. 2.4); microbiologically induced corrosion (MIC) is the primary concern. The purpose of these inspections is to monitor piping performance to ensure that any degradation is identified early and repaired. These piping inspections demonstrate that there is substantial wall thickness available in the piping downstream of the fan coil units; i.e., the areas which could be subjected to two phase flow conditions.

In general, pipe thinning due to erosion from two phase flow is time dependent; implying that the amount of erosion would be minor due to the short time period (hours) that two phase flow could be present at the discharge of the fan coil units. Further evaluation was performed based on information in NUREG 1344, "Erosion/Corrosion-Induced Pipe Wall Thinning in U.S. Nuclear Power Plants." NUREG 1344 indicates that several factors effect the rate of erosion of carbon steel piping. The two phase flow condition in the Cooling Water System was evaluated for these factors. Based on the brief time period that two phase flow may be present, acidic water chemistry conditions, low temperature, and relatively low flow rates, erosion is not a concern.

B. Basis for Continued Operability

The heat removal capability of the FCUs could be reduced by the predicted two phase flow condition. However, containment analysis shows that this reduced heat removal capability is more than that necessary to maintain containment pressure and temperature below design conditions. Analysis, to date, of the potential hydrodynamic loads indicates that loads on piping and supports will not exceed design limits. Analyses also indicate that there will be no adverse interactions in other portions of the system due to hydrodynamic loadings or steam accumulation and that erosion due to two phase flow is not a concern.

The two phase flow analysis and piping and support analysis have not yet been finalized. Based on information developed to date, there is reasonable assurance of system operability. System operability will be continually evaluated as more results become available.

C. Corrective Actions

Although the analyses show that the heat removal capability of the FCUs with the two phase flow condition is more than sufficient to satisfy the containment design basis, corrective actions to move the two phase flow condition outside of containment are being investigated. As previously noted in this report, orifices are installed in the return lines from the FCUs with a bypass valve which opens on the SI signal. Sensitivity studies with this bypass valve closed show that the current orifice size will provide sufficient back pressure to maintain single phase flow conditions upstream of the orifice. Flashing will still occur at downstream side of the orifice plate resulting in increased flow resistance and reduced flow conditions. Preliminary analysis shows that, with the reduced flow, the FCU heat removal capability will be more than sufficient to satisfy containment design. There is a tradeoff between providing back pressure upstream of the orifice and maximizing the FCU heat removal capability. Further sensitivity studies using the transient model are being performed to optimize the orifice plate sizing; i.e., provide sufficient back pressure to maintain single phase conditions upstream of the orifice while maximizing FCU heat removal. Based on these analyses, if it is concluded that the orifice plate should be replace, a modification will be initiated to replace the orifice plates. At the same time, if considered appropriate, a modification will be initiated to replace the bypass valve air operator with a manual operator, and the valve will be maintained in the closed position [illegible] both normal and initial post-accident operation.

A separate modification is currently being prepared to change the logic for the automatic closure of the isolation valve for the non-essential loads in the

Turbine Building. This isolation valve is currently designed to automatically close on a concurrent high flow/low pressure condition in the associated header. Results from the hydraulic model of the system at accident conditions indicates that this setpoint combination would not be reached even with the pump operating at 93% of the In-Service Testing pump curve. Closing the isolation valves for the non-essential loads in the Turbine Building during post-accident mitigation provides increased pressure in the CL header and at the FCUs. This modification will close these valves on a SI signal coincident with a low pressure condition in the header. The low pressure signal input is provided to prevent spurious SI closure and provide protection only if the header is in a degraded condition.

PART 2 - Potential Piping Overpressurization due to Thermal Expansion

Containment isolation is the capability to provide isolation for fluid systems penetrating the primary containment for a loss-of-coolant accident within containment or any other accident which calls for actuation of the same containment isolation provisions.

FSAR, Section 1.8, states:

> "the PINGP was designed, constructed, and will be operated so as to comply in so far as practicable with the Applicant's understanding of the intent of the AEC's proposed General Design Criteria for Nuclear Power Plant Construction Permits as expressed in recent licensing actions."

The proposed AEC General Design Criteria, Criterion 53, pertains to containment isolation valves and states: "penetrations that require closure for the containment function shall be protected by redundant valving and associated apparatus."

NSP responded (for the PINGP), in the FSAR, to Criterion 53 stating:

> "at least two barriers are provided between the atmosphere outside the containment and the containment atmosphere, the reactor coolant system, or closed systems which are assumed vulnerable to accident forces."

Several of the containment penetrations are provided with redundant isolation valves; both automatically close to isolate containment from the outside environment. This issue relates to the potential for water to be trapped between the isolation valves. Due to system configuration or operation during accident mitigation, water trapped between closed valves could result in system overpressurization if the fluid temperature significantly increases. The fluid temperature could increase due to heat transfer to the internal fluid from the

atmosphere surrounding the pipe inside containment. During a LOCA, the pipe (if not insulated) will be surrounded by a steam environment. The steam would condense on the cooler pipe. Due to the relatively high condensation heat transfer coefficient, heat transfer to the pipe wall would be significant. The heat would then be transferred through the pipe wall to the internal fluid. As the internal fluid temperature increases, the fluid pressure will also increase. A small increase in the internal fluid temperature will result in a significant internal pressure increase.

Generic er 96-06 specifically requested that licensees determine if piping systems that penetrate the containment are susceptible to overpressurization due to thermal expansion of internal fluid. The scope of the evaluation of this phenomena at Prairie Island was expanded to also include all fluid systems inside of containment and safety related systems outside of containment. This evaluation is documented in analysis ENG-ME-299, "Piping Internal Pressurization."

I. Analysis Methodology and Assumptions

The methodology for these evaluations was as follows:

A. Identify the piping sections of potential concern. Three general groupings were identified; i.e.:

- Containment penetrations
- Piping systems inside of containment
- Safety related piping systems outside of containment

B. Of the piping sections of potential concern, determine those which could be subject to significant thermally induced pressurization.

C. Evaluate the piping capability to withstand the maximum predicted internal pressure. Maximum allowable stress values from the USAR are used as the acceptance criteria for this analysis.

D. If the potential for over-pressurization does exist, based on piping stress analysis, operability was evaluated and corrective actions recommended.

E. For the evaluation of these penetrations, a breach in the pressure boundary due to thermally induced overpressurization is not considered as the single failure. Instead a thermally induced failure is a consequence of the event. In determining the resultant consequences, single active failures were considered.

F. Several of the piping sections are filled with a gas (nitrogen, air, etc.). With a constant volume the gas pressure will increase as a function of the temperature increase according to the ideal gas law. Evaluation shows that the pressure increase will be relatively insignificant compared to the capability of the piping.

G. Based on the temperature profiles, the LOCA steam mixture profile bounds the MSLB profile and will be used in this evaluation.

In order to ensure that these evaluations were conservative, the following assumptions were made:

A. The trapped fluid is assumed to be water solid; i.e., no gas voids are trapped with the fluid. This maximizes the pressure rise for the given temperature rise and is bounding.

B. Isolation valves are assumed to be leak tight. Containment isolation valves are leak tested in accordance with the containment leak rate test program. Results from this testing program indicate that very few valves are completely leak tight at test pressure (46 psid across the valve seat). Thus, valve leakage would be expected at higher pressures. Valve leakage could preclude an overpressurization event; therefore, this is a very conservative assumption. This assumption of complete leak tightness is not used for valves which physically have pressure relieving capability. For example, diaphragm valves will relieve internal fluid pressure when it exceeds some maximum value (based on spring size). The pressure which results in the diaphragm relieving the internal pressure is well above the containment leak rate test program, but well below the allowable internal pressure for the penetration pipe.

II. Fluid Systems Which Penetrate Containment

A. Analysis

A tabulation of containment penetrations was used to facilitate this evaluation (Table 1). Several of the penetrations were dispositioned based on normal operating temperature of the internal fluid (i.e., normal operating temperature would preclude a heatup of the internal fluid from the post-accident environment), the presence of a pressure relief device, etc. A few penetrations required a more detailed evaluation. The specific penetrations of concern were the Reactor Coolant Pump (RCP) Seal Water Return Line, the Sample Lines, and the SI Test Line.

The SI Test Line is heavy wall pipe (3/4" Schedule 160). The maximum internal pressure was evaluated assuming the maximum expected internal

fluid temperature increase from containment ambient to near peak accident conditions. No credit was taken for cooling afforded to the internal fluid by the piping volume located outside of containment. The piping was then evaluated to determine it's capability, within the design basis for a faulted condition as discussed in the USAR, to withstand the predicted internal pressure increase. This evaluation determined that piping internal pressure would not exceed the design basis allowable pressure for the piping. Thus, the piping would meet it's design basis function of maintaining containment isolation. These penetrations do not perform any other function for the accident being evaluated.

The Sample Lines are heavy wall tubing (3/8" outside diameter, 0.065" wall thickness). A detailed temperature transient analysis was performed for the internal fluid; accounting for condensation on the tube surface inside containment, mixing of the fluid within the tube, and heat transfer from the fluid to the tube wall then to the atmosphere(s) outside of containment. The maximum internal pressure was determined based on the maximum temperature increase of the internal fluid. The tubing was then evaluated to determine it's capability, within the design basis for a faulted condition as discussed in the USAR, to withstand the predicted internal pressure increase. This evaluation determined that piping internal pressure would not exceed the design basis allowable pressure for the tubing. Thus, the tubing would meet it's design basis function of maintaining containment isolation. These penetrations do not perform any other function for the accident being evaluated.

The RCP Seal Water Return penetration piping is heavy wall pipe (3" Schedule 160) with the exception that the welded joint to the isolation valves is counterbored to a much thinner wall. This thinner wall is the weak link in the penetration. This necessitated a much more detailed evaluation. A detailed temperature transient analysis was performed for the internal fluid; accounting for condensation on the pipe surface inside containment, mixing of the fluid within the pipe, and heat transfer from the fluid to the pipe wall then to the atmosphere(s) outside of containment. The maximum internal pressure was determined based on the maximum temperature increase of the internal fluid. The piping was then evaluated to determine it's capability, within the design basis for a faulted condition as discussed in the USAR, to withstand the postulated pressure increase. This evaluation determined that piping internal pressure would not exceed the design basis allowable pressure for the piping. Thus, the piping would meet it's design basis function of maintaining containment isolation. These penetrations do not perform any other function for the accident being evaluated.

B. Basis for Continued Operability

All penetrations satisfy their design basis. Therefore, no further operability evaluations are necessary.

C. Corrective Actions

As discussed above, the evaluations showed that the RCP Seal Return Line penetration piping would satisfy it's containment isolation design basis. However, due to the thin wall piping sections in this piping section, it is considered prudent to limit the potential internal pressure increase in this piping due to accident conditions. This will be accomplished by insulating the piping segment inside of containment from the penetration to the upstream side of the isolation valve. This will provide further protection by limiting the temperature transient of the internal fluid, minimizing the internal pressure transient.

III. Fluid Systems Inside Containment

A. Analysis

Fluid systems inside of containment were reviewed to identify any potential isolated portions of piping which could be fluid solid either due to normal operating alignment or valve positioning during accident mitigation. Table 2 (attached) provides a detailed listing of these systems and the disposition of each. The evaluation showed that the maximum pressure increase in the potentially susceptible fluid systems inside of containment would not result in the pipe exceeding it's design basis allowable pressure.

During this review, a situation was discovered where thermally induced internal pressure increase could be avoided in several RCS drain connections through proper sequencing of the isolation valves. Procedure changes were made to implement these changes.

B. Basis for Continued Operability

As discussed above, all piping inside of containment satisfies their design basis. Therefore, no further operability evaluations are necessary.

C. Corrective Actions

As discussed above, all piping inside of containment satisfies their design basis. Therefore, no additional corrective actions are necessary. Procedure changes have been implemented to sequence operation of the RCS drain valves.

IV. Safety Related Fluid Systems Outside Containment

A. Analysis

Safety related fluid systems outside containment were reviewed to identify any potential isolated portions of piping which could be fluid solid either due to normal operating alignment or valve positioning during accident mitigation. Table 3 (attached) provides a detailed listing of these systems and the disposition of each. The evaluation showed that the maximum pressure increase in any of the potentially susceptible fluid systems outside of containment would not result in the pipe exceeding it's design basis allowable pressure. The maximum postulated pressure assumed that the piping internal fluid temperature was consistent with room ambient temperature. The room ambient temperature was conservatively determined assuming that the room cooling system was not functioning.

B. Basis for Continued Operability

All safety related piping outside of containment satisfies their design basis. Therefore, no further operability evaluations are necessary.

C. Corrective Actions

All safety related piping outside of containment satisfies their design basis. Therefore, no corrective actions are necessary.

PART 3 - SUMMARY

The above report addresses the issues promulgated in NRC Generic Letter 96-06. As discussed abc[illegible] ie systems are considered operable and capable of performing their design basis functions

Actions which have yet to be completed to finish addressing these issues are as follows:

1. *Complete piping and pipe support analysis for the piping associated with the FCUs for potential hydrodynamic loadings.*

2. *Complete two phase flow analyses for the FCUs, including the assessment to ensure that the analysis of FCU 22 and 24 is the bounding configuration.*

3. *Complete the analyses of potential hydrodynamic loadings due to the two phase flow condition from the FCUs. Review these loadings against the pipe and support analyses to ensure that the analyses are bounding.*

Actions which are being considered to enhance system performance are as follows:

1. Perform sensitivity studies to optimize orifice sizing at the outlet of the FCUs.

2. Replace orifice at the outlet of the FCUs, if necessary, and modify orifice bypass valve to maintain the valve closed.

3. Complete the modification to control logic for the Cooling Water isolation valves for non-essential Turbine Building loads.

4. Install insulation on the RCP Seal Water Return piping inside of containment from the containment shell to the upstream side of the isolation valve.

TABLE 1

	Unit 1 Penetrations			
Penetration	Description	Service (Gas, liquid, steam)	Acceptable (Yes/No/Needs Eval)	Basis
1	PRT Gas Sample	Gas	Yes	35% increase in static pressure
2	PRT Nitrogen Supply	Gas	Yes	35% increase in static pressure
3	Spare (welded shut)	Gas	Yes	35% increase in static pressure
4	Primary System Vent Header	Gas	Yes	35% increase in static pressure
5	RC Drain Tank Pump Discharge	Liquid	Calculation ENG-ME-299	Diaphragm valves inside cntmt
6	Main Steam Header	Steam	Yes	Hotter than containment temp
7	Main Feedwater Header	Liquid	Yes	Hotter than containment temp
8	SG Blowdown	Liquid	Yes	Hotter than containment temp
9	RHR Loop Out	Liquid	Yes	Relief provided (RH-8-1)
10	RHR Loop In	Liquid	Yes	Thermal relief provided (RH-6-1)
11	CVCS Letdown Line	Liquid	Yes	Relief provided (VC-26-1)
12	CVCS Charging Line	Liquid	Yes	Relief provided (VC-17-1)
13	CVCS Seal Injection	Liquid	Yes	Check valves .w/ flow into RCS
14	CVCS Seal Return	Liquid	Calculation ENG-ME-299	Trapped Fluid
15	Pzr Steam Sample	Steam	Calculation ENG-ME-299	Trapped Fluid
16	Pzr Liquid Sample	Liquid	Calculation ENG-ME-299	Trapped Fluid
17	RCS Loop Sample	Liquid	Calculation ENG-ME-299	Trapped Fluid
18	Fuel Transfer Tube	Liquid	Calculation ENG-ME-299	Trapped Fluid
19	Service Air	Gas	Yes	35% increase in static pressure
20	Instrument Air	Gas	Yes	35% increase in static pressure
21	RCDT to Gas Analyzer	Gas	Yes	35% increase in static pressure
22	Containment Air Sample	Gas	Yes	35% increase in static pressure
23	Containment Air Sample	Gas	Yes	35% increase in static pressure
25	Containment Purge Supply	Gas	Yes	35% increase in static pressure
26	Containment Sump Pump Discharge	Liquid	Calculation ENG-ME-299	Diaphragm valves inside cntmt
27A	SG Blowdown Sample	Liquid	Calculation ENG-ME-299	Trapped Fluid
27B	Fire Protection	Liquid (drained)	Yes	Drained during normal operation
27C	Containment Pressure Test Panel	Gas	Yes	35% increase in static pressure
28A	Cold Leg SI	Liquid	Yes	Relieves to 28B
28B	Hot Leg SI	Liquid	Yes	Injection check valves to RCS
29	Containment Spray	Liquid	Yes	Vented to containment
30	RHR Suction from Containment Sump	None	Yes	No exposed fluid
31	Nitrogen to SI Accumulators	Gas	Yes	35% increase in static pressure
32	Component Cooling to RCP	Liquid	Yes	Vented to CC return
33	Component Cooling from RCP	Liquid	Yes	Vented to CC return
34	Electrical Penetrations	Gas	Yes	35% increase in static pressure
35	SI and Accumulator Test Line	Liquid	Calculation ENG-ME-299	Trapped Fluid
36	Instrumentation	Gas	Yes	Vented to containment
37	Cooling Water to CFCUs	Liquid	Yes	Thermal relief
38	Cooling Water from CFCUs	Liquid	Yes	Thermal relief
39	Component Cooling to Excess LD HX	Liquid	Yes	Thermal relief
40	Component Cooling from Excess LD H	Liquid	Yes	Thermal relief
41	Containment Vacuum Breaker	Gas	Yes	No exposed fluid
42A	Hydrogen Control	Gas	Yes	35% increase in static pressure
42B	In-Service Purge Supply	Gas	Yes	35% increase in static pressure
42C	Heating Steam Supply	Gas	Yes	35% increase in static pressure
42D	RVLIS Instrumentation	Liquid	Yes	RVLIS expansion bellows
42F	Heating Steam Condensate	Gas	Yes	35% increase in static pressure
43	In-Service Purge Exhaust	Gas	Yes	35% increase in static pressure
44	Containment ILRT Pressurization	Gas	Yes	35% increase in static pressure
45	Reactor Make-Up to PRT	Liquid	Calculation ENG-ME-299	Diaphragm valves inside cntmt
46	Auxiliary Feedwater	Liquid	Yes	Vented to steam generator
47	Electrical Penetrations	Gas	Yes	35% increase in static pressure
48	Low Head SI to Vessel	Liquid	Yes	Injection check valves to RCS
49	Instrumentation	Gas	Yes	Vented to containment
49B	Demineralized Water	Gas	Yes	35% increase in static pressure
50	Hydrogen Control	Gas	Yes	Vented to containment
EH	Equipment Hatch	Gas	Yes	Vented to containment
Airlock	Personnel and Maintenance Airlocks	Gas	Yes	Designed to 46psi, 35% > 14.7psi
Unit 2 Pentrations are similar; although some slight numbering differences exist.				

TABLE 2
Piping Inside of Containment

SYSTEM	SR/NSR	EVALUATION
Residual Heat Removal	SR	A section of RHR Piping from the RCS hot leg to the suction side of the RHR Pumps is normally isolated by two closed valves (per line). These valves remain closed during an accident, and could trap a water solid volume between the valves. The piping is insulated; which precludes a significant thermal transient. This is evaluated in Calculation ENG-ME-299.
Chill Water (CRDM Shroud Cooling)	NSR	The CRDM supply and return piping is automatically isolated from the Cooling Water piping inside of containment on the SI signal. Fluid could be trapped in this piping; however, a relief valve provides protection for the piping. This line is not required for post-accident mitigation. If the line were to rupture due to the relief valve failing to function, it would not affect post accident mitigation. In addition, if an isolation valve(s) from the Cooling Water System then failed open (single active failure), only one train of Fan Cooler Units would be effected. The other train would provide sufficient heat removal capability for accident mitigation. Similar to any other leak in the CL System during accident mitigation, the leak would be isolated to prevent sump water dilution and maintain containment integrity.
Letdown	SR	The Letdown Line (upstream of the orifice isolation valves) is normally in service, and not required for post-accident mitigation. This line's normal service temperature is greater than the post-accident temperature; thus, it would not be adversely affected by the containment temperature transient.
Excess Letdown	SR	The Excess Letdown Heat Exchanger and associated piping is not required for accident mitigation. Isolation of the heat exchanger could result in overpressurization of a tube. If a tube were to fail, there would be communication between the CVCS piping (between the two Control Valves which isolate the Heat Exchanger) and the Component Cooling System inside containment. A relief valve is provided to protect this portion of the CC System inside of Containment. If the relief valve failed to close, after opening, the isolation valves and the higher pressure in the CC system outside of containment would prevent containment leakage.

TABLE 2 (continued)

RCS Vents and Drains	SR	With the exception of the head vent piping, these piping sections are not required for accident mitigation. Concern for these valves pertains to normal operation. Several of these valves are operated during an outage, and the sequencing is not controlled to preclude trapping water between the valves. For valves located far enough away from the RCS that pressure change is only a function of ambient temperature change to the containment ambient temperature during normal operation. This was evaluated and determined that the piping would not be overpressurized. For valves which are located close to the RCS Piping, heat can be transferred from the RCS to the volume between the two isolation valves. This could result in a much more severe temperature and pressure transient. Note that this is an economic concern and not a safety issue. For the lines which could be potentially affected, procedures have been revised to specifically sequence valve operations to preclude trapping water between the two valves.

SR/NSR refers to "Safety Related" or "Non-Safety Related"

Conclusion

Based on the review summarized in the above table, there are no piping system inside of containment which could be subjected to thermally induced overpressurization during normal or post-accident operation which could adversely effect post-accident mitigation.

TABLE 3
Safety Related Piping Outside of Containment

SYSTEM	EVALUATION
Auxiliary Feedwater	Vented to Steam Generators. During isolation of a faulted SG, water could be trapped in the piping between the discharge check valve and the MOV used to isolate the AF Pump. Evaluation (Calculation ENG-ME-299) indicates that the piping is capable of withstanding the postulated thermal induced pressure increase.
Component Cooling	In Service. Two different areas of the system are reviewed. (1) With Auto isolation on SI signal, the downstream piping is vented to the Surge Tank through Check Valves. (2) Water could be trapped in the normally isolated cross-connect piping at the pump discharge. This piping is not used for post accident mitigation.
Cooling Water	In Service. With Headers Split on SI, water could be trapped between header isolation valves in Screenhouse or Auxiliary Building. The isolation valves for these portions of the system are large butterfly valves in the Cooling Water System. Due to the valve size and service duty (river water), it is reasonably concluded that some valve leakage would be expected. This valve leakage would preclude potential thermally induced over-pressurization.
Containment Spray	After injection operations, the CS piping near the pump is isolated. Relief valves provide overpressure protection for these sections of piping.
Residual Heat Removal	Piping between the Sump isolation valves is drained prior to unit heatup to preclude MOV pressure locking. RHR Cooldown line is in an area furnished with safety related unit coolers which maintains the ambient temperature. The RHR Cooldown line is not required for post-accident mitigation.
Safety Injection	Vented to RCS or RWST.
Volume Control	Vented to RCS or VCT.
Chill Water	Vented to Air Separator.

Conclusion

Based on the review summarized in the above table, there are no safety related systems outside of containment which could be subjected to thermally induced overpressurization during configurations or operation which could adversely effect post-accident mitigation.