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Point Beach Nuclear Plant
6610 Nuclear Road
Two Rivers, WI 54241

NPL 2000-0451

GL 96-06

October 12, 2000

Document Control Desk
U. S. NUCLEAR REGULATORY COMMISSION
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Ladies/Gentlemen:

DOCKETS 50-266 AND 50-301
REPLY TO REQUEST FOR ADDITIONAL INFORMATION TO
GENERIC LETTER 96-06, "ASSURANCE OF EQUIPMENT OPERABILITY AND
CONTAINMENT INTEGRITY DURING DESIGN BASIS ACCIDENT CONDITIONS"
POINT BEACH NUCLEAR PLANT, UNITS 1 AND 2;
NRC TAC NOS M96852 AND M96853

The NRC staff issued Generic Letter (GL) 96-06 on September 30, 1996. Wisconsin Electric Power Company (WE), then Licensee for the Point Beach Nuclear Plant (PBNP), provided its assessment of the waterhammer and two-phase flow issues for PBNP in letters dated January 28, June 25, and December 18, 1997, and related submittals dated September 9, September 30, and October 30, 1996. In a letter to WE dated June 25, 1998, the NRC requested additional information to complete their review of WE's GL 96-06 submittals. On September 4, 1998, WE replied to the staff's request for additional information (RAI). At that time, WE deferred responding to some of the items pending completion of the EPRI project associated with water hammer and two-phase flow. Since that effort is continuing, response to the deferred items is still pending.

As committed to in the WE letter dated September 4, 1998, this additional reply updates the responses on the subject. Specifically, PBNP has continued to refine the monitoring and analysis of the service water system as additional concerns have been identified, quantified, and/or resolved. These refinements have resulted in changes in the methods of analysis for two phase flow that were not included in previous responses. The overall intent and operability of all the analyses has remained consistent, so as to ensure the continued ability of the Service Water system and all supported Safety Significant SSCs to perform their design and license basis functions.

Sincerely,

D. Cole
Manager, Site Assessment

Attachment

A072

cc: NRC Regional Administrator
NRC Project Manager
NRC Resident Inspector
PSCW

In a letter to WE dated June 25, 1998, the NRC requested additional information to complete their review of WE's Generic Letter GL 96-06 submittals. On September 4, 1998, WE replied to the staff's request for additional information (RAI). The following are NMC's revisions of the responses to the subject NRC RAI.

RAI Item 2:

For both the waterhammer and two-phase flow analyses, provide the following information:

a. *No Change*

b. Describe and justify all assumptions and input parameters (including those used in any computer codes) such as amplifications due to fluid-structure interaction, cushioning, speed of sound, force reductions, and mesh sizes, and explain why the values selected give conservative results. Also provide justification for omitting any effects that may be relevant to the analysis (e.g., fluid-structure interaction, flow induced vibration, erosion).

Response:

Two-phase Flow:

The following discussion addresses the key parameters and assumptions for the steady state two-phase flow analysis. Containment temperatures for the two-phase analysis are taken from Reference 4. Appropriate margin (1°F for the injection phase of the LOCA and 10°F for the recirculation phase) is added as a measure of conservatism. CFC coils are assumed to have a fouling factor of 0.0001[1]/(hr ft^2 °F)/Btu. This fouling is much less than any field measurement has exhibited. The SW flow through each CFC and the SW exit pressure from each CFC is calculated in the WATER program. In the WATER model, adjustments have been made in flow resistances and pressure outputs to account for temperature-dependent changes in the properties of water. Each operating SW pump is assumed to be at the minimum allowable performance level. This results in under-prediction of SW pressure, thereby decreasing the calculated margin between predicted conditions and saturation conditions.

Results of the RELAP analysis [Ref 5] show no significant cyclical variations in pressure or flows about the steady-state values. This indicates that flow-induced vibration due to periodic bubble formation and collapse is insignificant, if not completely absent.

The current analysis demonstrates the preservation of steady state single phase flow at the outlet of the CFCs during the Design Basis Accident (DBA), which is a large break LOCA. The

[1] Although this value is used in the current analysis, PBNP recognizes that it is conservatively low to the point that it may be overly restrictive. Future analyses may use less restrictive values consistent with good engineering practice and the inherent safety significance. Further discussion of this potential is contained in the response to Item 3.

potential for two-phase flow does not exist in the absence of such an event. Therefore, erosion effects, which are typically long-term, need not be considered for this analysis.

c. Provide a detailed description of the "worst case" scenarios for waterhammer and two-phase flow, taking into consideration the complete range of event possibilities, system configurations, and parameters. For example, all waterhammer types and water slug scenarios should be considered, as well as temperatures, pressures, flow rates, load combinations, and potential component failures. Additional considerations for two-phase flow include:

- *the effects of void fraction on flow balance and heat transfer;*
- *the consequences of steam formation, transport, and accumulation;*
- *cavitation, resonance, and fatigue effects; and*
- *erosion considerations*

Response:

Two-phase Flow:

The SW System consists of 6 parallel pumps feeding a continuous flow ring header. Each of the two Safety Injection (SI) trains is associated with three of the pumps. Isolation valves in this header create the potential (for a limited time period as dictated by Technical Specifications) to interrupt the normal supply flow path and cause some components to be fed through a more flow-resistant supply path. In the unlimited operating condition there is no interruption of flow in the continuous flow ring header. Isolations in the continuous flow ring header are compensated for by imposed requirements on system configuration (including the number of operable pumps) and the relaxation of the single failure criterion.

Both the injection phase and the recirculation phase are analyzed for each configuration of the ring header. These configurations include all combinations of allowable SW continuous flow header isolations (including no isolation), as well as varying numbers of operating SW pumps. CFC heat loads are determined by the post-LOCA containment response curves. The heat removal capability and the potential for two-phase flow at the CFC outlets is evaluated in each scenario. The CFCs are assumed to have less than the minimum expected fouling when being analyzed for two-phase flow and the maximum expected fouling when being analyzed for adequate heat removal. All scenarios are analyzed using the maximum allowable SW inlet temperature.

The recirculation phase includes higher Component Cooling Water (CCW) flow but also includes more isolation of branch headers and lower containment temperatures than the injection phase. The results of the analyses of these configurations can be found in References 6 and 7.

The most limiting scenario with respect to two-phase flow at the CFC outlets occurs during the injection phase. Three SW pumps are assumed to be operating because a failure of one Safety Injection Train has been postulated, thus disabling the other three pumps. Maximum flow is assumed to all of the nonessential branch supply headers that lack redundant automatic isolation capability [2]. The continuous flow ring header is not interrupted.

In this limiting scenario, it was determined that there would be no two-phase flow at the SW exit of the CFCs (considered the most limiting location due to the combination of highest temperature and lowest pressure), and that there would be potential for two-phase flow in the CFC piping downstream of the outlet throttle valves. However, each CFC would remove the design basis heat load.

The potential for two phase flow to occur in partially occluded tubes was also evaluated. Periodic thermographic surveillance of the CFCs have shown that individual tubes exhibit degraded flow consistent with partial blockage (believed to be due to debris generated during periodic chemical treatments to control Zebra Mussel infestation). The reduced flow rate through these individual tubes could cause sufficient heat to be absorbed to result in two phase flow prior to their exits.

A bounding analysis was performed that determined how many flow degraded tubes could be tolerated before their combined heat input would raise the outlet enthalpy of the total coil flow stream to saturation and potentially cause steam binding of the entire coil. This analysis is now used as the basis for the acceptance criteria when performing the periodic monitoring.

New CFCs that will replace the existing units incorporate interpass mixing. Since debris large enough to obstruct a tube will be caught in the first pass, it is expected that this feature will reduce sensitivity to flow degradation due to partial blockage. However, since only the last passes are visible, it will also preclude effective monitoring for flow degradation by use of thermographic imaging. Accordingly, an analysis of the pending CFC replacements has been completed that accounts for the effects of both inter-pass mixing and a number of flow degraded tubes that exceeds historical observations.

The effects of two phase flow at the downstream throttle valves on the steady state flow and heat transfer were also taken into account and found acceptable by an analysis using the TREMOLO code [Ref. 11]. The consequences of steam formation, transport, and accumulation in the steady-state two-phase flow are deemed to be bounded by any transient waterhammer loads. Cavitation, resonance, fatigue effects, and erosion considerations were reviewed using Reference 10 and are not included in the analysis because of the short time frame that the piping would be exposed to the two-phase flow potential, as well as the absence of cyclical variations in the pressures and flows during this period.

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[2] The failure to isolate all non-essential branches having automatic isolation capability is due to a remaining weakness in the current plant configuration. Following the Unit 2 outage in the fall of 2000, modifications to the isolation logic for these branches are expected to be complete and all branch supply headers having automatic isolation capability will be analyzed as isolated.

d. Confirm that the analyses included a complete failure modes and effects analysis (FMEA) for all components (including electrical and pneumatic failures) that could impact performance of the cooling water system and confirm that the FMEA is documented and available for review, or explain why a complete and fully documented FMEA was not performed.

Response:

Two-phase Flow:

A complete FMEA was not performed. However, the failure of a complete electrical train of safety injection, which is the basis for LOCA analysis, was assumed. Two parameters affect the potential for steady state two-phase flow in the SW System. The first is the amount of SW flow through the CFCs. The second is the amount of heat input from containment atmosphere to Service Water. The potential impact from two-phase flow increases with increased heat transfer. Any degradation in the CFC performance from pristine conditions will decrease the potential impact from two-phase flow. The amount of SW flow is dependent on the CFC piping configuration (including throttle valve position), the supply header pressure and the return header pressure. The supply header pressure is dependent on the overall system resistance and the number of operating SW pumps. The only active components required to operate in order to reduce the potential impact from two phase flow for this limiting scenario are the SW pumps and the branch header isolation valves which divert flow from the CFCs. In the injection phase, a single failure of an entire SI train is assumed so that only three SW pumps are assumed to run and one nonessential branch header does not isolate[3]. There is one branch header per train that currently does not have redundant isolation valves. In the recirculation phase, a single failure of an entire SI train is assumed so that only three SW pumps are assumed to run; and all nonessential loads (except those necessary to support operation of the non-affected unit) are isolated as required by procedural verifications.

To ensure conservatism, the failure of one active component, one of the two CFC outlet MOVs, to open, was not assumed. Each of these valves is actuated by one SI train. Failure of one SI train would normally prevent the valve actuated by that train from opening. Failure of this valve to open increases CFC outlet pressure and thus provides more margin before two-phase flow occurs in the CFCs and therefore was not assumed in the analysis.

[3] This failure to isolate is due to a remaining weakness in the current plant configuration. Following the Unit 2 outage in the fall of 2000, modifications to the isolation logic are expected to be complete and all branch supply headers having automatic isolation capability will be analyzed as isolated.

e. Explain and justify all uses of "engineering judgment".

Response:

Two-phase Flow:

Any piping interactions are assumed to be bounded by the waterhammer analyses. The location (outside containment and downstream of the CFC outlet throttle valves) and stable pressure and flow profile (predicted by RELAP) are indicative of more stable conditions than the dynamic effects of waterhammer.

RAI Item 3:

Determine the uncertainty in the waterhammer and two-phase flow analyses, explain how the uncertainty was determined, and how it was accounted for in the analyses to assure conservative results.

Response:

Two-phase Flow:

We have addressed uncertainties in the two-phase flow analysis by a combination of conservative assumptions and analytical techniques. Individual uncertainties in the flow resistance of major flowpaths (CFCs, EDG HXs, and CCW HXs), pump performance, procedural setting of flows, instrumentation associated with surveillances and system alignments, SW inlet temperature, CFC fouling, etc. have been evaluated and statistically combined to arrive at the overall uncertainty for each parameter of interest (primarily the temperature and pressure at the CFC outlets). A large uncertainty (±30%) is assumed for those flowpaths which have not been validated at the time of the analysis (Reference 12). The resulting uncertainty is added to the nominal value for any parameter to establish the acceptance criteria.

The analyzed configurations include simultaneous system flushes, strainer backwashes, system leakage, and maximized flow rates in any variable nonessential loads that may not automatically isolate. Each of these factors tend to reduce the pressure available at the outlet of the CFCs.

The CFC fouling factor (0.0001 hr-ft^2-°F/Btu) currently used in the two-phase flow analysis is based on the minimum, most conservative value that can be shown to analytically support operability of the system. It has historically not been based on the measured values of fouling or standard engineering practices. Repeated performance testing of the PBNP CFCs has shown a very consistent total (combined water and air/steam side) fouling factor of 0.001 ±0.0003, despite attempts to chemically clean the inside of the tubes and one attempt to clean the outside of the CFC coils.

Published industry recommended design values for water side fouling of water cooled heat exchangers are 0.0005 for distilled water, 0.001 for treated boiler feed, city, or well water, and a minimum of 0.002 for muddy or silty water (Reference 13).

It is recognized that historical test data and published industry recommended design values may not be appropriate for newly installed heat exchangers that have not yet developed a fouling layer. Accordingly, pending sufficient demonstration of having established such a fouling layer by testing and/or an appropriate passage of time, the replacement CFCs will continue to be analyzed using a total fouling factor of 0.0001. However, it is expected that this very conservative figure will be relaxed in the future to as high as 0.0005 based on *in-situ* performance testing results. Use of this analytical value will retain significant safety margin between the expected observed value of 0.001 while removing unnecessarily and unjustifiably restrictive criteria.

A major conservatism included in the CFC analytical performance acceptance criteria is the condition that no two-phase flow may exist at the exit of each CFC. The following qualitative discussion addresses the implications and conservatism inherent in this condition.

Each CFC is composed of two equal columns of four coils each and the necessary piping connections to combine the effluent from each of the eight coils into one flow stream. Each coil is assumed to remove 1/8th of the total heat load of the CFC. Each coil in the column has a different exit elevation and a corresponding SW exit pressure. For simplicity, the current analysis treats the entire CFC as if it had the same outlet pressure as the top coil (i.e. the coil with the lowest outlet pressure). In reality, two-phase flow at the exit of the top coil does not necessarily indicate two-phase flow at the exit of the CFC. The considerations listed below further diminish the potential for two-phase flow and mitigate any potential effects at the exit of the CFC in the current analysis.

1. At the analyzed SW inlet temperature and the predicted SW flow and CFC outlet pressure, the heat removal rate required to initiate two-phase flow significantly exceeds the design required heat removal rate. Therefore, the per-coil heat removal rate would also significantly exceed 1/8th of the CFC design heat removal rate and potential reductions in heat removal from some coils experiencing two-phase flow would be offset by the higher per-coil heat removal and thus attain the design heat removal (in the same CFC).

2. Two phase flow in the upper coils would have a tendency to reduce flow to those coils The reduced flow to the higher elevation coil(s) would be redirected to the lower elevation coils (in the same CFC), thereby further increasing heat transfer in the lower elevation coils above the increased per-coil heat removal rate discussed above. This phenomenon will also decrease the outlet temperatures of the SW flow in the coils with increased flow.

3. The potential for SW two-phase flow in the CFCs decreases rapidly with time in the LOCA analysis because of decreasing containment temperature. Within ten minutes of the break, the containment temperature drops approximately 10°F and the potential for two-phase flow drops substantially. There is approximately 7°F more subcooling ten minutes after the break than at the peak temperature. The contribution to containment cooling from the CFCs during

the early part of the injection phase is a small fraction of the total heat removal afforded by latent containment heat sinks and containment spray, so that even a temporary decrease in CFC performance due to partial steam voiding, if it were to occur, would not significantly affect the containment pressure and temperature profiles.

RAI Item 6:

Describe in detail any plant modification or procedure changes that have been made or are planned to be made to resolve the waterhammer and two-phase flow issues.

Response:

Two-phase Flow:

Several plant modifications have been implemented (and more are in progress) to enhance the reliability of automatic isolation of non-essential SW loads during limiting accidents. These modifications will ensure that upon receipt of any SI signal, Spent Fuel Pool cooling, RadWaste system, Water Treatment System, and PAB auxiliary loads will isolate automatically using redundant and independent isolation valves. This will eliminate the potential to divert SW due to the limiting failure of a single train of SI to actuate. These modifications have been more completely described in the PBNP response to the NRC Request for Additional Information pertaining to PBNP Technical Specification Change Submittal 206 dated 12/21/1999. As these modifications become operable, credit is being taken for their capability to isolate in subsequent SW analyses. Pending acceptance of TSCR 206, administrative controls comparable to the proposed Technical Specification changes have been implemented to ensure that these valves will remain operable and capable of fulfilling their design functions.

References

1. WE letter to NRC, September 30,1996 letter, VPNPD-96-080
2. FAI/96-75, "Evaluation of Possible Waterhammer Loads in the Service Water System for DBA Conditions," dated September, 1996
3. S&L Calculation, M-09334-186.SW, "Operability Assessment for Transient Conditions in Point Beach Nuclear Plant Service Water System During a Coincidental Loss of Coolant Accident and Loss of Offsite Power," dated September 9, 1996
4. Westinghouse, Calculation, NSD-SAE-ESI-97-302, "Wisconsin Electric Power Company, Point Beach Units 1 & 2, Containment Analysis Assuming Reduced Fan Cooler Performance," transmitted May 29,1997.
5. S&L Calculation, M-09334-195.SW, "RELAP5 Modeling of Component Fan Cooler Service Water Return Lines," dated, September 27,1996
6. WE Calculation, 97-0054, Rev 4, "Service Water System, Injection Phase," dated 7/13/2000
7. WE Calculation, 97-0126, Rev 4, "Service Water System, Recirculation Phase," dated 7/13/2000
8. FAI/97-60 Rev 1, "Point Beach Containment Fan Cooler Analysis in Response to NRC Generic Letter 96-06," dated August 8, 1997
9. WE letter to NRC, September 9,1996 letter, VPNPD-96-065
10. NUREG/CR - 6031, "Cavitation Guide for Control Valves," J. Paul Tullis, dated April 1993
11. FAI/98-55, "Methodology for Determining Adequate Containment Fan Cooler (CFC) Flow," Rev 1, dated 6/15/98
12. WE Calculation, 99-0032, Rev 0 including Addendum A, "Application of Uncertainty to Hydraulic Modeling of the Service Water System," dated 7/13/2000
13. Standards of the Tubular Heat Exchanger Manufacturer's Association, Eighth edition