Wisconsin Electric
POWER COMPANY

Point Beach Nuclear Plant
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NPL 98-0718

10 CFR 50.4

September 4, 1998

U.S. NUCLEAR REGULATORY COMMISSION
Document Control Desk
Mail Station P1-137
Washington, DC 20555

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 (WEPCO) provided its assessment of the waterhammer and two-phase flow issues for the Point Beach Nuclear Plant (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 WEPCO dated June 25, 1998, the NRC requested additional information to complete their review of WEPCO's GL 96-06 submittals. Included as Attachment A to this letter is WEPCO's response to the NRC Request for Additional Information (RAI). As suggested in the RAI, our replies make significant reference to our previous submittals which address the staff questions.

The RAI is concerned with follow-up information on GL 96-06 issues of waterhammer and two-phase flow. To a large extent, our attached reply provides clarification and amplification of previously-transmitted information and supplements our previous responses with new information manifest in recent, ongoing evaluations. It should be noted that WEPCO is participating in the EPRI/Industry project to develop a utility guidance document to address industry wide NRC RAIs on waterhammer issues. The end result of this project, the utility guidance document, is scheduled to be issued by July 15, 1999. As indicated in Attachment A, WEPCO will defer response on some of the RAIs until after completion of the EPRI project and issuance of the utility guidance document.

Please contact us if you have further questions on this issue.

Sincerely,

Vito A. Kaminskas

Vito A. Kaminskas
Manager,
Regulatory Services & Licensing

Subscribed and sworn before me on
this 4th day of September 1998.

Christine K. Pozorski
Notary Public, State of Wisconsin
My Commission expires ~~November 11, 2001.~~ August 25, 2002

Attachments

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

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The following is WEPCO's response to the subject NRC RAI.

RAI Item 1:

If a methodology other than that discussed in NUREG/CR-5220, "Diagnosis of Condensation-Induced Waterhammer," was used in evaluating the effects of waterhammer, describe this methodology in detail. Also, explain why this methodology is applicable and gives conservative results (typically accomplished through rigorous plant-specific modeling, testing, and analysis).

Response:

Waterhammer:
A different methodology than that discussed in NUREG/CR-5220 was used. NUREG/CR-5220 provides reference material and diagnostic procedures concerning condensation-induced waterhammer in nuclear power plants. Five event-classes of condensation-induced waterhammer, which have similar phenomena and levels of damage, are defined in NUREG/CR-5220. Additionally, NUREG/CR-5220 provides case studies to illustrate the diagnostic methods and to document past experience. The majority of the examples and case studies presented in NUREG/CR-5220 deal with high temperature and high pressure systems. The fourth case study presented in NUREG/CR-5220 has some similarities to the Service Water (SW) event considered in GL 96-06, except that the temperature considered in the scoping study in NUREG/CR-5220 is approximately 25% higher and the refill flow rate is much higher than those in the CFC circuits. It should be noted that no pressure boundary damage was reported for this case study.

The following two paragraphs describe the alternative methodologies used in evaluating the effects of waterhammer.

Reference 2 describes a series of scaled waterhammer experiments performed over a range of conditions typical of the Point Beach Nuclear Plant (PBNP) SW system during the transient considered in GL 96-06. The experiment apparatus was constructed based on Froude number considerations and investigated the influence of void formation and steam condensation during the transient conditions. The results of these experiments demonstrate that no significant waterhammer transients were observed even with significant voiding and that peak pressures occurred during refill of the system. Additionally, the peak pressures were substantially less than those that would be calculated using standard waterhammer methodology.

Reference 3, Appendix A calculates Froude numbers for four pre-pump startup cases. Cases A1, A3, and A4 are based upon the containment post LOCA temperatures and structural heat transfer coefficients provided in the PBNP FSAR and clean CFC tubes, while varying the pump coastdown times. Case A2 is based upon the containment post LOCA temperatures and structural heat transfer coefficients 15% less than those provided in the PBNP FSAR, a fouling factor of 0.001 in the CFC tubes, and a pump coastdown time of 10 seconds. For Case A1, the flow velocities correspond to a Froude number of 0.91 to 0.78. The test results presented in Reference 2 show that condensation-induced waterhammer will not occur, for the PBNP configuration , at such a high Froude number. For Case A2, the flow velocities correspond to a Froude number of 0.48 to 0.3. These are still higher than the Froude number at which condensation-induced waterhammer was detected in the Reference 2 test. The results of Cases A3 and A4 show that the Froude number is insensitive to the pump coastdown time, as long as the flow stops before the containment temperature reaches its peak value.

This information has been presented in the September 9, 1996 submittal to the NRC, VPNPD-96-065. [Ref. 11] Any further information will be presented after completion of the EPRI project.

RAI Item 2:

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

a. Identify any computer codes that were used in the waterhammer and two-phase flow analyses and describe the methods used to benchmark the codes for the specific loading conditions involved.

Response:

Waterhammer:
Three computer programs were used in the waterhammer operability analysis; a FORTRAN code written specifically for this application to determine steam generation rate, HYTRAN to determine force time histories from the dynamic transient, and PIPSYS to evaluate piping stress. HYTRAN and PIPSYS are Sargent & Lundy (S&L) computer programs approved for general use on safety-related applications. The FORTRAN program was developed specifically for this application and was validated in accordance with the S&L QA program requirements for single use computer programs. TREMELO, which was used to predict force time histories for the design basis analysis has been benchmarked in accordance with FAI QA program by the following methods; comparison with experimental results, comparison with bounding hand calculation, and comparison with a steady state text book sample problem (subroutine XFORCE). Reference 10 discusses this validation in more detail.

Two-phase Flow:
Three computer programs, WATER, AIRCOOL, and RELAP5, were identified and the validation was discussed in Reference 1. Since that time we have further refined our analytic techniques and have used the TREMELO program developed by Fauske & Associates (FAI) to validate the methodology [Ref. 6], [Ref. 7], [Ref. 8], [Ref. 9], and. [Ref. 13],. The WATER model, produced by Municipal Hydraulics Inc., which predicts steady-state single-phase flow

distribution, has been shown to consistently predict CFC flows with respect to system pressure when the monthly checks are performed. AIRCOOL, which predicts CFC performance, was produced and benchmarked by Holtec International Corporation. RELAP5, used to study two-phase flow hydraulic effects, is the NRC's state-of-the-art transient flow and accident analysis program. TREMELO, has been benchmarked in accordance with FAI QA program by the following methods; comparison with experimental results, comparison with bounding hand calculation, and comparison with a steady state text book sample problem (subroutine XFORCE). Reference 10 discusses this validation in more detail.

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, erosic

Response:

Waterhammer:
This information will be presented after completion of the EPRI project.

Two-phase Flow:
The following discussion addresses the key parameters and assumptions for two-phase flow. Containment temperatures for the two-phase analysis were taken from Reference 4. Appropriate margin, (3°F for the injection phase of the LOCA and 10°F for the recirculation phase) are added as a measure of conservatism. CFC coils are assumed to have a fouling factor of 0.0001 BTU/Hr - ft^2. This fouling is much less than any field measurement has exhibited. 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. Two-phase flow potentially occurs only during a Design Basis Accident (DBA) event and then only for a period of hours. Therefore, erosion effects, which are typically long-term, can be considered insignificant 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:

Waterhammer:
Waterhammers were considered during both phases of the transient, the pre-pump start phase and the refill phase. Reference 2 indicated no evidence of condensate-induced waterhammer for the Froude numbers predicted in the pre-pump start phase. The following bounding assumptions are made in determining waterhammer effects in the refill phase; bounding the maximum flow rate to the coolers by assuming half of the total SW flow will go to the upper CFCs, neglecting the flow resistance through the CFC outlet throttle valves, and assuming zero psia backpressure throughout the transient. All of these assumptions tend to maximize the impact forces of the waterhammer during the refill phase. Any further information, such as a discussion of various types of waterhammer and water slug scenarios identified in NUREG/CR-5220, will be presented after completion of the EPRI project.

Two-phase Flow:
The SW System consists of 6 parallel pumps feeding a continuous flow ring header. Each of the plants two Safety Injection (SI) trains is associated with three pumps. There are isolation valves in this header so that it has the potential (for a limited time period) to have the normal supply flow path interrupted and as a result causing some components to be fed through a more flow-resistant supply path. In the unlimited operating condition there is no interruption of flow in this header. The SW System is currently analyzed for all bounding scenarios and two-phase flow downstream of the CFCs is considered in each one. Both injection phase and recirculation phase are analyzed for each configuration. CFC heat loads are determined by the post-LOCA containment response curves. The recirculation phase includes higher Component Cooling Water (CCW) flow but also includes more isolation of branch headers and reduced containment temperatures than the injection phase. These configurations include all combinations of allowable SW continuous flow header isolations (including no isolation), as well as differing numbers of operating SW pumps. The scenarios are further analyzed with the CFC outlet throttle valves at both extremes of their allowable range. The results of the analyses of these configurations can be found in References 6, 7, 8, and 9. The worst configurations from a CFC perspective were determined from these analyses and are detailed below.

Scenario #1: This is the most limiting scenario with respect to CFC heat removal. It occurs during the injection phase and includes an isolation of one main flow path strainer so that all flow is directed through the other strainer. Five SW pumps are assumed to be operating; however the non-accident unit CFCs are analyzed in the maximum flow position. This includes the outlet accident-flow MOVs being opened (for testing or maintenance). In addition, the CFC throttle valves are assumed to be at the low flow throttle position. No branch headers are assumed to be isolated, the CFCs are at the maximum allowable fouling, and the SW temperature is at the maximum design temperature. This condition requires the plant to be in a limiting condition for operation (LCO) for 72 hours.

Scenario #2: This is the most limiting scenario with respect to two-phase flow in the CFC return piping. It 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. In addition, the CFC throttle valves are assumed to be at the high flow throttle position. Two of the five branch headers are assumed to be isolated, the CFCs are at the minimum allowable fouling, and the SW temperature is at the maximum design temperature. This scenario results in the lowest system pressure and the lowest flow resistance in the CFC piping which minimizes the pressure in the CFC downstream piping. This condition can occur when the plant has not entered an LCO.

In both scenarios it was determined that there was no two-phase flow in the CFCs and that there would be two-phase flow in the CFC piping downstream of the outlet throttle valve, but each CFC was still able to remove the design basis heat load.

The effects of void fraction on flow balance and heat transfer on two-phase flow were taken into account in the methodology for determining adequate steady-state two-phase flow by the confirming TREMELO analysis for that methodology. [Ref. 13] 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 12 and are not included in the analysis because of the short time frame (several hours) 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.

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:

<u>Waterhammer:</u>
A complete FMEA was not performed. The waterhammer forces are dependent on refill rate. Refill rate is dependent on the number of SW pumps running and the amount of competing loads. The system design is such that operation of any relevant active component, i.e. pump starting or valve repositioning, tends to maximize flow to the CFCs and therefore refill rate. Because waterhammer loads tend to increase with increasing refill rates, the assumption of no failures is conservative. Any further information will be presented after completion of the EPRI project.

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 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 the SW flow. The degree of two-phase flow increases with increased heat transfer. Any degradation in the CFC performance will lessen the impact of two-phase flow. The amount of SW flow is dependent on the CFC piping configuration (including 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 SW pumps running. The only active components required to operate to reduce the effects of two phase flow for this limiting scenario are the SW pumps and the branch header isolation valves which divert flow from the CFCs. A single failure of an entire SI train is assumed so that only three SW pumps are assumed to run and three branch header isolation valves are assumed to remain open. The failure of an additional active component, one of the two CFC outlet MOVs, to open, increases CFC outlet pressure and thus provides more margin before two-phase flow occurs in the CFCs. Its failure was not assumed.

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

Response:

Waterhammer:
This information will be presented after completion of the EPRI project.

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:

Waterhammer:
The waterhammer analysis was performed using conservative assumptions (See RAI Item 2.c). Any further information will be presented after completion of the EPRI project.

<u>Two-phase Flow</u>:
WEPCO addressed uncertainties in the two-phase flow analysis by a combination of conservative assumptions and analytical techniques which represented mutually exclusive plant conditions. In addition, the following uncertainties have been accounted for in the analyses: IST to ensure pump performance is in accordance with the analysis includes both temperature and flow uncertainties, SW flow to the CCW heat exchangers during the recirculation phase of the LOCA includes instrument uncertainty, the SW inlet temperature includes instrument uncertainty when verifying that the system is operating within its design basis.

The CFC flow paths have two points of variable resistance in them. Each CFC has its own outlet throttle valve which is verified each month to be within the allowable throttle positions determined by the analysis. This position is checked by setting up the proper flow configuration and verifying the flow through each CFC as a function of system pressure. The valve is typically set in the middle of the allowable band. This throttle position accounts for the instrument uncertainties so that the allowable operational band in the field is less than the band allowed by analysis. In addition, the assumed resistance in the analysis is dependent on the parameter being analyzed. Each plant configuration is analyzed twice for CFC considerations. When analyzing the CFCs for minimum heat input, the highest fouling factor and the highest throttle valve position is assumed. Even though the valve is physically in the same position, when analyzing for two-phase flow the valve is assumed to be in its least resistant position and the same CFC is assumed to be at its lowest fouling factor.

The CFCs also have two parallel Motor-Operated Valves (MOVs) that, when open, increase flow through all CFCs simultaneously. Each one of these valves is powered by one SI train and open on an SI signal. In the scenario discussed, one SI train was assumed to fail (single failure). For conservatism, it was assumed that both MOVs would open even though the failure of one SI train would not only prevent the three SW pumps from starting but would also prevent one of the MOVs from opening. This condition could be entered if one unit only was in a SW LCO.

RAI Item 4:

Confirm that the waterhammer and two-phase flow loading conditions do not exceed any design specifications or recommended service conditions for the piping system and components , including those stated by equipment vendors; and confirm that the system will continue to perform its design-basis functions as assumed in the safety analysis report for the facility and that the containment isolation valves will remain operable.

Response:

Waterhammer:
Per Reference 11, the SW system was determined to be operable. The subsequent analyses tabulated in the response to Question 6 were performed to determine the acceptability of the SW system with respect to the allowable design loads of the piping using dynamic loads generated by TREMELO. The resultant modifications will, when complete, assure compliance with design allowable loads in the FSAR. Any further information will be presented after completion of the EPRI project.

Two-phase Flow:
It is our conclusion that any piping loads experienced because of the steady state two phase flow are much less than the bounding, transient loads. In addition, because the potential two phase flow occurs downstream of the CFCs and outside containment, a breach of this piping would not affect flow to the CFCs and would not represent a potential contact point between the containment atmosphere and the SW System and hence a potential release path for radioactivity The design basis for the CFCs is that they each be capable of removing 37.5 x 10^6 BTU/hr from the containment atmosphere under containment design conditions and that there is no two-phase flow in the CFCs. These conditions are still met.

RAI Item 5:

Provide a simplified diagram of the system, showing major components, active components, relative elevations, lengths of piping runs, and the location of any orifices and flow restrictions.

Response:

These figures are provided at the end of this attachment.

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:

Waterhammer:
The analyses referred to in the response to Question 4, their resultant piping support modifications, and the installation status of those modifications is tabulated below.

Unit 1 Inside Containment			**Unit 2 Inside Containment**		
Analysis	**Mod#**	**Installed**	**Analysis**	**Mod#**	**Installed**
WE-100121 Rev 1	96-064A	Yes	WE-200090 Rev 1	96-064C	No
WE-100123 Rev 1	96-064A	Yes	WE-200091 Rev 1	96-064C	No
WE-100125 Rev 1	96-064A	Yes	WE-200092 Rev 1	96-064C	No
WE-100126 Rev 1	96-064A	Yes	WE-200093 Rev 1	96-064C	No
WE-100129 Rev 1	96-064A	Yes	WE-200094 Rev 1	96-064C	No
WE-100131 Rev 1	96-064A	Yes	WE-200095 Rev 1	96-064C	No
WE-100132 Rev 1	96-064A	Yes	WE-200096 Rev 1	96-064C	No
			WE-200097 Rev 1	96-064C	No

Unit 1 Outside Containment			**Unit 2 Outside Containment**		
Analysis	**Mod#**	**Installed**	**Analysis**	**Mod#**	**Installed**
WE-300035 Rev 1	96-064B	Yes	WE-300044 Rev 1	96-064D	No

Two-phase Flow:
Plant procedure changes have been implemented to assure adequate flow to the CFCs to provide design basis heat removal and adequate pressure to prevent two-phase flow in the CFCs.

- EOP-1.3 was changed to ensure enough SW demands were isolated when going into the recirculation phase of a LOCA,
- OI-70 (operating instructions for the SW system),was changed to ensure that the SW system lineup is maintained in accordance with the existing analysis
- OI-71 (operating instructions for the CCW system), was changed to ensure that the SW system lineup is maintained in accordance with the existing analysis
- PBF-2033 (Unit 2 Turbine Hall Shift Log) was revised to preclude simultaneous timed blowdown from the main system strainers.
- PC-43.3 (Periodic Callup for SW Strainers) was revised to ensure that only one Spent Fuel Pit Heat Exchanger is on-line at any time.

- IT-72 (Service Water Valves [Quarterly]) was revised to ensure that only one Spent Fuel Pit Heat Exchanger is on-line at any time.

- IST IT 007C, (P-32C SW Pump Inservice Testing Criteria) was revised to ensure that pump performance exceeded that used in the analysis.

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, 96-0117, Rev 2, "Service Water Model Runs: Three Pump/Injection Phase," dated July 7, 1998

7. WE Calculation, 95-0119, Rev 3, "Service Water Model Runs: Three Pump/Recirculation Phase," dated July 7, 1998

8. WE Calculation, 97-0054, Rev 2, "Service Water System, Limiting Condition for Operation Injection Phase," dated July 7, 1998

9. WE Calculation, 97-0126, Rev 2, "Service Water System, Limiting Condition for Operation Recirculation Phase," dated July 7, 1998

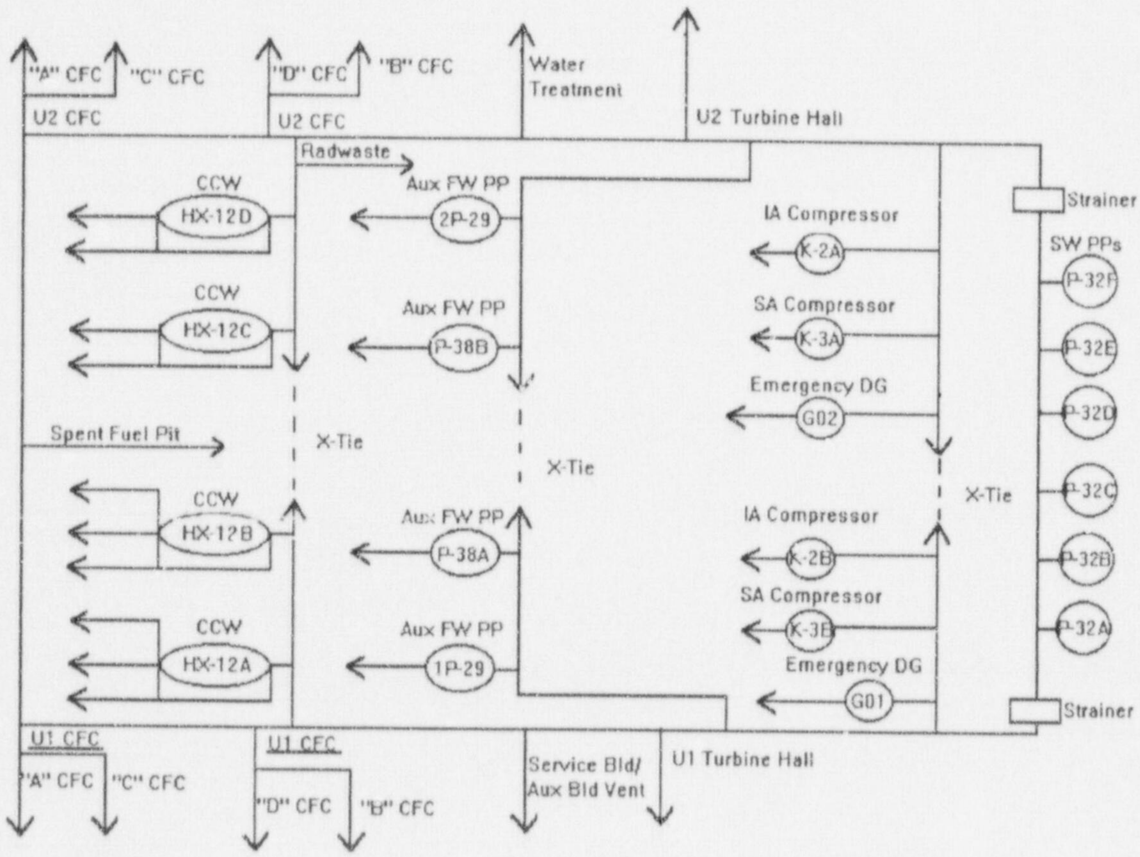
10. FAI/97-60 Rev 1, "Point Beach Containment Fan Cooler Analysis in Response to NRC Generic Letter 96-06," dated August 8, 1997

11. WE letter to NRC, September 9,1996 letter, VPNPD-96-065

12. NUREG/CR - 6031, "Cavitation Guide for Control Valves," J. Paul Tullis, dated April 1993

13. FAI/98-55, "Methodology for Determining Adequate Containment Fan Cooler (CFC) Flow," Rev 1, dated 6/15/98

The following is a simplified schematic of the SW System showing the relative positions of the SW pumps, the CFCs and the branch headers. The "A", "B", "C", and "D" CFCs are denoted on the following pages as 1HX-15A, 1HX-15B, where the prefix "1" is the unit number and the suffix "A" is the CFC identifier.



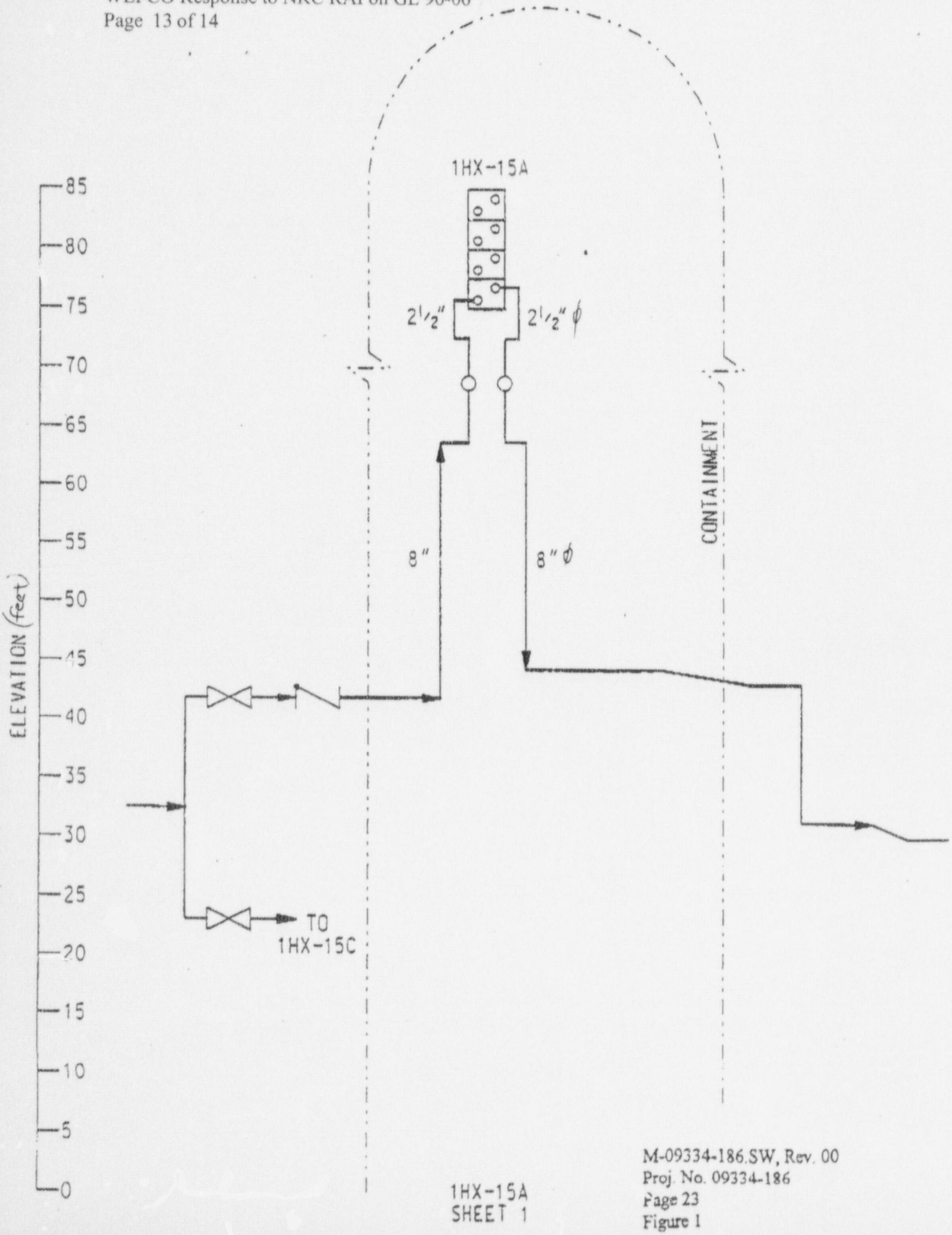


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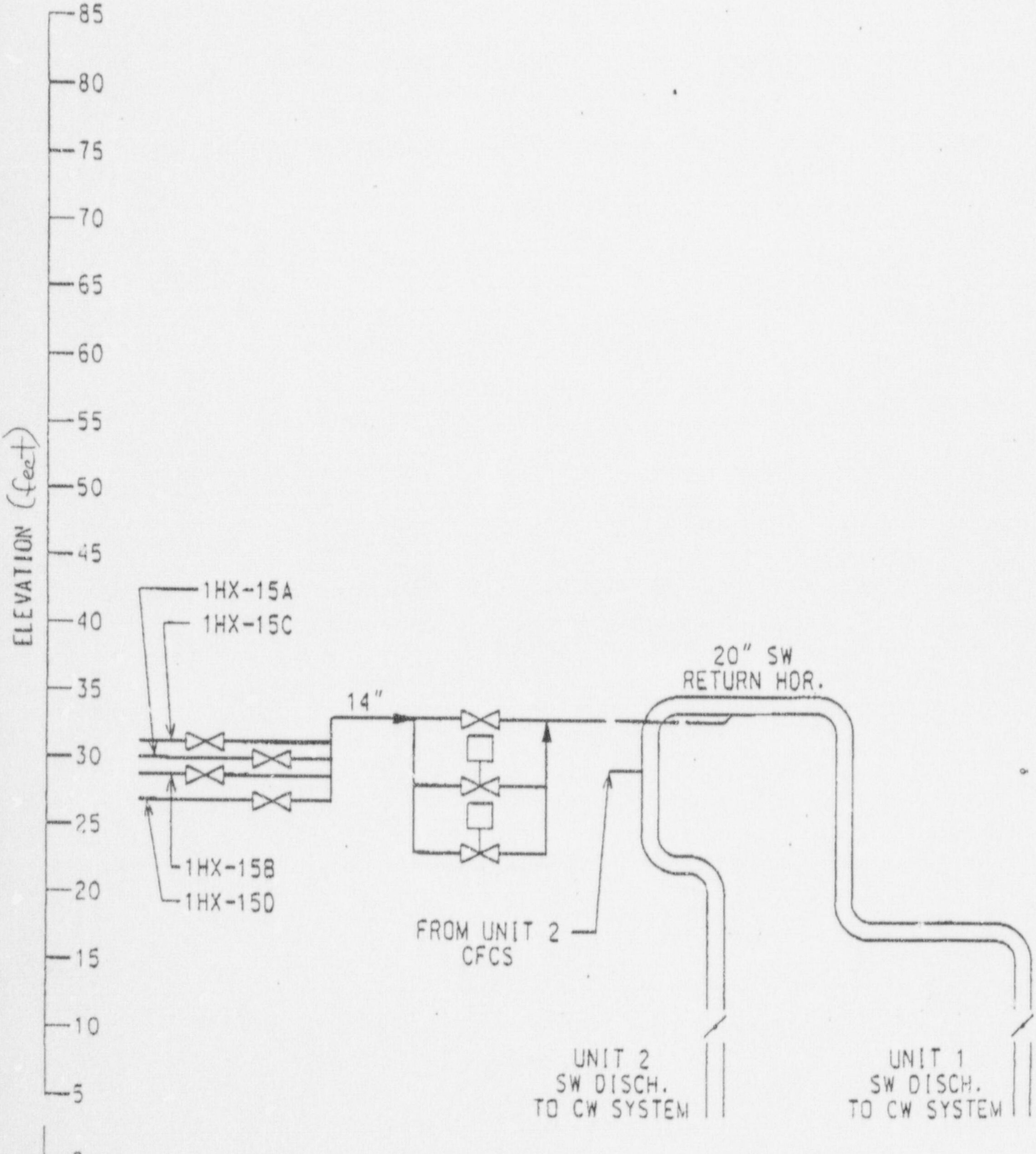
Figure 1

Figure 1



SHEET 5