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SUBJECT: Responds to NRC 981112 ltr re violations noted in insp rept 50-397/98-20.Corrective actions:implemented interim actions to assure that significant pressure surges do not occur in plant fire protection sys.

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WASHINGTON PUBLIC POWER SUPPLY SYSTEM
P.O. Box 968 • Richland, Washington 99352-0968

December 18, 1998
GO2-98-216

Docket No. 50-397

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555

Gentlemen:

Subject: **WNP-2, OPERATING LICENSE NPF-21, RESPONSE TO AN APPARENT VIOLATION IN NRC INSPECTION REPORT NO. 50-397/98-20**

References:

1) Letter dated October 16, 1998, TP Gwynn (NRC) to JV Parrish (SS), "NRC Inspection Report 50-397/98-20 and Notice of Violation"

2) Letter dated November 12, 1998, DW Coleman (SS) to TP Gwynn (NRC), "NRC Inspection Report 98-20, Response to Apparent Violation Extension Request"

The Supply System's response to the apparent violation, discussed in Reference 1 pursuant to the provisions of Section 2.201, Title 10, Code of Federal Regulations, is enclosed. This response is submitted under oath as described in the enclosed affidavit.

The Supply System acknowledges that the issues regarding the failure of the Fire Protection System are important and has chosen to respond by this letter to the apparent violation (EA 98-480) noted in Reference 1. The basis for our acceptance of the apparent violation and mitigating information related to severity level and escalated enforcement is discussed in Attachment A.

As committed to in Reference 2, Attachment B provides the details of the NFPA Code Section 14 and 20 compliance review which was recently completed. Attachment C to this letter contains additional information on the root cause of the June 1998 event. Also addressed is the significance of the NFPA noncompliances, identified in Reference 1, on the initiation and severity of the event.

IE01

When addressing the potential severity level of the apparent violation, and the possibility for exercising enforcement discretion, the Supply System requests that the NRC consider the determination of the root cause of the valve failure, as augmented in this letter, required considerable effort. This required the application of state of the art dynamic hydraulic analysis software not available when the system was designed or when we were attempting to reduce water hammer severity in the Fire Protection System in 1984. Additionally, analysis has shown that the design modification performed in 1984 reduced the severity of water hammers from our motor driven pumps and resulted in loads that were less severe than would have existed if the system design had fully complied with the NFPA code.

Furthermore, the design modification currently in progress on the Fire Protection System significantly reduces the water hammer loads, and with the improved dynamic hydraulic software available, we will be able to demonstrate that the design modification chosen will greatly reduce pressure surges from the water hammer mechanism that occurred during the June 1998 event.

Should you have any questions or desire additional information regarding this matter, please call Mr. PJ Inserra at (509) 377-4147.

Respectfully,

RL Webring
Vice President, Operations Support/PIO
Mail Drop PE08

Attachments

cc: EW Merschoff - NRC
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NRC Sr. Resident Inspector - 927N
DL Williams - BPA/1399
PD Robinson - Winston & Strawn

STATE OF WASHINGTON)
)
COUNTY OF BENTON)

Subject: Response to Apparent Violation in Inspection Report No. 50-397/98-20

I, RL WEBRING, being duly sworn, subscribe to and say that I am the Vice President, Operations Support/PIO for the WASHINGTON PUBLIC POWER SUPPLY SYSTEM, the applicant herein; that I have the full authority to execute this oath; that I have reviewed the foregoing; and that to the best of my knowledge, information, and belief the statements made in it are true.

DATE 12/18/ , 1998

RL Webring
Vice President, Operations Support/PIO

On this date personally appeared before me RL Webring, to me known to be the individual who executed the foregoing instrument, and acknowledged that he signed the same as his free act and deed for the uses and purposes herein mentioned.

GIVEN under my hand and seal this 18 day of December 1998

Notary Public in and for the
STATE OF WASHINGTON

Residing at W. Richland

My Commission Expires 3-29-01

APPARENT VIOLATION

Restatement of the Apparent Violation

As described in the FSAR, Section F.2.1, and Table F.2-4, the fire pumps were installed in accordance with NFPA 20-1974, "Standard for the Installation of Centrifugal Fire Pumps." Section 7-5 of NFPA 20 states that the controller for each unit of multiple pump units shall incorporate a sequential timing device to prevent any one pump from starting simultaneously with any other pump. The NFPA Fire Pump Handbook elaborates on this requirement by noting that the sequence starting requirement prevents excessive loading of the motor driven source (for motor-driven pumps) or excessive hydraulic stress to piping, valves, and other system components during pump acceleration. With the exception of Pump FP-P-1, none of the main fire pumps utilize time delay sequencing.

Although the installation of the bypass lines on the discharge of the motor-driven fire pumps and pressure setpoint variations would provide a "staggering" effect on low system demand, the same would not be true when large demands are placed on the system. As noted in the NFPA Fire Pump Handbook; sequence timers are required for fire protection systems with multiple pumps because staggering of the pressure switches will only sequence the pumps when very low water flows exist. At higher flows multiple pumps would otherwise start at the same time. The lack of time delay sequencing on the fire pumps was not technically justified in the FSAR as a deviation from NFPA 20.

In the root cause analysis, the licensee noted that the water hammer occurred within 6 seconds of event initiation. At that time, both motor-driven fire pumps were operating at close to runout conditions with their discharge bypass lines at least partially open and diverting a portion of the flow from the pumps. Pump FP-P-110 was also operating at close to runout conditions. Based upon the diversion of flow from the discharge of the motor-driven pumps, the licensee concluded that Pump FP-P-110 was the sole contributor to the void collapse and water hammer. As such, the licensee concluded that pump sequencing did not appear to be an event contributor (i.e., a single pump starting could generate sufficient hydraulic forces to fail the system). However, this conclusion was based upon qualitative information. The licensee did not have supporting data to show how much of the flow was being diverted to demonstrate that the pumps did not contribute to the reflood of the standpipe. Additionally, time delay sequencing was not analyzed using the Bechtel model to demonstrate that destructive forces would be generated even with sequencing. The inspectors found that the conclusion on the impact of pump sequencing was not supported by an adequate technical basis.

With regards to the installation of the bypass lines on the discharge of the motor-driven fire pumps, the inspectors noted that NFPA 20, Section 2-10, requires a check valve to be installed in the pump discharge assembly. For larger fire protection systems, the NFPA Fire Pump Handbook notes that the check valve may serve the purpose of protecting against water hammer generated by backflow when the pump is shut down. The NFPA Fire Pump Handbook further states that "no device other than a listed antiwater hammer check valve is permitted to be installed to prevent water hammer." In 1983, a formal interpretation was made by the NFPA code committee on this issue (Formal Interpretation 83-6A). As an example, the committee noted that it was unacceptable to install a slow-opening type of pressure regulating valve in the fire pump discharge line to prevent water hammer when the pump starts. This conclusion was based upon the potential for the failure of the valve to open when required. The same argument may also be applied to the installed bypass line isolation valves since failure of these valves to close could prevent adequate discharge flow to the fire main.

10 CFR Part 50, Appendix A, General Design Criterion 3, states that fire-fighting systems of appropriate capacity and capability be provided and designed to minimize the adverse effects of fires on structures, systems, and components (SSC) important to safety.

The ability of the fire protection water supply system design to generate hydraulic forces during expected system transients (e.g. preaction/deluge system actuation in response to a real fire) sufficient to rupture system piping is in direct contrast to the requirements of General Design Criterion 3. Any failure of system piping in response to an actual fire would have precluded the ability of the system to provide appropriate capability and capacity to minimize the adverse effects of the fire. Quantitatively this can be described as an inability to provide the design basis flow rate and volume of water (2350 gpm for 2 hours) because of the loss through the break. The design inadequacies in the fire protection water supply system were identified as an apparent violation of 10 CFR Part 50, Appendix A, General Design Criterion 3 (50-397/9820-01).

Conclusions

The root cause evaluation for the flooding event accurately concluded that the event resulted from design inadequacies of the fire protection water supply system. Those inadequacies allowed for the generation of destructive forces within the system that ultimately failed Valve FP-V-29D. The design inadequacies were attributed, in part, to noncompliances related to the installation of the fire pumps as specified in the NFPA code. The failure of the fire protection system pressure boundary upon a demand actuation would preclude the ability of the system to provide an appropriate capability and capacity to suppress a postulated fire and was identified as an apparent violation of 10 CFR Part 50, Appendix A, General Design Criterion 3.

Response to the Apparent Violation

The Supply System accepts the violation in that the design of the fire system did not meet the requirements of Branch Technical Position (BTP) 9.5-1: Appendix A, Section A.5, which forms the basis for WNP-2's compliance with 10 CFR Part 50 Appendix A General Design Criteria 3 (GDC 3). FSAR Appendix F, Table F.3-1, Section A-5 states: "Failure or inadvertent operation of the fire suppression system should not incapacitate safety-related systems or components." The failure of the fire suppression system on June 17, 1998 incapacitated two Emergency Core Cooling System (ECCS) subsystems and, thus, did not meet the BTP requirements. However, the event did not result in the complete loss of ECCS or Residual Heat Removal (RHR) safety functions, or the ability to safely shutdown the reactor, or maintain it in a safe shutdown condition (assuming power operation at the time of the event). Sufficient ECCS and RHR subsystems remained operable to perform the required safety function.

The Supply System has undertaken an aggressive and comprehensive program to thoroughly understand the basic reasons for the event and to initiate corrective actions that we believe will eliminate severe water hammer conditions from the WNP-2 fire protection system. The root cause investigation has determined that the design of the fire system was susceptible to moderate to severe water hammer conditions. A critical pipe hanger has been found to have the ability to flex and transfer loads normally absorbed by the hanger into the valve that ruptured during the June 1998 event. The conditions that resulted in the hanger being flexible are under investigation. We believe the flexibility was sufficient enough to effect the hanger's ability to mitigate the pressure surges on June 17, 1998, resulting in the failure of the reactor building standpipe isolation valve and subsequent flooding.

The inspection report (Reference 1) concluded that NFPA code noncompliances associated with time staggering the starting of the fire pumps and use of Clayton valves, in part, contributed to design inadequacies that resulted in the failure of the fire protection system pressure boundary. The inspection report also concluded that the failure would preclude the ability of the system to provide an appropriate capability and capacity to suppress a postulated fire. However, as summarized below, the Supply System has analyzed the nonconformances and determined that they did not contribute to the water hammer. Also, we have evaluated the NFPA code provisions that address the ability to fight a fire concurrently with a system rupture. The NFPA code requirements call for sectional isolation valves that can be used to isolate a ruptured piping section when fire suppression is needed. The WNP-2 fire protection system meets this NFPA design requirement.

When addressing the potential severity level of the apparent violation, and the possibility for exercising enforcement discretion, we request the NRC consider that the event, although severely impacting two ECCS subsystems, did not cause failure to meet any Technical Specification Limiting Condition for Operation (LCO) requirements in Mode 4. We have performed an analysis to determine the risk significance if the plant was at 100% power at the onset of the event. The Core Damage Frequency increase associated with the loss of the two ECCS subsystems was 6.01 E-8 or a 0.35% increase in total Core Damage Probability. Additionally, LCO 3.5.1, "ECCS-Operating," covers the condition of loss of two ECCS subsystems at power and allows 72 hours to meet the Required Action prior to requiring a plant shutdown. Sufficient ECCS and shutdown cooling subsystems were available to shutdown the plant.

We also request your consideration with respect to penalty assessment identification credit. Considerable effort was required to determine the root cause contributing factors and corrective actions. The determination of the valve failure mechanism (flexible hanger load transfer) required the application of state of the art dynamic hydraulic analysis software not available when the system was designed or when we were attempting to reduce water hammer severity in the fire protection system in 1984. The design change in 1984 was successful in limiting fire protection system damage for 14 years until the aforementioned hanger loosened to the extent that allowed the valve failure. Finally, the analysis we performed shows that the design modification implemented in 1984 considerably reduced the severity of water hammers from our motor driven pumps and resulted in loads that were much less severe than would have existed if the system design had fully complied with NFPA code.

Furthermore, the design modification currently in progress on the Fire Protection System significantly reduces the water hammer loads. With the improved dynamic hydraulic software available, we will be able to verify that the proposed design modifications will greatly reduce pressure surges from the water hammer mechanism that occurred during the June 1998 event.

Noncompliance with NFPA 20-1974, Section 7-5

This NFPA section requires sequential timing devices to prevent any one pump from starting simultaneously with any other pump. This is to prevent overloading power supply systems or creating excessive hydraulic stress in piping, valves, and other system components during pump acceleration. Compliance with this criteria would not have prevented or reduced the water hammer severity of the June 17, 1998 event. The hydraulic analysis, summarized in Attachment C, confirms the empirical evidence that the Clayton valves were more effective in reducing the water hammer loads than a design with time staggered pumps. Our analysis also shows that time sequencing of pumps without the Clayton valves simulates loads much higher than experienced during the June 1998 event.

Proposed Nonconformance with NFPA 20-1974, Section 2-9

This NFPA section requires a check valve to be installed in the pump discharge assembly. WNP-2 is in compliance with this requirement. Each WNP-2 fire pump contains a check valve in the discharge of the pump. This check valve functions to limit water hammer resulting from system drain down during pump standby conditions. However, this check valve would not mitigate the mechanism which caused the June 17, 1998 water hammer event.

The mechanism causing the water hammer was different. The mechanism was column rejoining of standpipe voids created by the demand of preaction system P66. The design purpose of the Clayton valves was not to prevent water hammer from voids created by system drain down through standby pumps, but rather was to prevent pressure surges from the motor driven pumps due to a sudden system demand such as preaction or deluge system actuation.

The code interpretation published in 1983 cited the potential for failure of a flow control device resulting in severely limiting the ability of the pump to supply needed flow. To address the reliability concern, the WNP-2 design employed redundancy such that a single failure of a Clayton valve to close would not incapacitate the primary system. The WNP-2 design employs three nearly full capacity pumps (2000 gpm versus 2350 gpm) as the primary fire suppression supply system. Any two of the three pumps will provide the required design basis flow. The Clayton valve design employs both a recirculation (pressure surge reducing on start) and pressure relief feature. Licensee Event Report (LER) 84-026 notified the NRC of the Supply System's intent to provide pressure surge reducing (Clayton) valves to minimize water hammer in the fire protection system caused by inadvertent preaction system demands. The valves were installed and the FSAR revised to reflect their use. As previously stated, Attachment C presents the results of the analysis which shows that resulting forces from a pump time delay (NFPA code compliant model) produced higher destructive forces than those produced by modeling the actual WNP-2 configuration (with Clayton valves). Thus, the use of pump discharge flow control devices did not increase the severity of the water hammer.

GDC 3 Apparent Violation

The final issue in the inspection report characterization of the apparent violation was that sufficient capacity was not available to fight a design basis fire concurrent with a system pressure boundary rupture. GDC 3 does not require that the system be designed to be able to sustain a line break and concurrently supply the design basis fire. Rather, the design philosophy is to provide the ability to segregate any system boundary rupture in an expedient manner so that rapid restoration of the fire system pressure boundary is achieved. This is a code of record requirement per NFPA 24-1973, "Standard For Outside Protection," Section 35, "Sectional Valves," which states: "Large yard systems shall have sectional controlling valves at appropriate points, in order to permit sectionalizing the system in the event of a break, or for making repairs or extensions." FSAR requirements establish a one hour time limit for obtaining fire suppression coverage from functional hose stations. The WNP-2 design employs a large yard loop concept with sectionalized piping in order to meet the requirement to isolate a section on a major pressure boundary break and still provide fire suppression to unaffected sections of the plant. The isolation of the June 17, 1998 line break could have been accomplished by isolating one valve (FP-V-19). During the June 17, 1998 event, after determining that there was not a fire, flooding mitigation actions were the highest priority; thus, the plant operators chose to secure the fire pumps. The requirement for providing the ability to sectionally isolate the fire suppression system is specifically for the ability to mitigate a rupture or major leak. If a fire had been the source of initiating the preaction system, the plant response would have considered both the need to limit flooding and fight the fire. Thus, the Supply System believes that sufficient capacity was available and that required isolation features would have been utilized if the fire suppression system was initiated by an actual fire.

In addition, substantial capacity to fight a fire concurrent with the break was available during the event. The event pressure data shows that FP-P-1 raised the pressure of the system during the break from approximately 115 psig to 125 psig from when it came on line approximately 32 seconds into the event until it was shutdown approximately 14 minutes later. This indicates that the output of pump FP-P-1 was available for fire suppression to concurrently fight a fire while isolating the ruptured section.

Conclusion on Inspection Report Noncompliances

The Supply System concludes that the NFPA code noncompliance identified in Reference 1 did not contribute to the event (see Attachment C). Notwithstanding this conclusion, the Supply System recognizes that the NFPA code noncompliances should have been formally documented and justified by engineering analysis.

In LER 84-026, the Supply System identified the addition of the pressure surge reducing valves (Clayton) for prevention of water hammer damage due to preaction system demand. However, this was not identified as a deviation from the NFPA code of record. The failure to provide an adequate deviation and engineering justification in the FSAR for not staggering the fire pump by use of a time delay device was an oversight. The design modification which installed the Clayton valves considered NFPA 20 Section 2.12 methods for pressure surge reduction and concluded that neither pressure relief nor pump start time delay would solve the pressure surge problem. The addition of the Clayton valves has prevented significant water hammer damage by the motor driven main fire pumps. Fire pump FP-P-110 starts, which caused the minor damage identified prior to the June 17, 1998 event, were not recognized to have the potential to cause the catastrophic valve rupture. The design still contained a sensitivity to developing water hammers by standpipe voiding of varying magnitude, depending on main fire pump status and system demands from normal usage or from actuation of preaction systems. We believe this sensitivity became critical when a hanger at the junction of seismic to nonseismic piping sections became too flexible and allowed the water hammer loads to be transferred to reactor building standpipe #1 (RB-1) isolation valve.

Reason for the Apparent Violation of GDC 3

The Supply System failed to comply with BTP 9.5-1 which requires that the fire protection system be designed such that "failure or inadvertent operation of the fire suppression systems should not incapacitate safety related systems or components." The BTP is cited in WNP-2 FSAR Table F.3-1 as the position we use for GDC 3 compliance. Contrary to this requirement, safety related subsystem and component damage occurred such that the intent of the BTP was not met.

Root Cause Analysis Update

The basic root cause for the design inadequacy lies in the failure to provide adequate design features to either minimize standpipe voiding or break the vacuum in the standpipe so as to provide damping of the column rejoining pressure surge.

The design of the fire system included multiple standpipes that would partially void on rapid system demand from preaction or deluge fire zones. Thus, the design allowed standpipe voiding as a normal system state for expected system transients. The standpipe voiding setup the conditions for water hammer of varying severity depending on initial system conditions and preaction system demand volume.

The hydraulic analysis model used to assess and validate assumptions in the root cause analysis was refined to include the pump characteristics, Clayton valve flow diversion, and additional pipe segments identified by our review. The final hydraulic analysis model for the event predicted loads that were marginal for having sufficient forces to cause the rupture of valve FP-V-29D during the June 1998 event (see Attachment C). This prompted a reinspection of the critical hanger that mitigates water hammer forces to FP-V-29D. The reinspection found hanger FP-56 degraded (Reference PER 298-2001, dated 12/10/98). The reinspection found that gaps exist between the hanger's four base plates and the supporting concrete wall that exceeds the minimum gap allowed. Additionally, several anchor bolts were found loose. This degradation was not sufficient to significantly impair the support's seismic and normal system performance ability, but is sufficient to impart increased flexural and torsional loads on FP-V-29D from pressure waves created during significant column rejoining impacts.

The design was able to accommodate loads generated by system water hammers until the June 1998 event occurred. The cause of the gap is under investigation, but includes potential initial installation errors and anchor bolt loosening through normal system demand and water hammer loading. We have had previous actuations of P65 and P79 that our model shows caused equal or larger hydraulic forces that did not result in valve damage. This would indicate the support has

become more flexible over time. However, the analysis indicates the forces are not large enough to have caused yielding in the support's anchor bolts. The details of the analysis of previous events and their loads are summarized in Attachment C. The flexibility of hanger FP-56 is a newly discovered contributing factor in the event. As we previously concluded, the root cause is that the system design is configured such that destructive level forces are generated during anticipated fire system demands.

Corrective Actions Taken and Results Achieved

The Supply System has implemented interim actions to assure that significant pressure surges do not occur in the WNP-2 fire protection system. These actions and measures include:

- strengthening the reactor building standpipe isolation valves
- sustaining fire protection pressure with a continuously running main fire pump
- establishing a nitrogen cushion at the top of reactor building standpipes to mitigate pressure surges
- upgrading the trim design of the preaction and deluge valves to preclude sympathetic actuation on pressure transients
- enhancing operability testing for the motor driven pump modulating bypass valves to assure reliable performance
- performing a comprehensive system functional test to verify the effectiveness of these interim actions

Some of these interim actions do not meet current NFPA or code of record requirements, but are effective interim engineering solutions for establishing operability of the WNP-2 fire suppression system. These interim actions will remain in place until design modifications can be implemented that meet NFPA requirements (or approved deviations).

We have also implemented a review of our compliance with the WNP-2 licensing basis for design of the fire protection pumps and standpipes. This review of NFPA 14 and NFPA 20 (motor driven pumps and backup diesel FP-P-110) is complete and noncompliances with the current NFPA code were identified and initially evaluated. The noncompliances were reviewed to determine if they contributed to the event's initiation or severity. None of the noncompliances identified individually or taken as a group significantly contributed to the WNP-2 fire protection system water hammer of June 17, 1998 (see Attachment B).

Corrective Steps That Will Be Taken to Avoid Further Violations

A design modification to provide standpipe vacuum breaker valves will be installed prior to or during the Spring 1999 maintenance shutdown. To assure adequate vacuum break response time, pump starts may be time delayed if necessary. This design does not employ current NFPA code approved methods and, therefore, will require engineering justification of code deviations.

To maintain a soft start capability for the motor driven pumps, the function performed by the Clayton valves will be replaced with controlled voltage starters. The starters will be of an NFPA

approved design. The controlled voltage starters coupled with the vacuum breakers will mitigate significant pressure surges in the system. This second phase will be completed by June 30, 1999.

The final phase of the program involves dispositioning each of the NFPA noncompliances identified by the NFPA 14 and 20 reviews. This phase will establish appropriate deviations or modifications at which time WNP-2 will meet the intent of the NFPA code of record either by direct compliance or an approved alternate approach. This phase will also include updating the FSAR, as appropriate, to reflect the WNP-2 compliance basis.

Date of Full Compliance

The interim actions identified above were completed on July 2, 1998 at which time WNP-2 fire suppression system met the intent of GDC 3 requirements. The design inadequacies in the fire protection water supply system have been mitigated through those interim actions, as demonstrated by full system testing. Permanent design changes will be implemented by June 30, 1999 to eliminated the need for these interim actions.

Attachment B, Section 1
Summary of NFPA Reviews For NFPA 14 and NFPA 20

Overview

NFPA 14 and 20 were reviewed against the WNP-2 design to identify any nonconformances to the NFPA-1996 code. The nonconformances were reviewed against the NFPA-1974 code requirements to determine any "code of record" deviations. Each of the deviations were evaluated to determine if they could have caused or contributed to the severity of the June 17, 1998 water hammer event. There were no cases found where an NFPA-1974 deviation would have increased the severity of the water hammer or where compliance with the code of record requirement would have mitigated the severity of the event. Each NFPA section is summarized below. For specific details see Sections 2, 3, and 4 of this attachment.

NFPA 14 Standpipes

The review of WNP-2's design to the NFPA 14-1996 code requirements for standpipes identified 15 nonconformances. These included:

- Three associated with welding methods, weld identification, and weld records.
- Three associated with pipe hanger Professional Engineer certification of hanger detailed calculations, listing of all hangers that are directly attached to piping, and a requirement for hangers if the distance between a standpipe and hose connection exceeds 18 inches.
- Five associated with hose station hose length limits and nozzle location for NPFA Class I & III service, hose connections for Class III systems meeting Class I & II requirements, labeling of hoses racks, and fire department connection requirements.
- Two associated with standpipe interconnections that are part of combined systems that require a control valve of the same size as the connection and that an interconnection should be provided at the bottom of multiple standpipes in the same building.
- Two associated with the minimum design pressure for standpipes, pipe sizes, and draining.

Each of the NFPA-1996 code nonconformances were evaluated to the WNP-2 1974 code of record requirements. Seven of these either met the code of record requirements or the intent and required no further action. Of the remaining eight that were potential code of record issues, two were code of record deviations previously evaluated in the FSAR, three require a documented code of record deviation evaluation, two met the intent of the code of record but require obtaining more formal documentation, and one was the suggested feature for interconnecting standpipes in the same building as discussed below.

One code of record issue identified that would have some effect on the system hydraulics was that an interconnection should be provided between standpipes in the same building. RB-1 and RB-2 are not directly interconnected within the reactor building. The primary purpose of interconnecting the standpipes is to facilitate supply of the standpipes from the fire department connection. The standpipe interconnection would allow the fire department to make one connection and supply all of the standpipes in the building. In addition, the interconnection,

when combined with isolation valves, can provide some additional availability of the water supply for the standpipes. This was evaluated and we determined the interconnection produces higher loads because the standpipe water hammers occur much closer together.

In conclusion, none of code of record deviations of NFPA 14-1974 would have mitigated the severity of the June 17, 1998 water hammer event.

NFPA 20, Pumps: Motor Driven Fire Pumps FP-P-2A & FP-P-2B

The review of WNP-2's design against the NFPA 20-1996 code requirements for motor driven pumps identified 17 nonconformances. These included:

- Four associated with pump discharge line configuration including a required relief valve, relief valve setpoint, visible detection of relief valve water flow, and relief valve sizing requirements.
- Ten associated with electrical supply and control features including supply breaker overload and protection devices and setpoints, motor terminal voltage limits, NFPA listing for motors, voltage surge arrestors on each phase, circuit isolation, instantaneous breaker trip settings, motor controller overcurrent protection devices, and phase rotation indication.
- Two associated with pressure sensing line location and prohibition of the use of sensing line isolation valves.
- One related to establishing time sequencing of pumps, when multiple pumps were required to meet the design demand.

Each of the NFPA 20-1996 code nonconformances for the motor driven pumps were evaluated to the WNP-2 1974 code of record requirements. Eight of these either met the code of record requirements or its intent and required no further action. Of the remaining nine, three required a documented code of record deviation, and six will be resolved by the corrective action to replace the Clayton valves with a standard pressure relief valve and controlled voltage starter design.

Two code of record issues were identified that had the potential to affect the fire water system hydraulics. They were the time sequencing between pump starts and the use of the Clayton bypass flow control devices on the discharge of the pumps. Both of these issues were the focus of an extensive hydraulic analysis. Meeting the NFPA requirement to include timing devices to delay subsequent pump starts from five to ten seconds would not have lessened the severity of the water hammer of June 17, 1998. Attachment C provides details on the analyzed loads. A case was created to simulate system transients assuming the pumps were time staggered without the Clayton valves on the motor driven pumps. The analysis shows that there would have been much higher loads by the use of time staggering of the motor driven pump starts. The analysis also shows that the motor driven pumps under Clayton valve control were not only effectively time staggered, but also had their flow rate into the loop gradually applied. Attachment C shows that the loads and pressures were essentially the same between a three pump start with the Clayton valves and when only the diesel pump was modeled to provide flow. Although the Clayton valve design effectively performed its intended function, reliability improvement is possible by use of controlled voltage starters to achieve the desired surge control. However, regardless of the order

of starting or the time sequencing of pumps chosen, standpipe voiding will occur and water hammer conditions would result. Vacuum breakers are being installed in susceptible standpipes to assure an air cushion is established prior to pump starting. A time delay to provide a sufficient period for establishing the standpipe air pocket will be implemented where necessary.

In conclusion, none of code of record deviations of NFPA 20-1974 would have affected the June 17, 1998 water hammer event.

NFPA 20, Pumps: Diesel Driven Fire Pumps

(Note: only diesel fire pump FP-P-110 is discussed, as FP-P-1 did not start until well after the water hammer occurred.)

The review of WNP-2's design to the NFPA 20-1996 code requirements for diesel driven pump FP-P-110 identified six nonconformances. These included:

- One associated with the diesels rating bases.
- One associated with the fuel supply tank capacity sizing bases.
- One associated with the functional testing frequency interval.
- One associated with prohibition of isolation valves in the pressure sensing lines.
- One associated with the overspeed shutdown device interlocks with the engine controller.
- One associated with time delay between pump starts.

Each of the NFPA 20-1996 code nonconformances for diesel driven pump FP-P-110 were evaluated to the WNP-2 1974 code of record requirements. Five of these either met the code of record requirements or its intent and required no further action.

The remaining code of record deviation identified was the time sequencing of pump starts. This deviation was summarized previously in the evaluation of motor driven pumps deviation of NFPA 20 and the conclusions are equally applicable to the FP-P-110.

In conclusion, none of the code of record deviations of NFPA 20-1974 associated with FP-P-110 would have affected the June 17, 1998 water hammer event.

Attachment B Section 2
NFPA 14 Review Details

1. 1996 Edition Code Requirement

2-4.2.7 Torch cutting and welding shall not be permitted as a means of modifying or repairing standpipe systems.

WNP-2 Position *Nonconformance. Torch cutting and welding is permitted in accordance with the cutting and welding permit procedure PPM 1.3.10A.*

1974 Edition Code of Record Requirement

642 All piping shall be installed by means of threaded or flanged fittings or other approved means. Welding of joints may be allowed. Permission for this work shall be obtained from the authority having jurisdiction. Welding should preferably be done in the shop and welding fittings used. Welding fittings should comply with ANSI Standard B16.9-1971, ANSI Standard B16.25-1972 and ASTM Designation A234-71.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. WNP-2 meets the requirements of the code of record. The administrative controls implemented by PPM 1.3.10A have been accepted by the NRC and insurance authorities and are adequate.*

Recommended Action: No further action is warranted.

2. 1996 Edition Code Requirement

2-4.2.9.1 Welders or welding machine operators shall, upon completion of each weld, stamp an imprint of their identification into the side of the pipe adjacent to the weld.

WNP-2 Position *Nonconformance. Weld records are available but the piping is not stamped adjacent to each weld. (Reference B & R Contract 2808-215)*

1974 Edition Code of Record Requirement

642 All piping shall be installed by means of threaded or flanged fittings or other approved means. Welding of joints may be allowed. Permission for this work shall be obtained from the authority having jurisdiction. Welding should preferably be done in the shop and welding fittings used. Welding fittings should comply with ANSI Standard B16.9-1971, ANSI Standard B16.25-1972 and ASTM Designation A234-71.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. WNP-2 meets the requirements of the code of record.*

Recommended Action: No further action is warranted.

3. 1996 Edition Code Requirement

2-4.2.9.2 Contractors or fabricators shall maintain certified records, which shall be available to the authority having jurisdiction, of the procedures used and the welders or welding machine operators employed by them along with their welding identification imprints. Records shall show the date and the results of procedure and performance qualifications.

WNP-2 Position *Nonconformance. Weld records are available but the piping is not* flow *stamped adjacent to each weld. (Reference B & R Contract 2808-215)*

1974 Edition Code of Record Requirement

None. There is no corresponding requirement in the code of record in effect at the time the system was designed.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. WNP-2 meets the requirements of the code of record.*

Recommended Action: No further action is warranted.

4. 1996 Edition Code Requirement

2-5.1 General. Hangers shall be in accordance with the requirements of 2-5.1.1 through 2-5.1.7.

Exception: Hangers certified by a registered professional engineer as to include all of the following requirements shall be permitted: (a) Hangers shall be designed to support five times the weight of the water-filled pipe plus 250 lb (114 kg) at each point of piping support.

Detailed calculations shall be submitted, where required by the reviewing authority, that show the stresses developed both in hangers and piping and the safety factors allowed.

WNP-2 Position *Nonconformance. Detailed calculations showing the stresses developed in the hangers and the piping and the safety factors allowed are not available for some of the standpipes.*

1974 Edition Code of Record Requirement

651 The pipe hangers shall be of approved type, so arranged that they will sustain the loads and retain the piping securely in position. They shall be used in sufficient number to prevent vibration in the piping when the standpipe is in use.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. Approved hangers and steel bracing have been used to support the system piping. Plant experience demonstrates that the standpipes are sufficiently supported to meet the code of record requirement. A review has concluded that this condition could not have contributed to the June, 1998 valve rupture/flooding event*

Recommended Action: Identify an action to locate or create the necessary documentation to justify compliance with the code of record.

5. 1996 Edition Code Requirement

2-5.1.1 The components of hanger assemblies that directly attach to the pipe or to the building structure shall be listed.

Exception: Mild steel hangers formed from rods shall not be required to be listed.

WNP-2 Position *Nonconformance. The hangers are all individually designed and thus are not listed.*

1974 Edition Code of Record Requirement

651 The pipe hangers shall be of approved type, so arranged that they will sustain the loads and retain the piping securely in position. They shall be used in sufficient number to prevent vibration in the piping when the standpipe is in use.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. Approved hangers and steel bracing have been used to support the system piping. Plant experience demonstrates that the standpipes are sufficiently supported to meet the code of record requirement. A review concluded that this condition could not have contributed to the June, 1998 valve rupture/flooding event.*

Recommended Action: Identify an action to locate or create the necessary documentation to justify compliance with the code of record.

6. 1996 Edition Code Requirement

2-7.2 Hose. Each hose connection provided for use by building occupants (Class II and Class III systems) shall be equipped with not more than 100 ft (30.5 m) of listed, 1 1/2-in. (38.1-mm), lined, collapsible or noncollapsible fire hose attached and ready for use.

Exception: Where hose less than 1 1/2 in. (38.1 mm) is used for 1 1/2-in. (38.1-mm) hose stations in accordance with 3-3.2 and 3-3.3, listed noncollapsible hose shall be used.

WNP-2 Position *Nonconformance. Several of the hose stations are equipped with more than 100 feet of hose. Most of these have 150 feet of hose and one has 200 feet of hose. This extra hose is required to provide the coverage required by Chapter 5.*

1974 Edition Code of Record Requirement

321 The number of hose stations for Class I and Class III services in each building and in each section of a building divided by fire walls shall be such that all portions of each story of the building are within 30 feet of a nozzle attached to not more than 100 feet of hose.

Note: Equipment should be so arranged as to permit directing the discharge from the nozzle into all portions of important enclosures such as closets and like enclosures.

WNP-2 Position *This Nonconformance has been previously evaluated and accepted by the NRC as documented in FSAR Table F.2-1. (Reference Nuclear Safety Evaluations 98-080 and NRC SER dated 3/17/83.) Several of the hose stations are equipped with more than 100 feet of hose. Most of these have 150 feet of hose and one has 200 feet of hose.*

Recommended Action: No further action is warranted.

<u>7. 1996 Edition Code Requirement</u>

2-7.5 Label. Each rack or storage facility for 1 1/2-in. (38.1-mm) or smaller hose shall be provided with a label that includes the wording "fire hose for use by occupants" and operating instructions.

WNP-2 Position *Nonconformance. The fire hose is labeled with the words "Fire Hose".*

1974 Edition Code of Record Requirement

432 Each rack for small hose shall be provided with a label affixed to include "Fire Hose for Use by Occupants" and operating instructions.

WNP-2 Position *The fire hose is intended for use by Fire Brigade members who are trained and drilled in the proper operation of the equipment as documented in FSAR Table F.2-1. Fire Brigade members are also provided with pre-fire plans which identify the locations of the hose stations. Employees are trained in General Employee Training that they are not expected to use the fire hose. Therefore, this is not a code deviation.*

Recommended Action: No further action is warranted.

8. 1996 Edition Code Requirement

2-9.1 Fire department connections shall be listed for a working pressure equal to or greater than the pressure requirement of the system demand.

WNP-2 Position *Nonconformance. A fire department connection is not provided for each standpipe.*

1974 Edition Code of Record Requirement

561 A connection through which the public fire department can pump water into the standpipe system makes a desirable auxiliary supply. One or more fire department connections shall be provided for each Class I or Class III standpipe system.

WNP-2 Position *This is a code deviation. A fire department connection is not provided for each standpipe since this is a private limited use water distribution system. If necessary, Fire Department pumpers can take suction from the cooling tower basins and pump into the underground supply loop utilizing a fire hydrant. (Reference M515-1)*

Recommended Action: Document this code deviation in a Licensing Document Change Notice (LDCN) for FSAR Appendix F Table F.2-1 in accordance with PERA 298-0813-04.

9. 1996 Edition Code Requirement

4-2.5.1 Each connection from a standpipe that is part of a combined system to a sprinkler system shall have an individual control valve of the same size as the connection.

WNP-2 Position *Nonconformance. Connections for the turbine oil reservoir sprinkler system on Standpipe No. TGB-1 and the RW building HVAC sprinkler on Standpipe No. RWB-1 do not meet this requirement. (Reference M515-1)*

1974 Edition Code of Record Requirement

145 Each outlet from a combined riser to the sprinkler system shall have an individual control valve of the same size as the outlet.

WNP-2 Position *This is a code deviation. The connections for the Turbine Oil Reservoir sprinkler system on Standpipe No. TGB-1 and the RW building HVAC sprinkler on Standpipe No. RWB-1 do not meet this requirement. (Reference M515-1) This condition did not contribute in any way to the June, 1998 valve rupture/flooding event.*

Recommended Action: Document this code deviation in an LDCN for FSAR Appendix F Table F.2-1 in accordance with PERA 298-0813-04.

10. 1996 Edition Code Requirement

4-4.2.1 Horizontal piping from the standpipe to hose connections that are more than 18 in. (457 mm) in length shall be provided with hangers.

WNP-2 Position *Nonconformance. There are several hose station connections which do not meet this requirement. The non-conforming hose stations are: HS/RB17, HS/RB27, HS/SB13, HS/RWB14, HS/RWB14, HS/RWB24, HS/RWB23, HS/RWB22, HS/RWB21, and possibly HS/RWB27 and HS/RWB28 (Reference CVI 215-00 and CVI 215-08 series drawings)*

1974 Edition Code of Record Requirement

651 The pipe hangers shall be of approved type, so arranged that they will sustain the loads and retain the piping securely in position. They shall be used in sufficient number to prevent vibration in the piping when the standpipe is in use.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. Approved hangers and steel bracing have been used to support the system piping. Plant experience demonstrates that the standpipes are sufficiently supported to meet the code of record requirement. A review concluded that this condition could not have contributed to the June, 1998 valve rupture/flooding event.*

Recommended Action: Identify an action to locate or create the necessary documentation to justify compliance with the code of record.

11. 1996 Edition Code Requirement

5-3.4 Class III Systems. Class III systems shall be provided with hose connections as required for both Class I and Class II systems.

WNP-2 Position *Nonconformance. Hose stations were designed so that all portions of each floor level of each building are within 180 feet of a hose connection provided with 150 feet of 1 1/2-in. hose except as documented in section 2-7.2. (M515-1)*

1974 Edition Code of Record Requirement

321 The number of hose stations for Class I and Class III services in each building and in each section of a building divided by fire walls shall be such that all portions of each story of the building are within 30 feet of a nozzle attached to not more than 100 feet of hose.

Note: Equipment should be so arranged as to permit directing the discharge from the nozzle into all portions of important enclosures such as closets and like enclosures.

WNP-2 Position *Nonconformance that has been previously evaluated and accepted by the NRC as documented in FSAR Table F.2-1. (Reference Nuclear Safety Evaluations 98-080 and NRC SER dated 3/17/83.) Several of the hose stations are equipped with more than 100 feet of hose. Most of these have 150 feet of hose and one has 200 feet of hose.*

Recommended Action: No further action is warranted.

12. 1996 Edition Code Requirement

5-5 Interconnection of Standpipes. Where two or more standpipes are installed in the same building or section of building, they shall be interconnected at the bottom. Where standpipes are supplied by tanks located at the top of the building or zone, they also shall be interconnected at the top; in such cases, check valves shall be installed at the base of each standpipe to prevent circulation.

WNP-2 Position *Nonconformance. Standpipes within buildings are generally not interconnected at the bottom. Several of the standpipes are interconnected at floor levels and several of the standpipes are not interconnected at all. (M515-1)*

1974 Edition Code of Record Requirement

614 Where two or more standpipes are installed in the same building or section of a building, they should be interconnected at the bottom. Where standpipes in a single building are supplied by tanks they should also be interconnected at the top; in such cases, check valves may be installed at the base of each riser to prevent circulation.

WNP-2 Position *The requirement in the code of record stated above is a "should" statement and not a "shall" statement and, therefore, it is not required that the standpipes be interconnected, it is merely recommended. The primary purpose of interconnecting the standpipes is to facilitate supply of the standpipes from the fire department connection. As long as the standpipes are interconnected the fire department need only connect to one fire department connection and they will be supplying all of the standpipes to the building. In addition, the interconnection, when combined with some isolation valves, can provide some additional availability of the water supply for the standpipes. A further review was conducted that determined that, if this interconnection was in place, that the standpipe's column rejoining time would be much closer together. The resulting pressure wave of the first would have a higher likelihood of combining with the second to produce even higher loads.*

Recommended Action: No further action is warranted.

<u>13. 1996 Edition Code Requirement</u>

5-7 Minimum Pressure for System Design and Sizing of Pipe. Standpipe systems shall be designed so that the system demand can be supplied by both the attached water supply, where required, and fire department connections. The authority having jurisdiction shall be consulted regarding the water supply available from a fire department pumper. (Also see NFPA 1901, Standard for Pumper Fire Apparatus.) Standpipe systems shall be one of the following:

(a) Hydraulically designed to provide the required water flow rate at a minimum residual pressure of 100 psig (6.9 bars) at the outlet of the hydraulically most remote 2 1/2-in. (63.5-mm) hose connection and 65 psig (4.5 bars) at the outlet of the hydraulically most remote 1 1/2-in. (38.1-mm) hose station; or

Exception: Where the authority having jurisdiction permits pressures lower than 100 psig (6.9 bars) for 2 1/2-in. (63.5-mm) hose connections, based on suppression tactics, the pressure shall be permitted to be reduced to not less than 65 psig (4.5 bars).

(b) Sized in accordance with the pipe schedule in Table 5-7 to provide the required water flow rate at a minimum residual pressure of 100 psig (6.9 bars) at the topmost 2 1/2-in. (63.5-mm) hose connection and 65 psig (4.5 bars) at the topmost 1 1/2-in. (38.1-mm) hose station. Pipe schedule designs shall be limited to wet standpipes for buildings that are not defined as high-rise.

WNP-2 Position *Nonconformance. Standpipes are sized consistent with Table 5-7, Pipe Schedule. The topmost 2 1/2 inch hose connection is at elevation 612' in the Reactor Building and the pump outlet is at approximately 446 elevation (612-446=166 x 0.434= 72 psig). Thus, the residual pressure requirement of 100 psig cannot be met at this hose station with the normal system lineup. This non-conformance applies to the two Reactor Building standpipes. The remainder of the standpipes appear to meet this requirement. Although specific calculations verifying this requirement could be met were not reviewed, a review of the piping diagram conservatively concludes that this requirement can be met based on the large pipe sizes utilized for the WNP-2 standpipes. (M515-1)*

1974 Edition Code of Record Requirement

532 The supply shall be sufficient to maintain a residual pressure of 65 pounds per square inch at the topmost outlet of each standpipe with 500 gallons per minute flowing.

WNP-2 Position *Although calculations verifying this condition could not be located, a review of the flow diagram indicates that this requirement should meet the exception at a pressure of not less than 65 psig (4.5 bars) based on the existing configuration due to the large pipe sizes and strong water supply characteristics. Therefore, this is not a code deviation.*

Recommended Action: Identify an action to locate or create the necessary documentation to justify compliance with the code of record.

<u>14. 1996 Edition Code Requirement</u>

5-11.2 Each standpipe shall be provided with a means of draining. A drain valve and piping, located at the lowest point of the standpipe piping downstream of the isolation valve, shall be arranged to discharge water at an approved location. Sizing shall be as specified in Table 5-11.2.

WNP-2 Position *Nonconformance. Standpipe RWB-2 is provided with a 2 inch drain that is upstream of the isolation valve. The remainder of the standpipes have a properly arranged drain valve downstream of the isolation valve. (M515-1)*

1974 Edition Code of Record Requirement

None. There is no corresponding requirement in the code of record in effect at the time the system was designed.

WNP-2 Position *WNP-2 is in conformance with the code of record in effect at the time the system was designed and installed. This condition does not affect the operability of the standpipe system, it only affects the way maintenance would be performed. Adequate compensatory measures and work planning are in affect to mitigate this minor non-conformance.*

Recommended Action: No further action is warranted.

<u>15. 1996 Edition Code Requirement</u>

5-12.1 One or more fire department connections shall be provided for each zone of each Class I or Class III standpipe system.

Exception: The high zone fire department connection(s) shall not be required to be provided where 7-4.3 applies.

WNP-2 Position *Nonconformance. A fire department connection is not provided for each standpipe.*

1974 Edition Code of Record Requirement

561 A connection through which the public fire department can pump water into the standpipe system makes a desirable auxiliary supply. One or more fire department connections shall be provided for each Class I or Class III standpipe system.

WNP-2 Position *This is a code deviation. A fire department connection is not provided for each standpipe since this is a private limited use water distribution system. If necessary, Fire Department pumpers can take suction from the cooling tower basins and pump into the underground supply loop utilizing a fire hydrant. (Reference M515-1)*

Recommended Action: Document this code deviation in an LDCN for FSAR Appendix F Table F.2-1 in accordance with PERA 298-0813-04.

Attachment B-Section 3
Summary of NFPA 20 Review
FP-P-2A & FP-P-2B

1. 1996 Edition Code Requirement

2-13.4.1 Pilot-operated pressure relief valves, where attached to vertical shaft turbine pumps, shall be arranged to prevent relieving of water at water pressures less than the pressure relief setting of the valve.

WNP-2 Position *Nonconformance. The Clayton relief valve is a normally open valve that begins relieving immediately until the pilot pressure closes the valve.*

NFPA 20-1974 Code of Record Requirement

2-9.6.1 Pumps connected to adjustable-speed drivers shall be equipped with a listed relief valve. Where pumps are driven by constant-speed motors and the pump shutoff pressure plus the static suction pressure exceeds the pressure for which the system components are rated, relief valves are required.

2-9.6.2 The relief valve shall be set to prevent pressure on the fire protection system in excess of that pressure which the system is capable of withstanding.

WNP-2 Position *This is a code deviation. The 1996 requirement has been modified to be more restrictive than the code of record. However, the installed Clayton valve design was not listed for fire protection. The Clayton valves (FP-V-290A/B) will be replaced by standard relief valves in conformance with the code of record and the current code.*

Recommended Action: Replace the Clayton valves with UL listed or FM approved relief valves. Refer to PERA 298-0813-02.

2. 1996 Edition Code Requirement

2-13.5 The relief valve shall discharge into an open pipe or into a cone or funnel secured to the outlet of the valve. Water discharge from the relief valve shall be readily visible or easily detectable by the pump operator. Splashing of water into the pump room shall be avoided. If a closed-type cone is used, it shall be provided with means for detecting motion of water through the cone. If the relief valve is provided with means for detecting motion (flow) of water through the valve, then cones or funnels at its outlet shall not be required.

WNP-2 Position *Nonconformance. The relief valve is piped back to the wet pit. No provision is made for viewing water discharge.*

NFPA 20-1974 Code of Record Requirement

2-9.6.6 The relief valve shall discharge into an open pipe or into a cone or funnel secured to the outlet of the valve. Water discharge from the relief valve shall be readily visible or easily detectable by the pump operator. Splashing of water into the pump room shall be avoided. If a closed-type cone is used, it shall be provided with means for detecting motion of water through the cone.

WNP-2 Position *This is a code deviation. A valve position indicator shows how far open the valve is, but is not representative of the flow through the valve. The Clayton valves (FP-V-290A/B) will be replaced by standard relief valves in conformance with the code of record and the current code.*

Recommended Action: Replace the Clayton valves with UL listed or FM approved relief valves in an approved configuration. Refer to PERA 298-0813-02.

3. 1996 Edition Code Requirement

2-13.7 The relief valve discharge pipe from an open cone shall be of a size not less than that given in Table 2-20. If the pipe employs more than one elbow, the next larger pipe size shall be used.

WNP-2 Position *Nonconformance. The relief valve is not piped to an open cone.*

NFPA 20-1974 Code of Record Requirement

2-9.6.8 The relief valve discharge pipe from an open cone shall be of a size not less than that given in Table 2-9.6.3. If the pipe employs more than one elbow, the next larger pipe size shall be used.

WNP-2 Position *This is a code deviation. The Clayton valves (FP-V-290A/B) will be replaced by standard relief valves in conformance with the code of record and the current code.*

Recommended Action: Replace the Clayton valves with UL listed or FM approved relief valves in an approved configuration. Refer to PERA 298-0813-02.

4. 1996 Edition Code Requirement

4-3.5.1 The following fittings shall be required for attachment to the pump: (d) Relief valve and discharge cone where required by 2-13.1.

WNP-2 Position *Nonconformance. A relief valve and discharge piping are provided; a discharge cone is not provided. (M515-1)*

NFPA 20-1974 Code of Record Requirement

2-9.6.8 The relief valve discharge pipe from an open cone shall be of a size not less than that given in Table 2-9.6.3. If the pipe employs more than one elbow, the next larger pipe size shall be used.

WNP-2 Position *This is a code deviation. The Clayton valves (FP-V-290A/B) will be replaced by standard relief valves in conformance with the code of record and the current code.*

Recommended Action: Replace the Clayton valves with UL listed or FM approved relief valves in an approved configuration. Refer to PERA 298-0813-02.

5. 1996 Edition Code Requirement

6-2.4.3 Supply conductors shall directly connect the power sources to either a listed combination fire pump controller and power transfer switch or to a disconnecting means and overcurrent protective device(s) meeting the requirements of 6-3.2.2, Exception No. 1.

Exception: Where one of the alternate power sources is an on-site generator, the disconnecting means and overcurrent protective device(s) for these supply conductors shall be selected or set to allow instantaneous pickup and running of the full pump room load.

WNP-2 Position *Nonconformance. Conformance with this section is not achieved by the design and connection of the power sources. (E502, EWD-62E-029)*

NFPA 20-1974 Code of Record Requirement

6-3.4.1 When power supply protective devices (fuses or circuit breakers) are installed in the power supply circuits at utility plants, substations, or plant load distribution centers ahead of the fire pump feeder circuits, such devices shall not open at the sum of the locked rotor currents of the fire pump motor(s) and the maximum plant load currents.

6-3.4.2 When power supply protective devices (fuses or circuit breakers) are installed in the fire pump feeder circuits, such devices shall not open at the sum of the locked rotor currents of the fire pump motor(s) and the necessary associated fire pump installation electrical accessory currents.

WNP-2 Position *This is a code deviation. WNP-2 experience during the surveillance and monthly operability testing is that pump starts have not resulted in any spurious trips. The setting of the circuit breakers from switchgear SL-51 to MC-5N and SL-61 to MC-6N will not open at the sum of the locked rotor currents of the fire pump motor and the maximum plant load per calculation E/I-02-95-01. However, this condition has not impacted system performance.*

Recommended Action: Document this code deviation in an LDCN for FSAR Appendix F Table F.2-1 in accordance with PERA 298-0813-04.

6. 1996 Edition Code Requirement

6-3.1.2 The voltage at the controller line terminals shall not drop more than 15 percent below normal (controller rated voltage) under motor starting conditions. The voltage at the motor terminals shall not drop more than 5 percent below the voltage rating of the motor when the motor is operating at 115 percent of the full-load current rating of the motor.

Exception: This starting limitation shall not apply for emergency-run mechanical starting. (See 7-5.3.2.)

WNP-2 Position *Nonconformance. The 15 percent limit cannot be verified by calculation at this time. Calculation E/I 0290-01 indicates that the 5 percent limit is not met by the system.*

NFPA 20-1974 Code of Record Requirement

6-3.3.2 The voltage at the motor shall not drop more than 5 percent below the voltage rating of the motors when the pumps are being driven at rated output, pressure, and speed, and when the lines between the power station(s) and motors are carrying their peak loads.

6-3.3.3 Where squirrel-cage motors are used, the capacity of the generating station(s), the connecting lines and the transformers shall be ample to keep the voltage from dropping more than 15 percent below normal voltage under motor starting conditions.

WNP-2 Position *This is a code deviation. The motor control center supplying the motors are nominal 480 volt AC. The voltage at the controller during a motor start has been calculated (E/I-02-90-01 working copy) to not drop more than 15% of controller rating during motor starts or (0.85 x 440) = 374. volts. Therefore, the voltage level during motor starts is better than required by the code. The code of record 6-3.3.2 requires that the voltage at the motor terminal be less than 5% below the voltage rating of the motors when the pumps are being driven at rated output. At rated output the voltages have been calculated (E/I-02-90-01 working copy) to be slightly below the requirement for a motor rated at 460 volts. Since NEMA standard motors are rated to operate satisfactorily at 90% voltage, providing slightly below 95% of rated voltage will not affect operability of these motors. However, this condition has not impacted system performance.*

Recommended Action: Document this code deviation in an LDCN for FSAR Appendix F Table F.2-1 in accordance with PERA 298-0813-04.

7. 1996 Edition Code Requirement

6-3.2.1 The power supply to the fire pump shall not be disconnected when the plant power is disconnected.

WNP-2 Position *Nonconformance. The normal source of power is the main plant generator alternatively supplied by off-site power via TR-S transformer. The intent of being able to isolate power to the entire plant without affecting the power supply to the pump motor is not achieved.*

NFPA 20-1974 Code of Record Requirement

6-4.2 Isolation. When transformers supplying current to the lights and motors in the building(s) served by the fire pump also supply the pump motor, arrangements shall be made so that all loads except the pump motor load can be quickly cut off when necessary. Switches for doing this shall be in the pump room.

Exception: If the transformer room is near the pump room, the switches may be in the transformer room.

WNP-2 Position *The two electric drive fire pumps are located in the circulating water pumphouse. Electric fire pump FP-P-2A is fed from motor control center E-MC-5N located in cooling tower electrical bldg. 2. Electric fire pump FP-P-2B is fed from motor control center E-MC-6N located in cooling tower electrical bldg. 1. Each of these feeders is separate from the feeders that supply auxiliary power for the circulating water pumphouse. Hence, disconnecting power to the circulating water pumphouse will not disconnect power to the fire pumps. The source of power for the two cooling tower electrical buildings is from the two 6.9 KV switchgear assemblies (SH-5 and SH-6) located in the turbine generator bldg. These switchgear assemblies in turn receive power from either the plant main generator via transformer TR-N2 or from the network via the X winding of transformer TR-S. Switchgear SH-5 and SH-6 are normally fed from TR-N2 and are provided with a fast transfer to TR-S in the event of a generator trip. If both the generator source and the 230 KV network source are lost, there will be no electric power to the electric drive fire pumps. Such a contingency is covered by the two diesel driven fire pumps. Therefore, this is not a code deviation.*

Recommended Action: No further action is warranted.

8. 1996 Edition Code Requirement

6-3.2.2 Power Supply Arrangements from Normal Source to Pump Motor. The supply conductors shall directly connect the power source to a listed fire pump controller.

Exception No. 1: A disconnecting means and overcurrent protective device(s) shall be permitted to be installed between the power supply and the listed fire pump controller if installed remotely from the other service(s) disconnecting means.

WNP-2 Position *Nonconformance. The requirements of this section are not complied with. (E502, EWD-62E-029)*

NFPA 20-1974 Code of Record Requirement

6-3.4.1 When power supply protective devices (fuses or circuit breakers) are installed in the power supply circuits at utility plants, substations, or plant load distribution centers ahead of the fire pump feeder circuits, such devices shall not open at the sum of the locked rotor currents of the fire pump motor(s) and the maximum plant load currents.

6-3.4.2 When power supply protective devices (fuses or circuit breakers) are installed in the fire pump feeder circuits, such devices shall not open at the sum of the locked rotor currents of the fire pump motor(s) and the necessary associated fire pump installation electrical accessory currents.

WNP-2 Position *This is a code deviation. WNP-2 experience during the surveillance and monthly operability testing is that pump starts have not resulted in any spurious trips. The setting of the circuit breakers from switchgear SL-51 to MC-5N and SL-61 to MC-6N will not open at the sum of the locked rotor currents of the fire pump motor and the maximum plant load per calculation E/I-02-95-01. However, this condition has not impacted system performance.*

Recommended Action: Document this code deviation in an LDCN for FSAR Appendix F Table F.2-1 in accordance with PERA 298-0813-04.

9. 1996 Edition Code Requirement

6-4.1.1 All motors shall be specifically listed for fire pump service. (This requirement shall be effective January 1, 1998.)

WNP-2 Position *Nonconformance. The motors were procured prior to 1/1/98. Prior to this date, motors were not listed for fire protection service by any national laboratories.*

NFPA 20-1974 Code of Record Requirement

The 1996 requirement has been modified to be more restrictive than the code of record. Therefore, this new requirement is not applicable to WNP-2.

Recommended Action: No further action necessary.

10. 1996 Edition Code Requirement

7-4.1 Voltage Surge Arrester. A voltage surge arrester complying with ANSI/IEEE C62.1 or C62.11 shall be installed from each phase to ground. (see 7-3.2.) The surge arrester shall be rated to suppress voltage surges above line voltage.

Exception No. 1: These voltage surge arresters shall not be mandatory for controllers rated in excess of 600 volts. (see Section 7-6.)

Exception No. 2: These voltage surge arresters shall not be mandatory if the controller can withstand without damage a 10-kV impulse in accordance with ANSI/IEEE C62.41.

WNP-2 Position *Nonconformance. Voltage surge arresters are not provided. (EWD-62E-029)*

NFPA 20-1974 Code of Record Requirement

The 1996 requirement has been modified to be more restrictive than the code of record. Therefore, this new requirement is not applicable to WNP-2.

Recommended Action: No further action is warranted. The controllers for fire pump FP-P-2A & FP-P-2B are being replaced by BDC 98-0070-1B under PERA 298-0813-05. The replacement controller will meet the listed requirements.

11. 1996 Edition Code Requirement

7-4.3.3 The circuit breaker shall have the following electrical characteristics:
(f) An instantaneous trip setting of not more than 20 times the full load current.

WNP-2 Position *Nonconformance. This value is not specified in plant records nor could any evidence of its being set or tested be found.*

NFPA 20-1974 Code of Record Requirement

7-4.2.9 The circuit breaker short-circuit current rating shall be selected by using Table 7-4.2.9 when the installation meets the criteria established in the notes to the table.

WNP-2 Position *The instantaneous trip setting of the molded case circuit breaker is set by the manufacturer. No documents were found on the setting and calibration from the vendor. However, specification 2808-29 which purchased the fire pumps & controllers required the equipment to meet NFPA standard 20, chapter 500, "Electric Drive Controllers," and Chapter 700, "Engine Drive Controllers." Based on this specification, this condition is not considered a code deviation. The existing setting has not caused any malfunction. The routine functional testing has not resulted in any spurious trips.*

Recommended Action: No further action is warranted. The controllers for fire pump FP-P-2A & FP-P-2B are being replaced by BDC 98-0070-1B under PERA 298-0813-05. The replacement controller will meet the listed requirements.

12. 1996 Edition Code Requirement

7-4.4 Locked Rotor Overcurrent Protection. The only other overcurrent protective device that shall be required and permitted between the isolating switch and the fire pump motor shall be located within the fire pump controller and shall possess the following characteristics:

(a) For a squirrel-cage or wound-rotor induction motor, the device shall be: 1) Of the time-delay type having a tripping time between 8 seconds and 20 seconds at locked rotor current (approximately 600 percent of rated full load current for a squirrel-cage induction motor); and 2) Calibrated and set at a minimum of 300 percent of motor full load current.

(c) There shall be visual means or markings clearly indicated on the device that proper settings have been made.

WNP-2 Position *a. Nonconformance. No evidence could be found that these settings are recorded or tested.*
c. Nonconformance. There are no such markings on the breaker.

NFPA 20-1974 Code of Record Requirement

7-4.2.7 The circuit breaker shall provide locked rotor and instantaneous short circuit protection.

(a) For a squirrel cage induction motor, the circuit breaker shall be of the time delay type and have a time delay of not over 20 seconds at locked rotor current (this is approximately 600 percent of rated full load motor current for squirrel cage induction motors); and shall be calibrated up to and set at 300 percent of the motor full load current.

WNP-2 Position *The setting for locked rotor overcurrent protection is pre-set by the manufacturer. No documents were found on the setting and calibration from the vendor. However, specification 2808-29 which purchased the fire pumps & controllers required the equipment to meet NFPA standard 20, chapter 500, "Electric Drive Controllers," and Chapter 700, "Engine Drive Controllers." Based on this specification, this condition is not considered a code deviation. The existing setting has not caused any malfunction. The routine functional testing has not resulted in any spurious trips.*

Recommended Action: No further action is warranted. The controllers for fire pump FP-P-2A & FP-P-2B are being replaced by BDC 98-0070-1B under PERA 298-0813-05. The replacement controller will meet the listed requirements.

<u>13. 1996 Edition Code Requirement</u>

7-4.6.2 Phase Reversal. Phase reversal of the power source to which the line terminals of the motor contactor are connected shall be indicated by a visible indicator.

Exception: When power is supplied from multiple power sources, monitoring of each power source for phase reversal shall be permitted at any point electrically upstream of the line terminals of the contactor provided all sources are monitored.

WNP-2 Position *Nonconformance. Phase reversal is not monitored. (EWD-62E-029, Electrical Design Engineer)*

NFPA 20-1974 Code of Record Requirement

The 1996 requirement has been modified to be more restrictive than the code of record. Therefore, this new requirement is not applicable to WNP-2.

Recommended Action: No further action is warranted. The controllers for fire pumps FP-P-2A & FP-P-2B are being replaced by BDC 98-0070-1B under PERA 298-0813-05. The replacement controller will meet the listed requirements.

<u>14. 1996 Edition Code Requirement</u>

7-4.7 Alarm and Signal Devices Remote from Controller. Where the pump room is not constantly attended, audible or visual alarms powered by a source not exceeding 125 volts shall be provided at a point of constant attendance. These alarms shall indicate the following:

(b) Loss of any phase at the line terminals of the motor contactor. (All phases shall be monitored.)

Exception: When power is supplied from multiple power sources, monitoring of each power source for phase loss shall be permitted at any point electrically upstream of the line terminals of the contactor provided all sources are monitored.

(c) Phase Reversal (see Section 7-4.6.2). This alarm circuit shall be energized by a separate reliable supervised power source, or from the pump motor power, reduced to not more than 125 volts.

WNP-2 Position *Nonconformance. All phases of the power supply are not monitored. (EWD-62E-029). (b) Refer to Section 7-4.6.2. (c) See Section 7.4.6.2.*

NFPA 20-1974 Code of Record Requirement

7-4.5 Alarm and Signal Devices Remote from Controller. Where the pump room is not constantly attended, audible or visual alarms powered by a source, not exceeding 125 volts, shall be provided at a point of constant attendance. These alarms shall indicate the following:

(b) Loss of line power on line side of motor starter, in any phase. This alarm circuit shall be energized by a separate reliable supervised power source.

WNP-2 Position *This is a code deviation. The existing controllers monitor one phase of the 3 phase power supply to alarm for loss of power.*

Recommended Action: No further action is warranted. The controllers for fire pump FP-P-2A & FP-P-2B are being replaced by BDC 98-0070-1B under PERA 298-0813-05. The replacement controller will meet the listed requirements.

15. 1996 Edition Code Requirement

7-5.2.1 Water Pressure Control. There shall be provided a pressure-actuated switch having independent high- and low-calibrated adjustments in the controller circuit. There shall be no pressure snubber or restrictive orifice employed within the pressure switch. This switch shall be responsive to water pressure in the fire protection system. The pressure sensing element of the switch shall be capable of withstanding a momentary surge pressure of 400 psig (27.6 bars) without losing its accuracy. Suitable provision shall be made for relieving pressure to the pressure-actuated switch to allow testing of the operation of the controller and the pumping unit. [see Figures A-7-5.2.1(a) and (b).]

(b) The pressure sensing line connection for each pump (including jockey pumps) shall be made between that pump's discharge check valve and discharge control valve. This line shall be corrosion-resistant metallic pipe or tube, and the fittings (brass, copper, or series 300 stainless steel) shall be of 1/2-in. (12.7-mm) nominal size. There shall be two check valves installed in the pressure sensing line at least 5 ft (1.5 m) apart with a 3/32-in. (2.4-mm) hole drilled in the clapper to serve as dampening. [see Figures A-7-5.2.1(a) and (b) for clarification.]

Exception: If water is clean, ground-face unions with noncorrosive diaphragms drilled with 3/32-in. (2.4-mm) orifices shall be permitted in place of the check valves.

WNP-2 Position *Nonconformance. The pressure sensing line connection is downstream (system side) of the discharge control valve. (M515-1)*

NFPA 20-1974 Code of Record Requirement

7-5.2.1 Water Pressure Control. In the controller circuit there shall be provided a pressure-actuated switch having high and low calibrated adjustments, and responsive to water pressure in the fire protection system.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. The affect of this configuration on the performance of the system has been evaluated and determined to be negligible. Therefore, this is not a code deviation.*

Recommended Action: No further action is warranted.

16. 1996 Edition Code Requirement

7-5.2.1(c) There shall be no shutoff valve in the pressure sensing line.

WNP-2 Position *Nonconformance. There is a shutoff valve in the pressure-sensing line. (M515-1)*

NFPA 20-1974 Code of Record Requirement

7-5.2.1 Water Pressure Control. In the controller circuit there shall be provided a pressure-actuated switch having high and low calibrated adjustments, and responsive to water pressure in the fire protection system.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. The affect of this configuration on the performance of the system has been evaluated and determined to be negligible. Therefore, this is not a code deviation.*

Recommended Action: No further action is warranted.

17. 1996 Edition Code Requirement

7-5.2.4 Sequence Starting of Pumps. The controller for each unit of multiple pump units shall incorporate a sequential timing device to prevent any one motor from starting simultaneously with any other motor. Each pump supplying suction pressure to another pump shall be arranged to start before the pump it supplies. If water requirements call for more than one pumping unit to operate, the units shall start at intervals of 5 to 10 seconds. Failure of a leading motor to start shall not prevent subsequent pumping units from starting.

WNP-2 Position *Nonconformance. The pumps (FP-P-1, FP-P-2A, FP-P-2B and FP-P-110) are sequentially started by varying the starting pressure. In addition, P-1 incorporates a 30 second time delay.*

NFPA 20-1974 Code of Record Requirement

7-5.2.3 Sequence Starting of Pumps. The controller for each unit in multiple pump units shall incorporate a sequential timing device to prevent any one pump from starting simultaneously with any other pump. If water requirements call for more than one pump to operate, the units shall start at intervals of 5 to 10 seconds. Failure of a leading pump to start shall not prevent subsequent pumps from starting.

WNP-2 Position *This is a code deviation. Refer to PER 298-0813. The effect of this configuration on the performance of the system has been dynamically modeled and was determined not to have been a contributor to the June, 1998 valve rupture/flooding event. Hydraulic analysis was performed to simulate system transients if the three pumps were time staggered without the Clayton bypass*

flow control valves on the motor driven pumps. The analysis shows that there would have been much higher loads by the use of time staggering. The analysis shows that the motor driven pumps were effectively staggered by the Clayton valves. Attachment C shows that the loads and pressures were essentially the same between a three pump start with the Clayton valves and when only the diesel pump was modeled.

Recommended Action: The controllers will be replaced with a soft-start design as documented in PERA 298-0813-05, however, both of the electric pumps will be started simultaneously. Document this code deviation in an LDCN for FSAR Appendix F Table F.2-1 in accordance with PERA 298-0813-04.

Attachment B-Section 4
Summary of NFPA 20 Review
PF-P-110

1. 1996 Edition Code Requirement

8-2.2.1 Engines shall be rated at standard SAE conditions of 29.61 in. (752.1 mm) Hg barometer and 77°F (25°C) inlet air temperature [approximates 300 ft (91.4 m) above sea level] by the testing laboratory. (See SAE Standard J-1349, Engine Power Test Code — Spark Ignition and Compression Engine.)

WNP-2 Position *Nonconformance. The engine is rated at standard SAE conditions approximating 500 feet above sea level at 85°F. (CVI 02-324-02)*

NFPA 20-1974 Code of Record Requirement

Sections 8-2.2.2/2.2.3 specify an engine horsepower rating deduction which shall be based on temperature and altitude corrections to sea level conditions.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. The engine produces the required horsepower. Therefore, this is not a code deviation.*

Recommended Action: No further action is warranted.

2. 1996 Edition Code Requirement

8-4.3 Fuel supply tank(s) shall have a capacity at least equal to 1 gal per horsepower (5.07 L/kW), plus 5 percent volume for expansion and 5 percent volume for sump. Larger capacity tanks might be required and shall be determined by prevailing conditions, such as refill cycle and fuel heating due to recirculation, and shall be subject to special conditions in each case. The fuel supply tank and fuel shall be reserved exclusively for the fire pump diesel engine.

WNP-2 Position *Nonconformance. The fuel tank capacity is nominally 300 gallons and the BHP rating of the pump is approximately 357 horsepower. (CVI 02-324-02)*

NFPA 20-1974 Code of Record Requirement

Section 8-4.3 specifies "Fuel supply tank(s) shall have the capacity to operate the pump engine for not less than 8 hours. Larger capacity may be required and shall be determined by prevailing conditions and be subject to special condition in each case."

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. The existing tank meets this 8 hour requirement when it is approximately half full. Therefore, this is not a code deviation.*

Recommended Action: No further action is warranted.

3. 1996 Edition Code Requirement

8-6.1 Engines shall be started no less than once a week and run for no less than 30 minutes to attain normal running temperature. They shall run smoothly at rated speed.

WNP-2 Position *Nonconformance. The pump is started and run for testing purposes once per month. (PPM 15.1.4)*

NFPA 20-1974 Code of Record Requirement

8-6.1 Engines shall be started not less than once a week and run for not less than 30 minutes, to bring up to normal running temperature. They shall run smoothly at rated speed.

WNP-2 Position *Plant experience was utilized to establish a performance based periodicity for this functional test. FSAR Appendix F.2.2.1 requires that differences between the installed plant configuration and the design be listed in Table F.2-1. Other requirements were imposed for testing, such as the FSAR F.5.2.3.1.b surveillance requirement to test this pump at least once per month. The change in the pump testing frequency was justified by evaluation as documented in Fire Protection Engineering Evaluation (FPEE) FPF 2.15 Item 1 which was approved by the authority having jurisdiction (AHJ). Therefore, this is not a design code deviation.*

Recommended Action: No further action is warranted.

4. 1996 Edition Code Requirement

9-5.2.1 Water Pressure Control (c) There shall be no shut-off valve in the pressure sensing line.

WNP-2 Position *Nonconformance. There is a shut-off valve FP-V-301 in the pressure sensing line. (M573-2)*

NFPA 20-1974 Code of Record Requirement

9-1.5.1(a) Water Pressure Control. A pressure actuated switch having high and low calibrated adjustments and responsive to water pressure in the fire system shall be provided in the controller circuit.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. The affect of this configuration on the performance of the system has been evaluated and determined to be negligible. Therefore, this is not a code deviation.*

Recommended Action: No further action is warranted.

<u>5. 1996 Edition Code Requirement</u>

9-5.2.4 Sequence Starting of Pumps. The controller for each unit of multiple pump units shall incorporate a sequential timing device to prevent any one engine from starting simultaneously with any other engine. Each pump supplying suction pressure to another pump shall be arranged to start before the pump it supplies. If water requirements call for more than one pumping unit to operate, the units shall start at intervals of 5 to 10 seconds. Failure of a leading engine to start shall not prevent subsequent engines from starting.

WNP-2 Position *Nonconformance. The pump controller does not incorporate a sequential timing device. (M573-2, CVI 02-324-02)*

NFPA 20-1974 Code of Record Requirement

9-1.5.1(c) Sequence Starting of Pumps. Each controller in multiple pump units shall incorporate a sequential timing device to prevent any one pump from starting simultaneously with any other pump. If water requirements call for more than one pump to operate, the units shall start at intervals of 5 to 10 seconds. Failure of a leading pump to start shall not prevent subsequent pumps from starting.

WNP-2 Position *This is a code deviation. Refer to PER 298-0813. The effect of this configuration on the performance of the system has been dynamically modeled and was determined not to have been a contributor to the June, 1998 valve rupture/flooding event. Hydraulic analysis was performed to simulate system transients if the three pumps were time staggered without the Clayton bypass flow control valves on the motor driven pumps. The analysis shows that there would have been much higher loads by the use of time staggering. The analysis shows that the motor driven pumps were effectively staggered by the Clayton valves. Attachment C shows that the loads and pressures were essentially the same between a three pump start with the Clayton valves and when only the diesel pump was modeled.*

Recommended Action: Incorporate a starting time delay feature as documented in PERA 298-0813-07.

<u>6. 1996 Edition Code Requirement</u>

9-5.4.2 Automatic Shutdown After Automatic Start (d) The controller shall not be capable of being reset until the engine overspeed shutdown device is manually reset.

WNP-2 Position *Non-conformance. The vendor instruction manual indicates that the controller can be reset without first resetting the engine devices and warns that this will result in immediate overspeed shutdown of the engine on the next demand. (CVI 02-324-02, pg. 5)*

NFPA 20-1974 Code of Record Requirement

9-1.5.4(b) Automatic Shutdown After Automatic Start (ii) When the emergency overspeed governor operates, the controller shall cause the engine to shutdown without time delay, and lockout until manually reset.

WNP-2 Position *The 1996 requirement has been modified to be more restrictive than the code of record. The controller design will not accommodate this feature. Therefore, this is not a code deviation.*

Recommended Action: Consider revising the operating procedure to include caution and posting the controller with a caution placard.

Attachment C
Hydraulic Analysis of Water Hammer & Validated Event Water Hammer Transient

This attachment provides summary results of the hydraulic analysis of the fire protection system configuration during the June 17, 1998 flooding event (Table C-2). This summary addresses the extent of the preaction system P81 contribution, the NFPA nonconformances associated with the Clayton valves and pump start time staggering, and the effect of a flexible hanger on water hammer severity. Also Table C-1 presents a revised event timeline. Figure C-1 presents post event pump performance data superimposed on event pressure data.

Preaction System P81

The analysis shows that preaction system P81 did not actuate prior to the water hammer but most likely actuated on the pressure surge caused by the water hammer.

Cases 1B & 2B (not shown) were established to represent the scenario with P81 actuating prior to the water hammer (assumed to be four seconds into the transient) on loop pressure increase. The results of these cases show that P81 would significantly dampen the resulting pressures and forces. The initiation of P81 at four seconds was initially chosen because a change of slope in the event pressure data downstream of the motor driven pumps indicated a second system demand. It was assumed, pending hydraulic analysis confirmation, that this was due to P81 actuating. This has been shown not to be the case. In case 3B (three pumps without P81) the pressure at P81 was modeled. The analysis shows that the pressure at P81 did not reach a point to cause P81 to actuate until the water hammer pressure surge occurred. The decrease in recorded pressure at around four seconds in the June 1998 event is shown in the analysis to be related to system demand from P66 and plant standpipes. The root cause timeline has been modified to reflect that P81 most probably initiated sympathetically during the pressure surge immediately following the peak pressure at RB-1 due to the resulting column rejoining pressure surge.

Effect of Clayton Valves

The analysis showed that the Clayton valves functioned as expected to stagger the flow supplied to the fire loop and to reduce motor driven pump forces on starting.

In case 3B, the motor driven pumps are modeled with the Clayton valves in order to compare water hammer forces with case 5B that models no motor driven pump participation. The loads predicted by case 3B and case 5B are very similar showing that the motor driven pump's contribution to the water hammer loads was negligible. The analysis simulates an initial pressure rise of the motor driven pumps discharge that is higher than post event test data. The hydraulic analysis also provides flow velocity time histories for the motor driven pump bypass line upstream of the Clayton valves. These time histories show that, during the first 6.5 seconds of the simulated transient, most of the flow from the motor driven pumps is bypassed, further substantiating that the motor driven pumps do not appear to have contributed to the water hammer event of June 17, 1998. This strongly correlates with empirical data (see Figure C-1). Post event tests indicate that the Clayton valves induced delays between each

pump's start of sustained flow into the loop. Once pump discharge pressure exceeded loop pressure, the flow into the loop gradually increased as the Clayton valves came to their fully closed position. The pressure relief function of the Clayton valves was not needed as the three pumps could not raise loop pressure above the relief setpoint before or after the RB-1 water hammer. Further, the analysis data indicates that the water hammer had occurred before the discharge pressure of the motor driven pumps significantly exceeded loop pressure.

Cases 3B & 5B also allowed correlation of the analysis pressure response at FP-PT-10 with event data. Both cases 3B & 5B closely simulate the pressure transmitter FP-PT-10's output during the event up to the water hammer. Case 3B simulates higher than measured pressures at FP-PT-10's location prior to the water hammer, most probably due to the modeling of the motor driven pumps.

The loads from the root cause analysis model predicted by both case 3B & 5B were marginal for having sufficient forces to cause the rupture of valve FP-V-29D. Therefore, a reinspection of the critical hanger that would mitigate loads to FP-V-29D was conducted. This reinspection found hanger FP-56 degraded (Reference PER 298-2001, dated 12/10/98). Preliminary evidence shows a gap exists between each of the hanger base plates and the supporting concrete wall that exceeds the minimum gap allowed. Additionally, one anchor bolt appeared to be pulled out and two others appeared to be loose. This degradation was not sufficient to significantly impair the support's seismic and normal system performance ability, but was sufficient to impart increased flexural and torsional loads on FP-V-29D from pressure waves created during significant column rejoining impacts.

<u>Flexibility of FP-56 Hanger:</u>

The flexibility of hanger FP-56 was the primary reason that water hammer forces were transferred to FP-V-29D, causing sufficient torsional and flexural loading to rupture the valve.

In order to evaluate hanger FP-56's previous load history, a review of the history of fire protection actuations was conducted. Three past events were chosen for hydraulic simulation. The first was the simulation of an almost identical actuation (Reference PER 298-0112, dated 2/5/98) that occurred in February 1998 with a main fire pump on line. Case 3C investigates the loads of this event. The simulated results were loads that were 1/3 to 1/4 the level of the June 1998 event and were below the levels of concern for the hanger. The second was the simulation of an actuation (P65) that occurred in March 1990 (Reference PER 90-0141, dated 3/9/98). Case 6B investigates the loads of this event. The simulated results were equivalent to the levels of the June 1998 event, however, they were still below the levels of concern for the hanger. The third actuation simulated was an actuation of preaction system P79 (Reference PER 292-0417, dated 5/5/92) that occurred during a refueling outage. Case 7B simulated preaction system P79 tripping. The fire system pressure was being maintained by the jockey pump at the time. The subsequent pressure transient caused three pumps to start. Although the P79 volume is smaller than P66 (approximately 65%) the simulation yields much higher loads. The forces and pressure are approximately 60% higher than the loads in the June 1998 event, but not high enough to cause anchor bolt yielding in the hanger. Table C-2 provides the analysis results of preaction systems.

The hanger was able to accommodate loads generated by system water hammers until the June 1998 event occurred. The cause of the gap is under investigation. This may include potential initial installation errors and anchor bolt loosening through normal system demand and water hammer loading. Reviewing system transient history, it is apparent that the hanger has become more flexible over time. The flexibility of hanger FP-56 is a newly discovered contributing factor in the event.

Effect of Time Staggering Pump Starts Instead of Clayton Valve Staggering

Time staggering the start of the pumps would result in significantly higher forces than occurred during the June 1998 event. The Clayton valves were more effective at reducing water hammer forces than time staggering pump starts.

Case 4B was established to assess the effect of staggering the loading of the pumps through five second time delays between pump starts without the Clayton valves diverting pump flow. This would be the code compliant case. The analysis shows this configuration to have significantly higher loads than case 3B (pump loading controlled by Clayton valves). This case also shows that if the order of starting is reversed to have a motor driven pump lead, that although the water hammer is delayed, the motor driven pumps produce higher water hammer forces than when FP-P-110 is the lead pump with the motor driven pump's loading delayed by Clayton valves (case 3B). Case 4B shows that time delay of the pumps in accordance with NFPA requirements would not have mitigated the water hammer. Additionally, case 5B can be viewed as the code compliant case with an infinite time between the first and second pump starts with FP-P-110 being the lead pump (as the motor driven pumps are not started).

Conclusion:

The post event data and hydraulic analysis show strongly that the actuation of preaction P66 was the sole initiator to the event pressure drop and standpipe voiding. Preaction system P81 sympathetic action did not contribute to standpipe voiding and the resulting water hammer when the water column impacted at the top of RB-1 standpipe. The sympathetic opening of P81 is a result of the pressure surge due to this column rejoining impact.

Hydraulic analysis confirms that fire pumps FP-P-2A & FP-P-2B were under Clayton valve bypass sufficiently long that the motor driven pumps did not participate significantly in the water hammer. Likewise, post event empirical data indicate that the motor driven pumps did not contribute prior to the water hammer. FP-P-1 was time delayed to the extent that it played no role in generating the pressure surge when the void in standpipe RB-1 collapsed. The contribution of the jockey pump, FP-P-3, occurred throughout the event, however its discharge capacity was sufficiently low to discount its contribution to the water hammer.

The pre-existing flexibility of hanger FP-56 allowed the transfer of flexural and torsional loads to FP-V-29D instead of being absorbed by the hanger. The analysis shows that the flow provided by FP-P-110 without motor driven pump participation was sufficient to cause significant water hammer forces and, coupled with the flexibility of hanger FP-56, resulted in valve rupture.

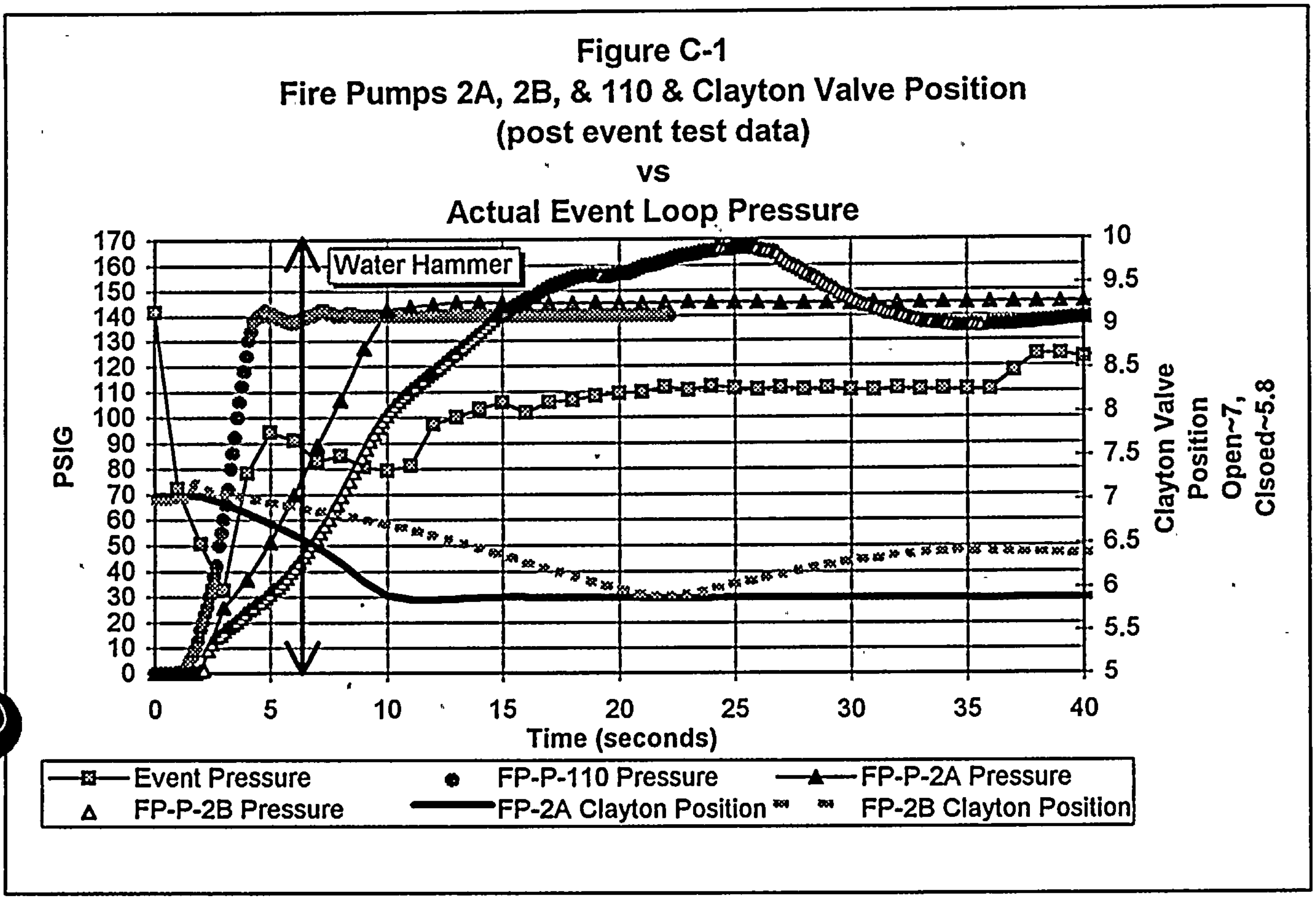
A revised timeline to that contained in Attachment 2 of the inspection report (Reference 1), follows.

Table C-1 Validated Transient Time History
Initial conditions
Fire main pressure at 144 psig, jockey pump on line; system demand is essentially zero, two motor driven pumps & two diesel driven pumps in standby, hanger FP-56 flexible but functional.
Transient conditions
Time zero (13:43:49); Preaction system P66 is actuated by smoke detector, system pressure starts to drop
Second 1; FP-PT-10 is at 72 psig, both motor driven pumps and one diesel driven pump receive start signals. Motor driven pumps start initial lift from Circ water basin. FP-P-110 pump starts at full engine throttle. Air volume downstream of P66 valve begins filling by system pressure and gravity drain from standpipes.
Second 2; FP-PT-10 is at 51 psig, FP-P-110 commences initial discharge into the fire main, preaction P66 air volume continues to fill from standpipes creating a void in building standpipes as water level drops from top of stations tallest standpipes. Pressure oscillations occur in system as standpipes interact.
Second 3; FP-PT-10 is at 32 psig; FP-P-110 pump discharging into loop at low pump speed, preaction P66 continues to fill from FP-P-110 combining with standpipes, motor driven pumps begin to establish a discharge pressure with Clayton valves in full open position. Preaction P81 deluge valve (Clapper) actuation chamber pressure is dropping following the system pressure decrease (due to check valve leakage).
Second 4; FP-PT-10 rapidly rises to 79 psig, Fire Pump FP-P-110 is at near full rated speed but discharging low flow. Motor driven pumps are still under Clayton valve diversion. Rx building riser RB-1 void is at maximum size. Standpipes levels stabilize. P66 is being filled by FP-P-110. Pressure oscillations at P81 stabilize along with Clapper valve chamber pressures equalizing with average system pressure.
Second 5; FP-PT-10 pressure at 95 psig, FP-P-110 pump begins to discharge significant flow into the loop. The analysis shows that FP-P-110 discharge pressure is nearing 145 psig . Increasing flow demand on FP-P-110 after 5 seconds causes the pump discharge pressure to slowly decrease as the pump responds along pump head curve. Pressure increase slows.
Second 6; FP-PT-10 at 90 psig. Preaction system P66 air volume continues to fill. FP-P-110 discharge pressure continues to decrease as the discharge flow increases .
~Second 6.5, Pressure spikes occur due to water hammer when Rx Building RB-1 riser <u>vapor</u> bubble collapses (as the water fills the riser and hits the end cap). The water impact created pressure wave is not sufficiently mitigated by the hanger support system resulting in transfer of flexural and torsional loads to FP-V- 29D. The valve ruptures spilling water to stairwell. Additionally, the pressure wave travels throughout the system. When this wave reaches the inlet to preaction P81 clapper valve, the pressure there exceeds the actuation chamber pressure by at least a factor of two and actuates the P81 valve. RB-2 & P66 continue to fill.
Second 7; FP-PT-10 at 82 psig. FP-P-110 supplying demand from break and P81. Pump FP-P-2A Clayton valve closing raises pump discharge pressure to above system pressure and begins participating in recovering header pressure and supplying P66, P81 and the flow out of the broken valve (breach).
Second 8-9; FP-PT-10 between 85-80 psig, FP-P-110 continues to fill P66, P81 and the breach. Oscillation occur as FP-P-110 and FP-P-2A supply the system demand.
Second 10-12; FP-PT-10 between 80-82 psig, Pump FP-P-2A Clayton valve is nearing full close position providing full pump discharge flow to P81 and the breach. P66 is nearing completion of fill (flow velocity drops).
Second 12-21; FP-PT-10 rises from 98 to 110 psig. Pump FP-P-2B Clayton valve closing raises pump discharge pressure to above system pressure.
Second 22; Pump FP-P-2B Clayton valve nears full close position providing full FP-P-2B discharge flow to the breach.
Second 22-36; Pump FP-P-2A, FP-P-2B, and FP-P-110 maintaining pressure at FP-PT-10 near 110 psig and supplying system breach. FP-P-1 time delayed starts ~ 34 seconds
Second 36 to 38, Diesel pump FP-P-1 begins increasing header pressure, FP-PT-10 stabilizes at 125 psig with four main fire pumps supplying the breach and flooding stairwell and into RHR-C pump room.
Second 39 to 105, four main fire pumps continue at full discharge flow ~10,000 gpm through breach.
Second 106 (13:45:25) RHR-C Pump room water level high alarm received in control room.
Minute 14 Second 26, (13:58:05) First motor driven main fire pump shut down
Minute 14 second 49, Last fire pump at Circ Water Pump house stopped.

Hydraulic Analysis Summary Table

Table C-2						
	Case 3B	Case 5B	Case 4B	Case 3C	Case 6B	Case 7B
Note: P81 not actuated prior to water hammer in Cases 3B- 7B & Case 3C	P66 Actuates FP-P-110, FP-P-2A, FP-P-2B, & Clayton Valves.	P66 Actuates FP-P-110 alone. Note: Electric pumps not started.	P66 Actuates Time Stagger pumps 5 Sec. intervals FP-P-2A, FP-P-2B, FP-P-110 Without Clayton Valves	P66 Actuates FP-P-2A on-line FP-P-110, FP-P-2B, & Clayton Valves. Simulates an Actuation on 2/5/98	P65 Actuates FP-P-110, FP-P-2A, FP-P-2B, & Clayton Valves. Simulates an Actuation on 3/9/90	P79 Actuates FP-P-110, FP-P-2A, FP-P-2B, & Clayton Valves. Simulates an Actuation on 5/5/92
Location	Peak Pressure psig	Peak Pressure psig	Peak Pressure psig	Peak Pressure psig	Peak Pressure psig	Peak Pressure psig
RB-1	1104	1057	1824	203	1147	1727
FP-V-29D	692	690	1064	210	794	1067
Pipe Segment At	Force Kips/ Time-Sec.	Force Kips/ Time-Sec.	Force Kips/ Time-Sec.	Force Kips/ Time-Sec.	Force Kips/ Time-Sec.	Force Kips/ Time-Sec.
6 Before FP-56	-32/6.3	-31/6.4	-59/14	-8/3.1	-33/8.9	-51/8.5
7 At FP-56	-42/6.3	-39/6.4	-70/14	-7.9/3.1	-44/8.9	-69/8.5
8 Bottom RB-1	-32/6.3	-30/6.4	-58/14	-8/3.1	-32/8.9	-516/8.5
9 FP-V-29D	-31/6.3	-30/6.4	-57/14	-7/3.1	-33/8.9	-50/8.5
13 Top RB-1	-18/6.3	-17/6.4	-29/14	-3/3.1	-18/8.9	-28/8.5

5024



Post event testing of the motor driven pumps and the affect of the Clayton valves is shown superimposed on the actual event pressure curve in Figure C-1. The event pressure data was obtained from pressure transmitter FP-PT-10 located on the loop side of the motor driven discharge check valves. This data shows that FP-P-110 was the first pump to supply flow to the system (i.e., was much faster than the motor driven pumps in taking part in the transient). Both motor driven pumps' discharge is delayed, due to the lift time from the circulating water basin, by at least two seconds and the discharge was bypassed significantly during the initial water hammer transient. The combined effect was that loading of the motor driven pumps was effectively staggered by the Clayton valves.