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SUBJECT: Forwards 120 Day response to GL 96-06 re PVNGS,Units 1,2&3.

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APS
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Generating Station

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102-03855-JLM/AKK/JRP
January 28, 1997

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Dear Sirs:

Subject: **Palo Verde Nuclear Generating Station (PVNGS)**
Units 1, 2, and 3
Docket Nos. STN 50-528/529/530
Response to NRC Generic Letter 96-06

This letter provides the 120 day response to NRC Generic Letter 96-06. The Generic Letter requires that Licensees determine if Containment air cooler cooling water systems are susceptible to either waterhammer or two-phase flow conditions during postulated accident conditions and, if piping systems that penetrate the containment are susceptible to thermal expansion of fluid so that overpressurization of piping could occur.

The enclosed response details the actions taken by Arizona Public Service Company (APS) in response to the above issues. The PVNGS susceptibility evaluation is presented as well as the associated operability assessments. As described in the enclosure, further analyses and testing are in progress regarding the containment penetration issue. These analyses and test results will be used to determine if futher actions are required. A supplement to this letter will be provided by May 30, 1997 to describe the final conclusions.

Should you have any questions please contact Scott A. Bauer at (602) 393-5978.

Sincerely,

James M. Levine

A072

JML/AKK/JRP/mah

040062

Enclosure

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J. W. Clifford
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	W. E. Ide	(7616)
	M. F. Hodge	(7561)
	M. A. Radspinner	(7561)
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	W. G. Borrero	(7561)
	M. L. Renfroe	(7153)
	M. E. Powell	(7543)
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CONCURRENCE

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M. E. Powell	MEP 1/24/97 (Approved version reviewed @ 2:40pm on 1/24/97)
J. H. Hesser	JHHesser 1/24/97

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J. H. Hesser	JHHesser 1/24/97

STATE OF ARIZONA)
) ss.
COUNTY OF MARICOPA)

I, J. M. Levine, represent that I am Senior Vice President - Nuclear, Arizona Public Service Company (APS), that the foregoing document has been signed by me on behalf of APS with full authority to do so, and that to the best of my knowledge and belief, the statements made therein are true and correct.

J M Levine

J. M. Levine

Sworn To Before Me This 28 Day Of January 1997.

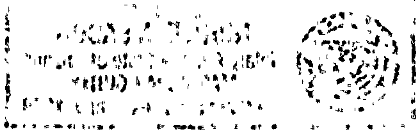
Nora E. Meador

Notary Public

My Commission Expires

OFFICIAL SEAL
NORA E. MEADOR
Notary Public - State of Arizona
MARICOPA COUNTY
My Comm. Expires April 6, 1999

April 6, 1999



COMMITMENTS

1. Implement Defense-in-depth measures for WC and NC Systems as described in Jan 28, 1997 letter

RESPONSIBILITY M. F. HODGE

RCTS 042315.05

DATE DUE May 30, 1997

2. Submit GL 96-06 Supplement

RESPONSIBILITY M. F. HODGE

RCTS 042315.06

DATE DUE May 30, 1997

VERIFICATION of ACCURACY

Letter 281-01985 MFH/JDH, dated January 10, 1997, Subject: closure of RCTS 042315, Action 02.

UFSAR CHANGES

1. Generate LDCR to update FSAR with results of GL 96-06 evaluation

RESPONSIBILITY M. F. HODGE

RCTS 042315.04

DATE DUE July 30, 1997

PALO VERDE NUCLEAR GENERATING STATION

GENERIC LETTER 96-06: 120 DAY RESPONSE

Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions

INTRODUCTION

Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions", was issued by the NRC on September 30, 1996. This letter requires that addressees determine:

(1) if containment air cooler cooling water systems are susceptible to either waterhammer or two-phase flow conditions during postulated accident conditions;

(2) if piping systems that penetrate the containment are susceptible to thermal expansion of fluid so that overpressurization of piping could occur.

According to Generic Letter 96-06, several utilities may not have previously adequately addressed the potential for the post LOCA and MSLB in-containment environment to cause the heatup of containment cooling water systems to the point that steam voids may form within the piping. Such steam voids may subsequently collapse causing an unanalyzed waterhammer event to occur. The potential for two-phase flow to exist in the system piping is also discussed. The identified concern is that the two phase flow conditions may result in system flow being reduced below predicted design basis minimum values. The Generic Letter further discusses the potential for isolated piping sections inside containment to overpressurize due to post-accident environmental conditions.

This response details the actions taken by PVNGS in response to the above requested items. The PVNGS susceptibility evaluation is presented as well as the associated operability assessments. The specific circumstances relating to the affected systems will be identified as well as the schedule for determining the necessity of long term corrective actions.

ISSUE 1: WATERHAMMER AND TWO PHASE FLOW

PVNGS Containment Heat Removal Systems

The following systems were included in the PVNGS waterhammer and two phase flow evaluation scope:

- Normal Chilled Water (WC) System
- Nuclear Cooling Water (NC) System
- Essential Cooling Water (EW) System
- Containment Spray (CS) System

The Normal Chilled Water (WC) System provides the normal non-essential means for in-containment environmental heat removal. The Nuclear Cooling Water (NC) System provides the normal non-essential means for removal of heat from various non-safety related equipment in containment. These two systems are the containment cooling water systems which correspond to those described in Generic Letter 96-06 with the exception that, at PVNGS, they are non-safety related.

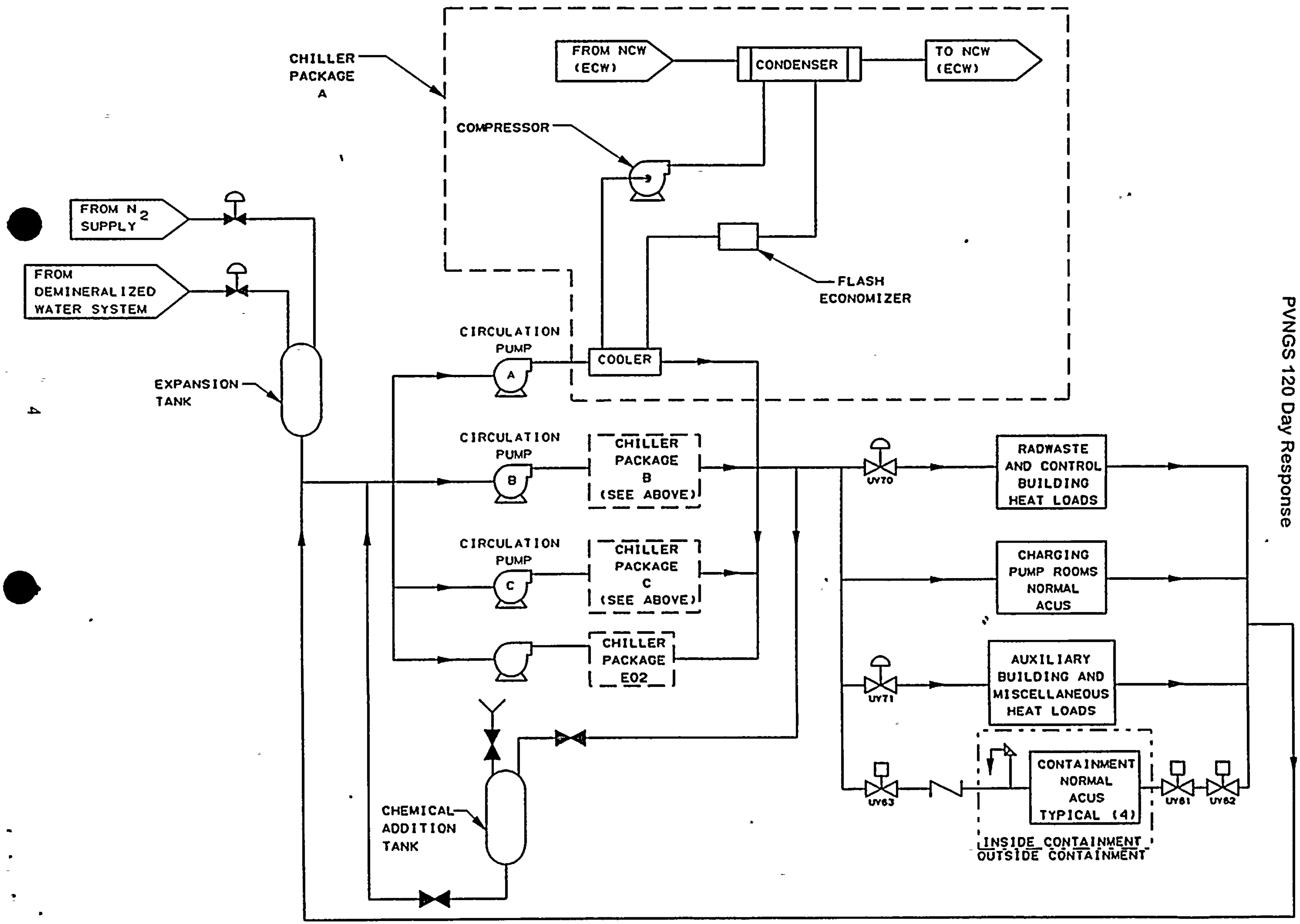
The Essential Cooling Water (EW) System supplies safety related cooling systems outside containment. However, the EW system may be cross-tied to the NC System to supply cooling water for "priority loads", inclusive of the in-containment equipment. The EW system was included in the evaluation scope due to this capability to be aligned with the NC system.

The PVNGS design and licensing basis relies upon the Containment Spray (CS) System for the safety related means of in-containment post accident environmental heat removal. The CS system was added to the evaluation scope to ensure any issues regarding transportability are addressed.

Normal Chilled Water (WC) System Susceptibility Evaluation

The Normal Chilled Water (WC) System provides the normal non-essential means for in-containment environmental heat removal at PVNGS. The WC System removes in-containment environmental heat by providing cooling water to the Containment Fan Cooler Units. (See Figure 1, page 4) The four Containment Fan Cooler Units are non-safety related and are not credited for containment heat removal following design basis events. The WC System is designed to continue to provide cooling water to the containment following those design basis events that do not result in a Containment Isolation Actuation Signal (CIAS). Upon receipt of a CIAS, the automatic WC System Containment

FIGURE 1: NORMAL CHILLED WATER (WC) SYSTEM SCHEMATIC



Isolation Valves 13JWCBUV0061, 13JWCAUV0062, and 13JWCBUV0063 automatically close. The WC supply line inboard containment isolation valve 13PWCAV0039 is a check valve which will close to isolate containment upon loss of WC flow. As a result, the portions of the WC System located in containment are isolated from the balance of the WC System following the design basis pipe rupture events that result in elevated containment pressures and temperatures.

During normal operation, there is no credible mechanism for a water hammer event to occur. The system is a closed loop and maintained water solid via an expansion tank (13MWCNT01) which is outside containment and is physically located at the system high point. As a result, there is no potential for water column separation during system transients. There are also no sources of heat under normal operation that could cause steam voids to develop.

Thermal relief valves (WCNPSV0131, 132, 133, and 134) are provided on the piping within the equipment isolation boundary for each of the four Containment Fan Cooler Units. These relief valves are designed to provide equipment overpressure protection when the equipment has been isolated and a heat source causes the heatup and expansion of the trapped fluid within the isolation boundary. The combined relieving rate of the relief valves has been determined to be adequate to discharge the amount of water required to preclude overpressurization during accident conditions. In addition, the relief valve setpoints are higher than the saturation pressure of the post accident heated water in the system. Thus, the formation of steam voids is prevented, which precludes the development of waterhammer or two-phase flow conditions.

While there is no safety related requirement to restore WC flow to the Containment Fan Cooler Units following design basis pipe rupture events, the plant emergency procedures [Ref. 1 to Ref. 4] allow for the restoration of Containment Cooling in some situations. The process of restoration of WC flow to the Containment Fan Cooler Units following a design basis event could have the undesirable potential to depressurize the in-containment piping, thereby allowing the formation of steam voids in the piping and creating the potential for a water hammer upon WC flow restoration. This potential is avoided by verifying that the WC System is operating prior to the opening of the WC Containment Isolation Valves, as is presently required by the operating procedures. This will ensure that the system remains pressurized at all times, precluding the potential for steam void formation.

Per the foregoing discussion, installed thermal relief valve capacities and setpoints preclude the development of waterhammer or two phase flow conditions within the WC system as a result of elevated post accident temperatures in containment. However, the following actions will be implemented as defense-in-depth measures and to ensure adequate documentation within the design bases:

- The minimum relief capacity contained in the design specifications for the WC system thermal relief valves (WCNPSV0131, 132, 133, and 134) is not sufficient to accommodate the expected expansion rate of the post accident system water. However, the as - built relief capacity of the valves installed in the plant is greater than that required in the specification and has been found to be adequate. Therefore, the design specifications will be revised to require a relief capacity equal to that actually installed in the PVNGS operating units to ensure any future replacements are adequately sized for the discussed scenarios.

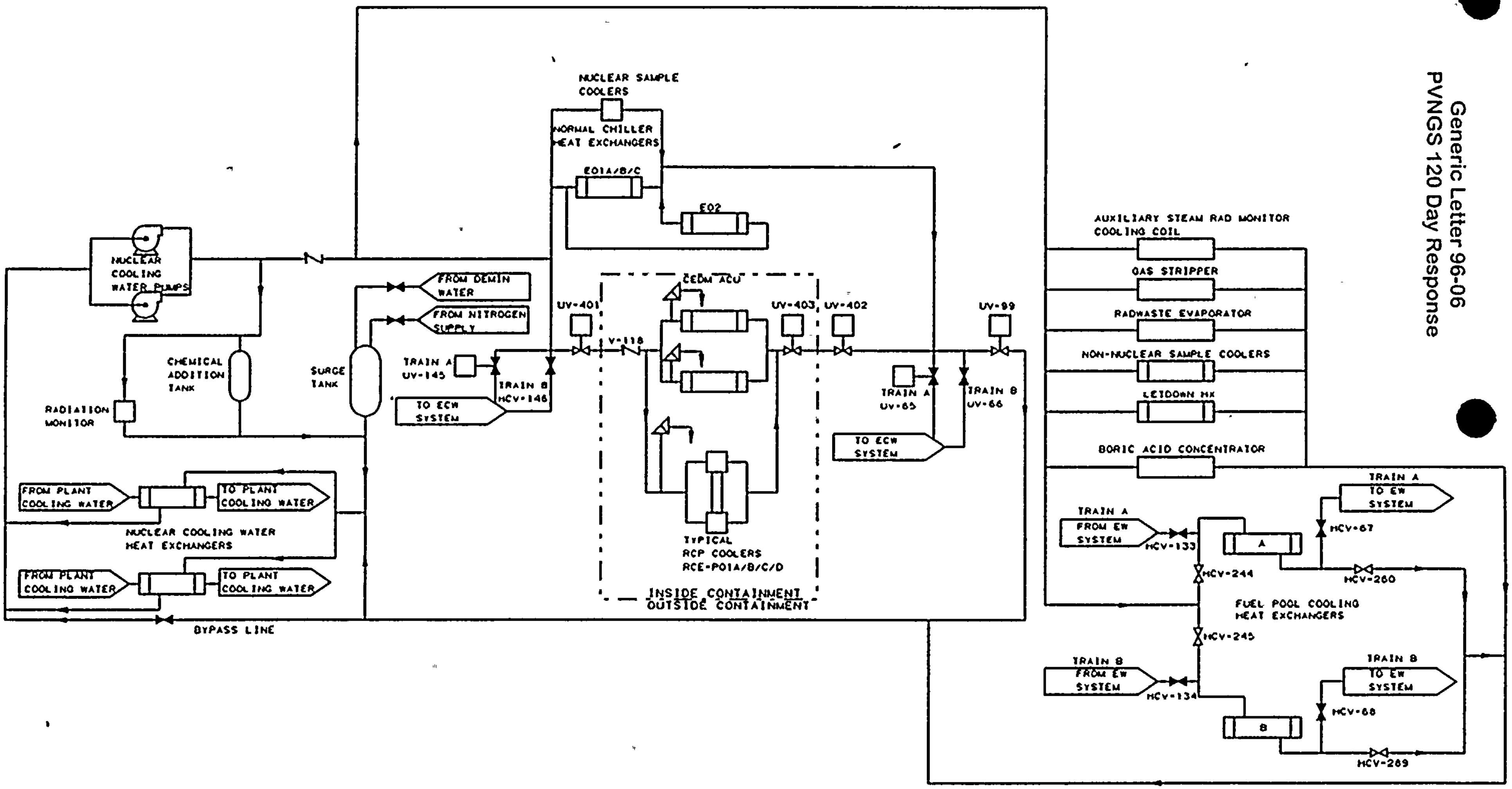
- Procedural guidance will be implemented to specify the valve opening sequence for restoration of WC cooling flow to the Containment Fan Cooler Units. The designated sequence will be to open Valve 13JWCBUV0063 first, Valve 13JWCBUV0061 second, and Valve 13JWCAUV0062 last. This opening sequence will serve as an added measure to maintain the pressure of the in-containment piping above the saturation pressure and further minimize the development of waterhammer conditions upon system restoration.

Nuclear Cooling Water (NC) System Susceptibility Evaluation

The Nuclear Cooling Water (NC) System provides the normal non-essential means for removal of heat from various non-safety related equipment in containment. The NC System removes in-containment equipment heat by providing cooling water to the Control Element Drive Mechanism (CEDM) Air Cooling Units (ACU's) and the Reactor Coolant Pump (RCP) High Pressure (HP) Cooler, Seal Cooler and Thrust Bearing Lube Oil Cooler. (See Figure 2, page 7) The NC System is designed to continue to provide cooling to the containment following those design basis events that do not result in a Containment Spray Actuation Signal, provided that a Loss Of Power (LOP) has not occurred. Upon receipt of a CSAS, the NC System Containment Isolation Valves 13JNCBUV0401, 13JNCAUV0402, 13JNCBUV0403 automatically close. The NC supply line inboard containment isolation valve 13PNCEV0118 is a check valve which will close to isolate containment upon loss of NC flow. As a result, the portions of the NC System in containment are isolated from the balance of the NC System following the design basis pipe rupture events that result in elevated containment pressures and temperatures.

During normal operation, there is no credible mechanism for a water hammer event to occur. The system is a closed loop and maintained water solid via an expansion tank (13MNCNT01) which is outside containment and is physically located at the system high point. As a result, there is no potential for water column separation during system transients. There are also no sources of heat that under normal operation could cause steam voids to develop.

FIGURE 2: NUCLEAR COOLING WATER (NC) SYSTEM SCHEMATIC



Following a design basis pipe rupture event such as a LOCA or MSLB, and upon receipt of a CSAS, the NC system Containment Isolation valves close to isolate the in-containment portions of the NC System. The NC System piping in-containment, which is not insulated, will heat up to the post event containment ambient conditions. This heatup will cause thermal expansion of the water trapped in the piping and components.

Thermal relief valves are provided on the piping within the equipment isolation boundary for both the CEDM ACU's and the RCP Coolers. These relief valves (13JNCNPSV0480, 13JNCNPSV0499, 13JNCNPSV0414, 13JNCNPSV0415, 13JNCNPSV0416 and 13JNCNPSV0417) are designed to provide equipment overpressure protection when the equipment has been manually isolated and a heat source causes the heatup of the trapped fluid within the isolation boundary. The NC System is also provided with two large relief valves (13JNCAPSV0614 and 13JNCBPSV0615) designed to protect the containment penetration and isolation valves from being overpressurized in the event of an intersystem LOCA via the Reactor Coolant Pump (RCP) High Pressure (HP) Coolers. These relief valves are adequately sized to relieve any pressure buildup that could occur following a design basis event. However, the 13JNCNPSV0480, 13JNCNPSV0499, 13JNCNPSV0414, 13JNCNPSV0415, 13JNCNPSV0416 and 13JNCNPSV0417 thermal relief valves are predicted to provide adequate pressure relief at system pressures lower than the minimum setpressure of valves 13JNCAPSV0614 and 13JNCBPSV0615. Therefore, it is not expected that the 13JNCAPSV0614 and 13JNCBPSV0615 relief valves will open following a design basis pipe rupture inside containment. However, as the blowdown setpoint pressure of all the NC System in-containment thermal relief valves is above the saturation pressure corresponding to any of the design basis pipe rupture event peak temperatures, the water that remains in the NC System piping and components will remain in its subcooled liquid state and the system will remain water solid.

While there is no safety related requirement to restore flow to the NC System in-containment heat loads following design basis pipe rupture events, the plant emergency procedures [Ref. 1 to Ref. 4] allow for the restoration of Nuclear Cooling if continued operation of the RCP's and/or restoration of operation of the RCP's is desired. The process of restoration of NC flow to the in-containment heat loads following a design basis event could have the undesirable potential to depressurize the in-containment piping, thereby allowing the formation of steam voids in the piping and creating the potential for a water hammer upon NC flow restoration. This potential is avoided by verifying that the NC System is operating prior to the opening of the NC Containment Isolation Valves, as is presently required by the operating procedures. This will ensure that the system remains pressurized at all times, precluding the potential for steam void formation.

Per the foregoing discussion, installed thermal relief valve capacities and setpoints preclude the development of waterhammer or two phase flow

conditions within the NC system as a result of elevated post accident temperatures in containment. However, the following actions will be implemented as defense-in-depth measures and to ensure adequate documentation within the design bases:

- The minimum relief capacity contained in the design specifications for the NC system thermal relief valves (13JNCNPSV0480, 13JNCNPSV0499, 13JNCNPSV0414, 13JNCNPSV0415, 13JNCNPSV0416 and 13JNCNPSV0417) is not sufficient to accommodate the expected expansion rate of the post accident system water. However, the as - built relief capacity of the valves installed in the plant is greater than that required in the specification and has been found to be adequate. Therefore, the design specifications will be revised to require a relief capacity equal to that actually installed in the PVNGS operating units to ensure any future replacements are adequately sized for the discussed scenarios.

- Procedural guidance will be implemented to specify the valve opening sequence for restoration of NC cooling flow to the in-containment equipment. The designated sequence will be to open Valve 13JNCBUV0401 first, Valve 13JNCBUV0403 second, and Valve 13JNCAUV0402 last. This opening sequence will serve as an added measure to maintain the pressure of the in-containment piping above the saturation pressure and further minimize the development of waterhammer conditions upon system restoration.

Essential Cooling Water (EW) System Susceptibility Evaluation

The Essential Cooling Water (EW) System does not have any portions located within the containment building and is therefore not directly subject to the environmental effects of the post design basis event containment environment. However, either train of the EW System can be cross-tied with the NC System to provide a back-up source of cooling to those portions of the NC System that are considered "priority" heat loads. (See Figure 2, page 7) The in-containment CEDM ACU's and the RCP Coolers are considered priority heat loads and can be cooled via a cross-tied train of the EW System. A-Train cross-tie supply and return isolation Valves 13JEWAUV0065 and 13JEWAUV0145 are automatic and close upon receipt of a Safety Injection Actuation Signal (SIAS), thereby automatically isolating EW Train A from the NC System. B-Train cross-tie supply and return isolation Valves 13PEWBHCV0066 and 13PEWBHCV0146 are manual valves.

There are no safety implications as a result of operation with EW cross-tied to the NC System priority heat loads for the following reasons:

- Valves 13JEWAUV0065 and 13JEWBUV0145 which are the cross-tie supply and return isolation valves, close automatically upon receipt of a Safety

Injection Actuation Signal (SIAS), thereby isolating EW Train A from the NC System. Train A is designated by Procedure as the "preferred" EW train to cross-tie to support NC.

- The NC Containment Isolation Valves will close to isolate the in-containment portions of NC System from the cross-tied EW System upon a CSAS.

- The EW Train cross-tied to the NC System priority loads must be considered inoperable as throttling of the EW system flow is required to redirect it to the NC System in-containment equipment [Ref. 2]. Per ANSI 51.1, Section 3.2.1.h, it is not required to postulate a design basis event during the time period one train of a safety related redundant system is declared inoperable in accordance with the plant Technical Specifications.

No corrective actions are required or recommended for the Essential Cooling Water System in response to Generic Letter 96-06.

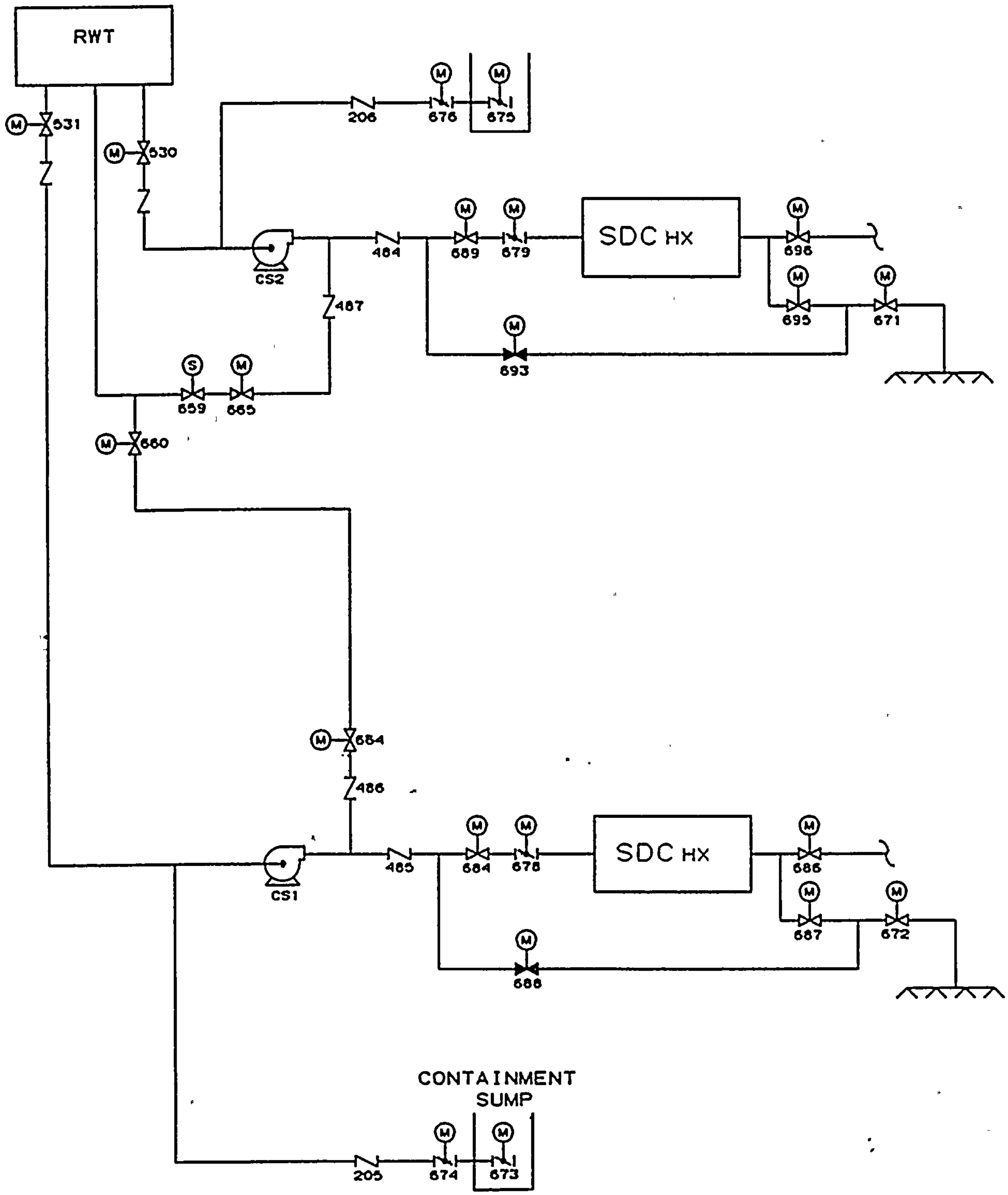
Containment Spray (CS) System Susceptibility Evaluation

The containment spray system is designed to provide the essential means of containment heat removal following design basis events that result in both an elevated pressure and temperature, such as a LOCA, MSLB, or FWLB. The CS System is automatically actuated on high - high containment pressure (8.5 psig per Technical Specification Table 3.3-4). Two separate and redundant trains are provided as a part of the CS System design.

The development of two phase flow conditions within the CS system would result in the undesirable effect of reducing the mass flow rate of subcooled water in the piping. However, the CS system is not a closed loop system but discharges directly to the post accident containment atmosphere. (See Figure 3, page 11) Thus, by virtue of the CS system design, the pressure within the CS piping must be greater than that of the containment atmosphere. This means that the operating pressure of the CS system is higher than the saturation pressure of the post accident containment environment, precluding the formation of steam voids within the CS piping. Therefore, there is no potential for the development of two phase flow conditions within the CS system while it is operating post accident.

The CS System has been analyzed for a waterhammer event. The postulated waterhammer event is that steam from the design basis event fills the containment spray header during the period following event initiation and prior to the containment spray header being filled. The waterhammer is postulated to occur when the "cold" containment spray water (assumed to be at the Reactor Water Tank (RWT) minimum temperature of 40°F) contacts the steam in the piping and causes it to condense and collapse. This scenario is bounding for both the initial system fill in response to the CSAS, and for any subsequent

FIGURE 3: CONTAINMENT SPRAY (CS) SYSTEM SCHEMATIC



operator initiated containment spray actuations, such as utilization of the redundant train upon restoration of that train. The containment spray waterhammer analyses are documented in References 6, 7, 8, 9, and 10.

The Containment Spray System is properly analyzed and designed for the post design basis event containment environment, inclusive of potential waterhammer or two phase flow conditions. No corrective actions are required or recommended for the Containment Spray System in response to Generic Letter 96-06.

Summary

The PVNGS containment cooling water systems are not susceptible to the development of waterhammer or two phase flow conditions as discussed in Generic Letter 96-06. No corrective actions are required. However, limited, defense in depth actions will be taken to further enhance the system design with respect to these conditions.

ISSUE 2: OVERPRESSURIZATION OF IN-CONTAINMENT PIPING

PVNGS Isolable Piping Systems Penetrating Containment

During the development of the Motor Operated Valve design basis, as required by NRC Generic Letter 89-10, PVNGS self-identified that isolable sections of piping, without installed relief valves, existed in containment. Condition Report/Disposition Request (CRDR) 9-5-0669 was initiated, per the PVNGS corrective action program, on June 30, 1995 and an operability assessment performed regarding the potential in-containment post accident effects on the identified systems. This assessment concluded that the identified issue was not an operability concern. Since that time, the PVNGS staff has been performing analysis and testing in order to evaluate an acceptable, long term, design solution for the identified piping systems.

Table 1 below lists the identified isolable piping, without installed relief valves, which penetrate the containment structure and are susceptible to overpressurization.

TABLE 1: PVNGS ISOLABLE CONTAINMENT PENETRATIONS

SYSTEM	PENETRATION	ISOLATION VALVES
Nuclear Cooling Water (NC)	U033 (return from containment)	JNCAUV0402 JNCBUV0403 (MOV butterfly valves)
Radioactive Waste Drains (RD)	U009 (drain from containment)	JRDAUV0023 JRDBUV0024 (MOV/SOV gate valves)
Normal Chilled Water (WC)	U061 (return from containment)	JWCAUV0062 JWCBUV0061 (MOV gate valves)
Demineralized Water (DW)	U006 (supply to containment)	PDWEV061 PDWEV062 (manual globe valves)
Fuel Pool Cooling and Cleanup (PC)	U050 (return from containment)	PPCEV070 PPCEV071 (manual gate valves)
Fuel Pool Cooling and Cleanup (PC)	U051 (supply to containment)	PPCEV075 PPCEV076 (manual gate valves)

In addition to the piping sections listed above, piping directly adjacent to the in-containment side of the PDWEV062, PPCEV071, and JRDAUV0023 isolation valves, also has the capability to trap system water. These sections of piping are

non-safety related and will be addressed in conjunction with each associated penetration.

The Nuclear Cooling Water (NC) and Normal Chilled Water (WC) systems have been described previously within this report. The NC, and WC isolation valves identified in the table above are normally open with their respective systems operating at full flow conditions. The WC valves close upon the receipt of a Containment Isolation Actuation Signal (CIAS) and the NC valves close upon a Containment Spray Actuation Signal (CSAS). These valves have no ESF safety function requirement to open post-accident.

The Demineralized Water system processes water from the reverse osmosis units of the Domestic Water system to remove dissolved gas and solids, stores the demineralized water, and transfers it to each unit. The DW penetration identified above is the makeup supply piping to the Containment Spray system header. The manual operated DW isolation globe valves are normally locked closed during power operation.

The Radioactive Waste Drain System drains the noncorrosive, radioactive or potentially radioactive liquid wastes from the floor and equipment drains of the unit. Wastes collected are pumped to the Liquid Radwaste System for processing. The RD penetration piping identified above is the flowpath by which the containment radwaste sumps are drained to the Liquid Radwaste Holdup Tanks. The RD system isolation valves JRDAUV0023 and JRDBUV0024 are normally open and close upon the receipt of a Containment Isolation Actuation Signal (CIAS).

The Fuel Pool Cooling and Cleanup System (PC) provides the safety related functions of removing decay heat from the spent fuel pool and providing water retention for shielding and decontamination factor in the event of a fuel failure. In addition, the PC system provides the non-safety related function of maintaining water clarity capability and providing radioactive cleanup for the Refueling Water Tank and the spent fuel pool, which are located outside of containment, as well as the refueling pool. The sections of PC piping identified in Table 1 are associated with the non-safety pool cleanup function. Specifically, the identified penetrations are the water supply and return for the refueling pool. The manual operated PC gate valves (PPCEV070, PPCEV071, PPCEV075, PPCEV076) are normally locked closed during power operation.

In each case identified above the isolation valves under consideration have no design basis safety function to actuate open post-accident. The concern is that these sections of piping may become overpressurized during high temperature, harsh containment conditions and catastrophically fail so as to compromise containment integrity.

Actions Taken By PVNGS Staff

PVNGS staff self identified the condition of isolable containment piping systems which penetrate containment and have no installed relief valves in June of 1995. CRDR 9-5-0669 was initiated to evaluate the identified condition and an operability assessment was performed. This assessment concluded that the identified condition did not place operability of the PVNGS units in question. The PVNGS staff has also determined that the configuration of the penetrations identified in Table 1 are documented and defended in the PVNGS Licensing Basis. However, efforts have been made to develop measurable, predictable, quantifiable arguments to more accurately model the behavior of the isolated penetrations and components under postulated design basis accident conditions.

An independent thermal analysis was performed and documented in APS Study 13-MS-A99 [Ref. 5]. This analysis developed the internal pressure & temperature time history for the penetrations during and after a LOCA condition inside of containment for the identified RD, NC, and WC penetrations. These profiles assume that the valves and piping are water solid and that no leakage from the piping or valves occurs. The study concluded that, given these conservative assumptions, overpressurization of the components is expected. The study did not consider the PC and DW penetrations, but these piping sections are subjected to the same environmental conditions as those considered. Therefore, it was considered reasonable to assume that PC and DW penetrations will overpressurize as well under the same conservative assumptions.

Although Study 13-MS-A99 concluded that overpressurization is expected, it is the opinion of the PVNGS staff, based on testing and analyses, that intrinsic pressure relief mechanisms exist for the penetration piping and valves which would prevent catastrophic failure of these components or loss of containment integrity under accident environmental conditions. This position will be detailed later in this report under the section regarding the PVNGS operability assessment.

The Emergency Operating Procedures (EOPs) were evaluated for those valves provided with remote actuation capability. As previously stated, the identified containment isolation valves have no design basis safety function to actuate open post-accident. However, the EOPs do provide direction to open the RD, NC, and WC isolation valves under some conditions, if they are available. The evaluation concluded that the inability to open the RD, NC, and WC containment isolation valves would prevent some steps in the EOPs from being performed. However, none of these steps describe actions credited in the design basis or the UFSAR. Two of them, restoration of normal containment cooling (WC and NC) and restoration of RCP cooling water (NC) are steps described in the generic Emergency Procedure Guideline, CEN-152. The inability to perform these steps could result in a recovery that is not optimal, but is no more limiting

than the recovery that would take place under the design conditions of a loss of offsite power with only safety related systems available.

Analyses have been performed, and are being finalized, which predict the system component pressure loads and expected behavior under the postulated accident conditions. Verification testing to validate the analytical models is also being performed. These analyses and testing have further supported the initial operability assessments. The analyses and test reports will be documented in APS Study 13-MS-B06 (in process) and will assist in determining the most appropriate long term design solution. Details of this work will be discussed in the operability assessment sections to follow in this report.

PVNGS has been accomplishing the above actions under an action plan associated with CRDR 9-5-0669 and this plan is nearing completion. Generic Letter 96-06 was issued in the course of completing these actions, which are detailed in this response. The schedule for submitting the results of the PVNGS evaluation is May 30, 1997.

PVNGS Compliance With Licensing Basis

The PVNGS Containment Isolation System is described in section 6.2.4 of the PVNGS Updated Final Safety Analysis Report (UFSAR) [Ref. 12]. The PVNGS units 1 - 3 were licensed, in part, utilizing the Independent Design Review (IDR) process. Section 1.8, "Unique Review Methods", of the PVNGS Safety Evaluation Report (SER) [Ref. 11] states the following:

"During the review of PVNGS 1 - 3, the staff used, in addition to the traditional approach, the two innovative methods of review discussed below."

Section 1.8.1, "Independent Design Review", of the PVNGS SER further states:

"The Independent Design Review (IDR) is a systematic, technically - oriented, and documented evaluation of a system and associated equipment against requirements by a team of independent specialists. Such reviews were performed by industry engineers (with the participation of the NRC staff) who are familiar with the design requirements of the system in question, but who were not directly involved in the design of that system. The objective of such a review was to ensure that the design satisfies NRC requirements and to document that finding in sufficient detail to permit an NRC staff reviewer to make a finding of design acceptability."

PVNGS is committed to Containment Isolation Standard ANSI N271-1976/ANS 56.2 via the commitment to Regulatory Guide 1.141, Revision 0, April 1978. Standard ANSI N271-1976/ANS 56.2 does not mandate specific configurations

wherein overpressure protection is required. The language of the standard places responsibility for determining the necessity of overpressure protection for a given piping/component configuration on the licensee. However, during the Containment Systems Independent Design Review (1981) the Review Board did request that PVNGS justify the decision not to install overpressure protection on certain containment penetrations which isolate cold water. The following excerpt pertains to the issue of overpressure protection for isolable containment penetrations at PVNGS [Ref. 6]:

"On Table 6.2.4 - 1 of the FSAR, several penetrations normally contain cold water between the isolation valves or the blind flanges; for example, Penetration 53, the fuel transfer tube, and Penetrations 61 and 62, which are chilled water. These lines from the inside isolation valve or flange to the containment penetration will be exposed to elevated post - accident temperatures with a fixed volume of cold water trapped between the isolation valves. Will the increased pressure inside these lines as a result of heating cause rupture of the piping?"

The transcripts of this Design Review, inclusive of the excerpt above, were transmitted to the USNRC under the letter listed in Reference 6 of this report. This correspondence to the NRC from PVNGS is listed in the PVNGS SER, Appendix A, "Chronology Of Radiological Review" [Ref. 11]. Penetration 61 noted above is listed in Table 1 of this report. Penetrations 53 and 62 listed above were evaluated under CRDR 9-5-0669 and determined not to be susceptible to overpressurization.

PVNGS responded to the request to examine the need to add relief systems to closed - cold penetrations detailed above as follows [Ref. 7]:

"The theoretical expansion of water in a perfectly rigid, closed, vaporless container can result in high pressure, although the amount of expansion or volume leakage required to reduce the pressure is quite small (4%). The containment penetrations are not assumed to be perfectly rigid, nor are the valves assumed to be leak-tight at excessive pressures. In addition, the trapped fluid will not attain the maximum pressure associated with the containment atmosphere temperature due to heat loss from the pipe to the environment. The flued head penetration design at PVNGS has only the flued head exposed to the elevated temperatures. We do not believe relief systems need to be added to closed - cold penetrations."

This response, regarding the justification for not installing overpressure protection on isolable containment penetrations at PVNGS, was transmitted to the USNRC under the letter listed in Reference 7 of this report. This correspondence to the NRC from PVNGS is listed in the PVNGS SER, Appendix A, "Chronology Of Radiological Review" [Ref. 11].

Per the references detailed above, the justification for not installing overpressure protection on isolable containment penetrations was reviewed by the USNRC under the licensing process documented in the PVNGS SER. Section 6.2.4 of the PVNGS SER, "Containment Isolation System", states the following:

"The staff concludes that the PVNGS containment isolation system meets the requirements of GDC 54, 55, 56, and 57 and NUREG 0737 Item II.E.4.2, satisfies the provisions of RG 1.141, and conforms to all staff positions and industry codes and standards, and is therefore acceptable, with the exception of the three issues previously mentioned above."

The three issues to which exception was taken do not relate to overpressure protection for containment penetrations [Ref. 11, page 6-17].

Per the PVNGS licensing documentation presented above, the PVNGS staff considers the as-built configuration of the isolable containment penetrations listed in Table 1 to be in compliance with the PVNGS Licensing Basis.

General Considerations Regarding The PVNGS Operability Assessment

During the licensing process, PVNGS addressed the issue of overpressure protection on containment penetrations which isolate cold water, as discussed above. The PVNGS response to this issue, contained in the Containment Systems Independent Design Review open items responses [Ref. 7], consisted of the following points:

- **The containment penetrations are not assumed to be perfectly rigid.** Thus, the piping and components can be expected to plastically deform so as to accommodate some of the effects of the increased internal pressures.

- **The valves are not assumed to be leak-tight at excessive pressures.** Thus, a degree of pressure relief is anticipated to result via valve leakage.

- **The isolated, trapped fluid will not attain the maximum pressure associated with the peak containment atmosphere due to heat loss from the pipe to the environment.** Thus, heat transfer effects are expected to limit the maximum attainable pressures.

The response further stated that the amount of volume leakage required to preclude system/component over-pressurization was quite small. Therefore, given the specified inherent relief mechanisms, the PVNGS response concluded that the addition of relief systems to closed, cold penetrations was not required. The PVNGS staff considers that these arguments remain valid with regard to

precluding over-pressurization to the point of catastrophic failure and loss of containment integrity.

In addition to the qualitative reasons presented above, efforts have been made to develop a measurable, predictable, quantifiable method to more accurately model the behavior of the isolated penetrations and components under postulated design basis accident conditions. This work involved the development of analytical models and verification testing to predict gasket leakage pressures and corresponding leakage rates. The testing was performed on a test mock-up which consisted of a three inch stainless steel Anchor/Darling wedge gate Motor Operated Valve and three inch schedule 40 stainless steel pipe. The leakage pressures and rates were determined for various valve bonnet bolting torques and utilized the new gasket constants proposed by the Pressure Vessel Research Council (PVRC). The new gasket constants determined by the PVRC define the gasket mechanical and leakage behavior. In addition, analysis and testing were conducted to evaluate the line pressures required to deflect the flex wedge disk away from the valve seat. Deflection of the gate valve disk allows leakage transfer from the piping into the valve bonnet cavity.

The results of the analysis and testing were reviewed with respect to each of the penetrations identified under the original disposition of CRDR 9-5-0669. It was established that the maximum pressures that the piping and valves can sustain without loss of pressure integrity are above those that can realistically be expected to develop within the components as a result of a Design Basis Accident. This conclusion was clearly demonstrated during the hot testing performed wherein the test piping and valve were heated at rates equivalent to the maximum heat up rates expected in the components and to final temperatures which exceeded those postulated. In particular, it was found that once the gasket initially leaked, further pressurization due to temperature increase was not possible. That is, as soon as leakage occurred, the pressure increase was dampened such that the pressure at which leakage started remained essentially constant despite continued temperature increase. It is surmised that this effect is due to the amount of air trapped in the system despite great efforts to remove as much air as possible. In order to remove trapped air, the test valve utilized in the hot test was vented through a connection in the upper portion of the bonnet neck and by loosening the packing. This degree of venting is not attempted nor achievable in the actual field installations. Thus, the containment penetrations of concern will posses a greater amount of trapped air when isolated than that observed during the controlled testing. Therefore, pressurization above the initial pressure leakage levels is not a reasonable expectation. This conclusion applies to each containment penetration under review.

The expected range of pressures in the piping system were calculated assuming a water solid pipe with no trapped air and crediting pipe deformation. The minimum pipe deformation was calculated utilizing only circumferential

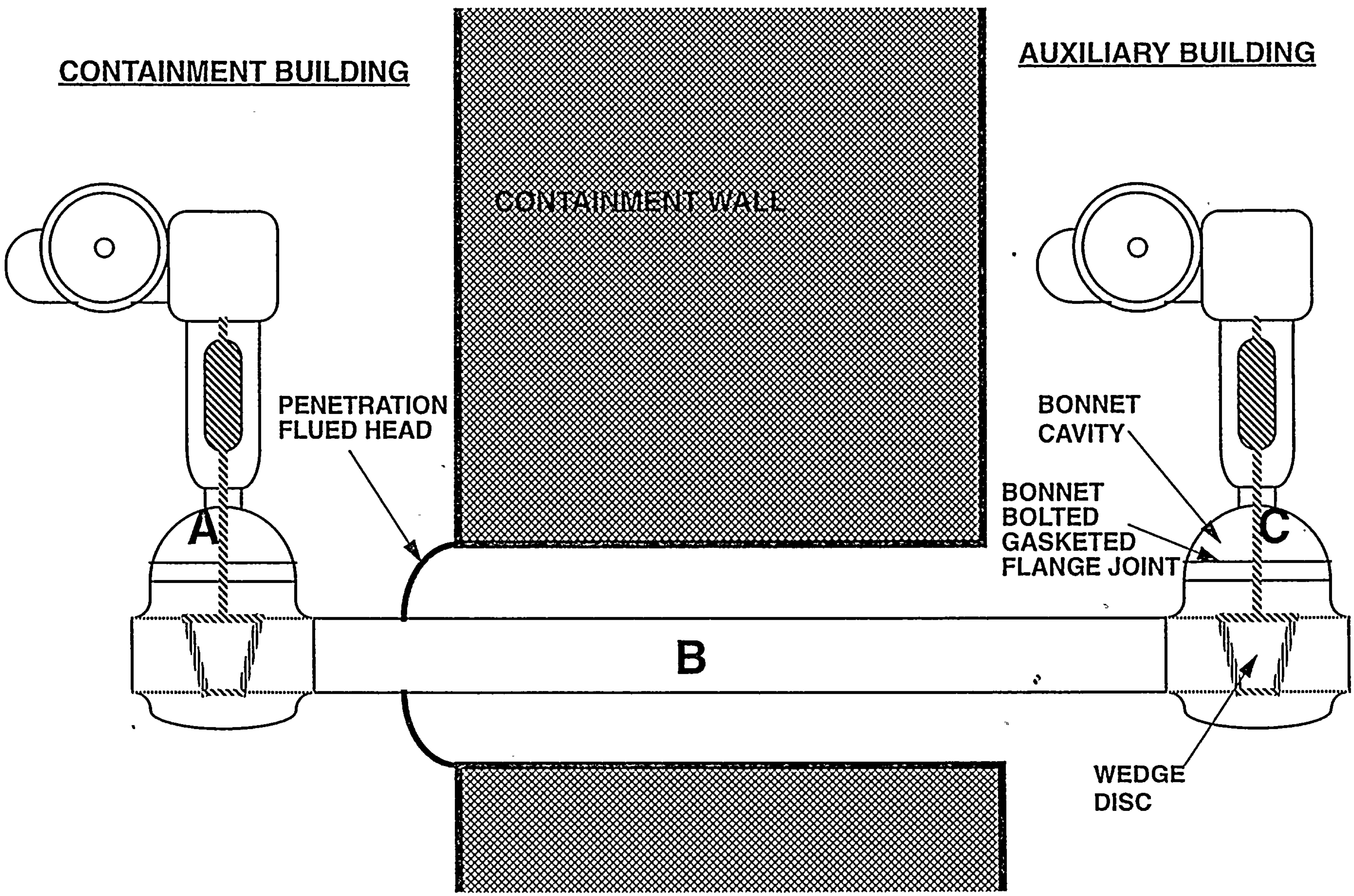
expansion. The maximum pipe deformation was calculated using both circumferential and longitudinal expansion. These analyses result in internal pressures which will plastically deform the pipe up to an approximate strain level of 2%. This 2% strain level is well below the 6% to 8% strain levels at which failure typically occurs in the type of pipe analyzed. The postulated pressures are also below the empirically estimated bursting pressure limit as well. The expected failure point of pipe is further confirmed by industry burst test data [Ref. 10]. These industry tests utilized coupons of existing service water pipe from a nuclear station which had been subjected to Microbiologically Influenced Corrosion (MIC) corrosion/erosion and repaired in discrete areas with a weld overlay. These coupons were then pressure tested to failure. Burst failures occurred at pressure values near the values predicted by the empirical bursting pressure equation with large strain deformations. The failures initiated with cracks in the thinned areas of the pipes which propagated longitudinally forming a typical fish-mouth appearance. The propagating crack was arrested in the vicinity of the weld overlay area.

Based on the analyses and testing described above, the piping penetrations are considered capable of accommodating the thermal expansion of the trapped water without compromising their structural integrity. Thus, the newly obtained testing data and analyses further confirm the assertions contained in the original operability assessment. A detailed discussion of the expected pressure loads in the system, system behavior, and leakage mechanisms, specific to each penetration configuration, will be presented in the operability assessment sections to follow.

Gate Valve Penetration Operability Assessment

Valves JRDAUV0023, JRDBUV0024; JWCAUV0062, JWCAUV0062; and PPCEV070, V071, V075, V076 are Anchor/Darling wedge disc, gate valves. (See Figure 4, page 21) As the containment atmosphere increases in temperature, the internal temperature and consequently, pressure, of the inboard valve bonnet cavity (A) and interconnecting piping (B), will increase. Analysis and testing indicate that the increased pressure in the interconnecting piping (B) will cause the outboard (and in some cases, the inboard also) valve disc seats, closest to the penetration piping, to push over and allow pressurization of that bonnet cavity (A & C) from the piping. However, the outermost disc seating surface is expected to remain sealed due to the applied pressure from the piping and bonnet cavity. The bonnet gaskets will then relieve the pressurized system water as the effects of the internal bonnet cavity pressure un-seat the bonnet gasket. Once the internal pressure in the valves (A & C) and piping (B) have sufficiently reduced, the bonnet gasket will re-seat.

FIGURE 4 : TYPICAL ISOLATION GATE VALVE PENETRATION



Plastic deformation of the penetration piping is capable of accommodating the majority of the increased volume of water in the system due to the thermal expansion. Additional pressure relief through the bonnet gaskets, as described above, will maintain the internal pressures below values which would threaten the structural integrity of the piping and valves, assuming water solid conditions. (See Appendix A) However, as stated earlier, the presence of air pockets in the pipe and valve bonnet are very realistic expectations, based on the test results. Therefore, the actual pressures and leakage rates under accident conditions will be greatly diminished from the theoretical values listed in Appendix A. Thus, catastrophic failure of the RD, WC, and PC penetration piping and valves, identified in Table 1, and/or loss of containment integrity is not expected under harsh containment conditions.

Globe Valve Penetration Operability Assessment

The PDWEV061 and PDWEV062 globe valves are expected to relieve excess pressure through their bonnet gaskets in a manner similar to that described for the gate valves. Again, the presence of air pockets in the piping/valves greatly diminishes the theoretically determined leakage pressures and leakage rates listed in Appendix A. Due to the design of the globe valves, penetration piping water is immediately adjacent to the gasketed pressure boundary of one valve. Therefore, fluid inside the penetration does not have to displace the valve disk in order to relieve through the bonnet gasket, as is the case for the gate valves.

Butterfly Valve Penetration Operability Assessment

Valves JNCAUV0402 and JNCBUV0403 are Henry Pratt 1100 series butterfly valves. These valves utilize a rubber E.P.T. seat, filled internally with epoxy resin, which makes an interference fit with the butterfly disc edge in order to accomplish the valve seal. The seat side of the valve is flanged and the opposite end of the valve is welded. These NC butterfly valves are installed in the plant such that the seat side, or flanged end, of each valve is furthest from the containment wall and the welded ends are nearest the containment wall. It should also be noted that JNCBUV0403 (inboard) is located upstream of JNCAUV0402 (outboard). Thus, the inboard valve seat (JNCBUV0403) is located on the upstream side of the valve, while the outboard valve seat (JNCAUV0402) is located on the downstream side of the valve.

Qualification testing was performed at Wyle Laboratories and documented in ECE-NC-A004 for the JNCAUV0402 and JNCBUV0403 valves. This testing included determination of the leaktight capabilities and leakage characteristics of the valves. Appendix F of Reference 8 describes the orientation of the tested valve as being with the seat side upstream and the welded end downstream, which is the same orientation as the inboard containment valve (JNCBUV0403).

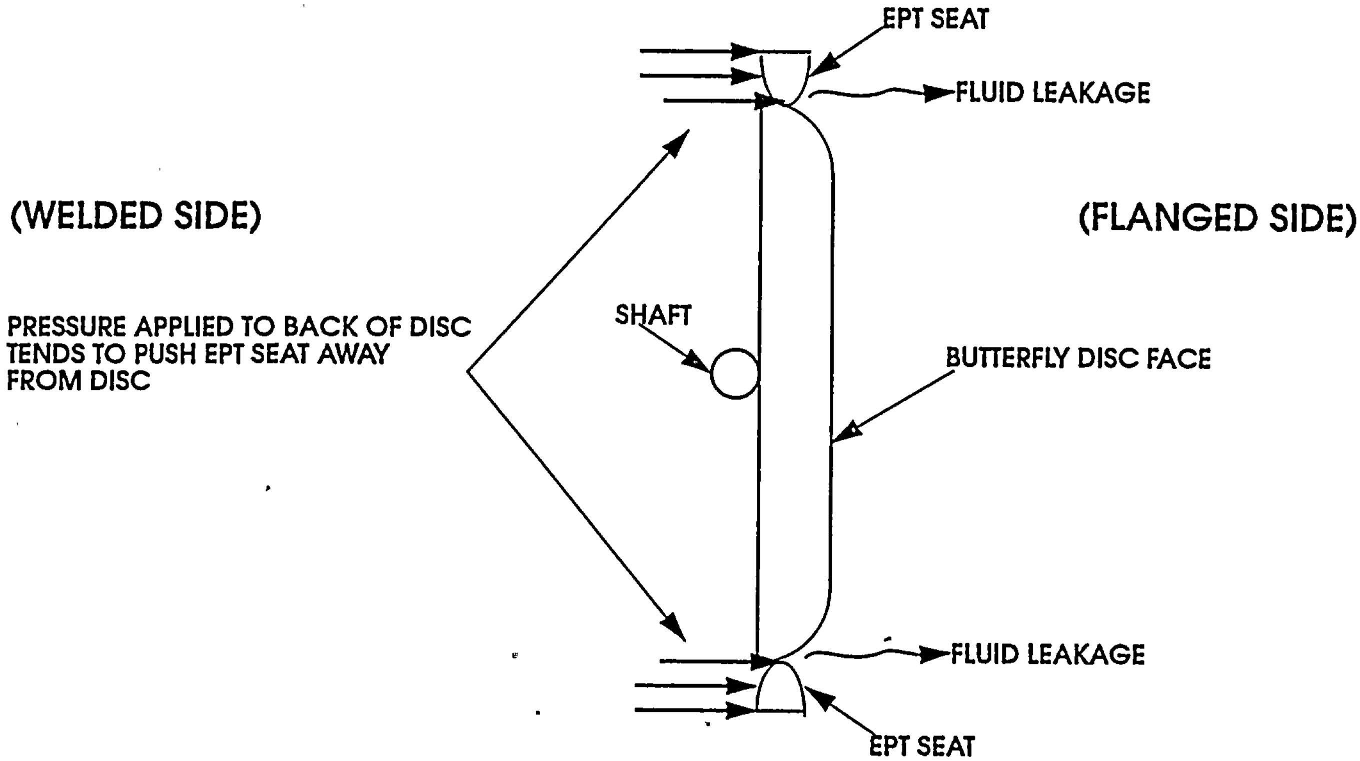
Various Design Basis Accident (DBA) and other testing was performed which included leakage testing with internal pressure applied, alternately, to each side of the valve disc. The following excerpt from the test report describes leakage testing performed on the valve:

> **"Having finished the DBA and post DBA tests, the valve still in the closed position was removed from the chamber and mounted horizontally to an air test chamber. An air leakage test was performed at 52 psig for a period of 15 minutes (LLRT test requirements) with the pressure on the upstream side. The leakage across the seat was zero. The same air test was performed on the reversed side and the maximum leakage measured was 573 cc/min, which is below the LLRT criteria of 2500 cc/min. Therefore is acceptable. Note that as stated earlier the valve was tested in the preferred flow direction (upstream side) because this is the normal path of the fluid media and most severe accident test conditions." [page F18 of F83]**

The excerpt above shows that with pressure applied on the "upstream side", or flange side of the disc, the seal remained leaktight. However, when the test pressure was applied on the "reversed side", or welded side of the disc, the leakage significantly increased to 573 cc/min. The cited leakage testing was conducted with air, as opposed to water. These results are analogous to the containment penetration isolated by the JNCAUV0402 and JNCBUV0403 valves being leaktight to fluid entering the penetration, either from inside or outside containment. Correspondingly, this testing demonstrates that fluid isolated inside the penetration piping would be prone to leak out of the valve seats, at both valves, as the trapped fluid increases in pressure.

These results are expected due to the E. P. T. seat-to-disc interface design of the Pratt 1100 series butterfly valve. As depicted on the valve cross-section drawing (Figure 5, page 24), the outer edge of the disc is tapered where it meets the E. P. T. seat. This results in the back of the disc (i.e. welded side) being slightly wider than the disc face (i.e. flange side). Thus, pressure applied to the back of the disc tends to push the E. P. T. seat away from the disc edge. This results in fluid leakage out of the penetration. Conversely, the valves become more leaktight as pressure is applied to the disc face. As both valves JNCAUV0402 and JNCBUV0403 are orientated with their discs facing away from the containment wall, leakage will occur at both valves as the penetration piping is internally pressurized. The air leakage rate of 573 cc/min is significant as the applied pressure to achieve this rate was only 150 psig.

FIGURE 5: PRATT BUTTERFLY VALVE DISC-TO-SEAT INTERFACE



The amount of pressure buildup in the penetration piping is restricted by the yield stress limit of the butterfly valve shaft which is approximately 1500 psi. At this pressure the leakage through the E.P.T. seat, backfilled with epoxy resin, is expected to be significant. An industry expert, involved in the PVRC gasket testing program, was hired by PVNGS to review the gasket relief analyses and provided an analytical method [Ref. 9] to calculate the equivalent liquid leakage rate of the butterfly valve seats at 1500 psi. This method utilized the previous air test leakage results in conjunction with the PVRC leakage Tightness Parameter (T_p) concept. T_p is a term which conveniently correlates pressure and mass leak rate for any given value of gasket stress and does not rely on empirical gasket data. As such, the method is independent of the type of seal. The results of the analysis was that leakage on the order of 20 to 144 pints per hour are expected for both butterfly valve seats combined. In addition, the relief rate is expected to increase with increasing pressures due to the fact that the E.P.T. seats are self de-energizing. That is, the higher the pressure, the wider the leakage gap. An independent deflection analysis, performed by PVNGS staff, utilizing the actual geometry of the seat and properties of the epoxy resin confirmed the above conclusion. The expected deflection of the E.P.T. seat away from the disk is on the order of 2.8 to 6.8 mills, which is equivalent to an orifice of 0.32 to 0.50 inches. An orifice of this size is adequate to pass the required water volume to preclude overpressurization. Therefore, satisfactory pressure relief is expected above the required rate of 57 pints per hour because of both the de-energizing nature of the seat and the fact that considerable flow and pressure relief would have occurred before the maximum relief rate is reached for the confined fluid. Thus, it is expected that the leakage past the E. P. T. seats of valves JNCAUV0402 and JNCBUV0403 will be sufficient to preclude catastrophic failure under harsh environmental conditions.

Consideration Of Adjacent In-Containment Piping

In addition to the piping sections listed in Table 1, piping directly adjacent to the in-containment side of the PDWEV062, PPCEV071, and JRDAUV0023 isolation valves, also has the capability to trap system water. These sections of piping are non-safety related, seismic category 3 components, and have no associated safety functions. The NQR valves bordering the NQR piping sections are expected to relieve excess pressure through their respective bonnet gaskets in a similar fashion as that described above for the safety related valves (See Appendix A). However, catastrophic failure of these valves will not impact the ability of the adjacent valves and piping to perform their safety related functions.

Summary

The containment penetrations identified in Table 1 of this report were designed without overpressure protection devices. This design was evaluated during initial plant licensing and was accepted based upon a qualitative assessment. This qualitative assessment asserted that intrinsic pressure relief mechanisms exist for the penetration valves and piping which would prevent catastrophic failure of these components or loss of containment integrity under harsh environmental conditions. APS has performed quantitative analyses and testing which support the conclusions of the qualitative assessment and, as such, conclude that there are no immediate operability concerns. These analyses to develop a model which predicts and quantifies the expected gasket relieving pressures and rates, as well as verification testing, are still in process and will be documented in an APS issued study. Upon completion, the results of this study will be used to assist the PVNGS staff in determining if additional actions are required for the identified penetrations. APS will inform the NRC of the final conclusions by May 30, 1997.

REFERENCES

1. PVNGS Procedure 40EP-9EO03, "Loss of Coolant Accident"

2. PVNGS Procedure 40EP-9EO05, "Excess Steam Demand"

3. PVNGS Procedure 40EP-9EO09, "Functional Recovery"

4. PVNGS Procedure 40EP-9EO10, "Standard Appendices"

5. "Evaluation of Thermal Transient Effects on Closed Spaces Between Isolation Valves", PVNGS Study 13-MS-A99, Rev. 1 (Report prepared by Structural Integrity Associates, Inc. for APS, Contract No. PV95-22923).

6. Letter from E. E. Van Brunt (APS) to H. R. Denton (NRR) regarding transmittal from APS to NRR of the transcripts from the PVNGS Containment Systems Independent Design Review conducted on May 21, 1981. APS Ltr: ANPP-18147-JMA/KWG, dated June 4, 1981.

7. Letter from E. E. Van Brunt (APS) to R. L. Tedesco (NRR) regarding transmittal from APS to NRR of the responses to the PVNGS Containment Systems Independent Design Review open items. APS Ltr: ANPP-18668-JMA/KWG, dated August 17, 1981.

8. "Qualification of Various Components per DCP 13-PM-NC-041", APS No. ECE-NC-A004, Rev. 01.

9. Memorandum from Jim Payne (JPAC, Inc.) to Winston Borrero, dated September 13, 1996.

10. "Weld Overlay Repair Of Erosion And Corrosion Mock-Up Testing - Phase 1", May 10, 1991, by Bruce Newton, Union Electric Co.

11. "Safety Evaluation Report related to the operation of Palo Verde Nuclear Generating Station, Units 1, 2, and 3", Docket Nos. STN 50-528/529/530; U.S. Nuclear Regulatory Commission, Office Of Nuclear Reactor Regulation; November 1981. (NUREG - 0857)

12. "Updated Final Safety Analysis Report", Revision 8; Palo Verde Nuclear Generating Station Units 1, 2, and 3; Docket Nos. STN 50-528/529/530.

Appendix A: Summary Of Analyses (in process)

INBOARD VALVE		PENETRATION PIPING		OUTBOARD VALVE	
EQID & Type Gasket Leakage Pressures[1] With Corresponding Leakage Rates	Required Gasket Leakage Rate to Prevent Valve Failure[2]. Valve Gate Disc Opening Pressure[3]	Predicted Internal Pressure Range[4] & Required Leakage Rate if Any to Prevent Failure of Pipe	Calculated Bursting Pressure of Pipe	EQID & Type Gasket Leakage Pressures[1] With Corresponding Leakage Rates	Required Gasket Leakage Rate to Prevent Valve Failure[2]. Valve Gate Disc Opening Pressure[3]
13JRDAUV0023 3"-150# Motor Operated Gate Valve 3989 - 5967 psig. With respective leakage rates of less than 0.3 to greater than 21pints/hour.	0.46 pints/hr to maintain pressure in the bonnet at slightly above 3989 psig. The valve is able to handle a pressure of 5967 psig in the bonnet and >7378 psig in the nozzles. Disc opening pressure is 8589 - 10567 psig.	6584 - 7378 psig. No leakage required.	For the 3" Sch. 40S Piping the Bursting Pressure is estimated to be 9010 psig.	13JRDAUV0024 3"-150# Air Operated Gate Valve 6182 psig Initial Leakage Pressure with Leakage Rate less than 0.3 pints/hour.	0.13 to 0.27 pints/hour to maintain pressure in the bonnet at or below 6182 psig. Valve is able to handle pressure of 6605 psig in the bonnet and >7378 psig in the nozzles. Disc opening pressure is estimated to be in a range of 4700 to 10782 psig.
13JWCBUV0061 10"-150# Motor Operated Gate Valve 1791 - 2117 psig. With respective leakage rates of less than 0.3 to greater than 7 pints/hour.	2.12 pints/hr to maintain pressure in the bonnet between 1791 & 2117 psig The valve is able to handle a pressure of 2117 psig in the bonnet and >3728 psig in the nozzles. Disc opening pressure is 2800 - 3126 psig.	3214 - 3728 psig. No leakage required.	For the 10" Sch. 40 Piping the Bursting Pressure is estimated to be 4218 psig.	13JWCBUV0062 10"-150# Motor Operated Gate Valve 1791 - 2117 psig. With respective leakage rates of less than 0.3 to greater than 7 pints/hour.	1.06 to 2.12 pints/hr to maintain pressure in the bonnet between 1791 & 2117 psig. The valve is able to handle a pressure of 2117 psig in the bonnet and >3728 psig in the nozzles. Disc opening pressure is 2800 - 3126 psig.

INBOARD VALVE		PENETRATION PIPING		OUTBOARD VALVE	
EQID & Type Gasket Leakage Pressures[1] With Corresponding Leakage Rates	Required Gasket Leakage Rate to Prevent Valve Failure[2]. Valve Gate Disc Opening Pressure[3]	Predicted Internal Pressure Range[4] & Required Leakage Rate if Any to Prevent Failure of Pipe	Calculated Bursting Pressure of Pipe	EQID & Type Gasket Leakage Pressures[1] With Corresponding Leakage Rates	Required Gasket Leakage Rate to Prevent Valve Failure[2]. Valve Gate Disc Opening Pressure[3]
13PPCEV071 & 075 4"-150# Manual Gate Valve 3368 - 4934 psig. With respective leakage rates of less than 0.3 to greater than 18 pints/hour.	1.06 pints/hr to maintain pressure in the bonnet at slightly above 3368 psig. The valve is able to handle a pressure of 4934 psig in the bonnet and >7683 psig in the nozzles. Disc opening pressure is 6300 - 7866 psig.	6804 - 7683 psig. 0.64 to 1.63 pints/hour to maintain piping pressure at or below 6300 psig.	For the 4" Sch. 40S Piping the Bursting Pressure is estimated to be 7617 psig.	13PPCEV070 & 076 4"-150# Manual Gate Valve 3368 psig Initial Leakage Pressure with Leakage Rate less than 0.3 pints/hour.	.29 pints/hr to maintain pressure in the bonnet at or below 3368 psig. The valve is able to handle a pressure of 4934 psig in the bonnet and >7683 psig in the nozzles. Disc opening pressure is estimated to be in a range of 3032 - 6300 psig.
13PDWEV062 2"-150# Manual Globe Valve Not Applicable. Bonnet is open to the upstream pipe inside containment and not exposed to the containment penetration overpressure condition.	Not Applicable. Bonnet is open to the upstream pipe inside containment. The valve is able to handle a pressure > 9437 psig in the nozzles.	8391 - 9437 psig. 0.27 to 0.55 pints/hour to maintain piping pressure at or slightly above 7535 psig (2% strain).	For the 2" Sch. 40S Piping the Bursting Pressure is estimated to be 9499 psig.	13PDWEV061 2"-150# Manual Globe Valve 7655 psig Initial Leakage Pressure with Leakage Rate less than 0.3 pints/hour.	.27 pints/hr to maintain pressure in the piping system, bonnet and nozzle below the analyzed value of 7655 psig. The valve is able to handle a pressure of 7655 psig in the bonnet and in the nozzles.

NOTES:

1. The first pressure value provided is the Initial Pressure at which the gasket starts leaking. This leakage consists of drops of water emerging from the flange faces interface at a very slow rate in the order of tenths of pint per hour. The second pressure value is the Final Pressure at which the gasket is continuously leaking with small laminar streams of water flowing out from the flanges interface at a consistent and continuous rate. The method utilized to calculate the gasket leakage pressure and corresponding leakage rate uses the new Pressure Vessel Research Council (PVRC) gasket constants (G_b, a, G_s) which define the gasket mechanical and leakage behavior. An ASME SWG on Bolted Flange Joints is implementing the new PVRC constants, which will replace the old m and y factors, along with several other changes to the traditional bolted flange design rules of Appendix 2 (Section VIII, Div. 1).

2. The leakage rate value listed is the required rate to maintain the pressure in the bonnet between the range of gasket leakage pressures. This rate assumes a water solid system, i.e., no air trapped in the high points of the system such as the bonnet, and no leakage through the packing which are very conservative assumptions based on test results of a similar proto-type valve and pipe configuration. The valve structural integrity is verified by utilizing the actual wall thickness values of the valve and applying ASME Section III Code Faulted Allowables, Appendix F1000 to the crotch area of the valve. The valve nozzles are stronger than the piping by virtue of the larger section modulus and cross sectional area. Therefore, the nozzles can withstand the piping maximum expected pressures.

3. The disc opening pressure value represents the required piping pressure force, given an initial bonnet pressure (see Bonnet Leakage Pressures), to deflect the gate valve disc inward such that an annular gap of 0.003" around the Seat is achieved. The value of 0.003" gap around the seat is a conservative estimate to allow major transfer of pressure (i.e., several 100 psi) from the pipe into the valve bonnet and is based on test results. Minor leakage from the pipe into the bonnet is expected at seat gap values as low as 0.001"..Once the disc is forced opened by the piping pressure some of the fluid in the pipe is forced into the bonnet thus increasing its pressure and decreasing the pressure in the pipe. The disc will reseat after the bonnet pressure increases and the differential pressure required to open the disc falls below the threshold value although small leakage may continue as explained earlier. If leakage through the bonnet gasket develops at this point or soon after it the bonnet pressure will drop and the whole disc opening cycle will repeat again.
It is important to recognize that the disc opening pressure for the outboard valve bonnet is lower than for the inboard valve due to the delayed heat up of the bonnet and its expected lower steady state temperature.

4. The first pressure value listed represents the expected pressure in the pipe assuming a water solid system and circumferential and longitudinal expansion of the pipe, due to pressure and thermal expansion, up to 2% strain deformation. Similarly, the second pressure, upper bound value, is calculated assuming only circumferential expansion of the pipe. Note that the first calculated value is a more reasonable maximum pressure to expect since the pipe is more likely to deform radially as well as longitudinally near penetrations and interfacing building structures due to the flexibility of the piping system and the radial expansion of the containment liner when sub-

jected to the LOCA or MSLB Temperature and Pressure environmental conditions. The 2% value chosen for strain deformation ensures that there is enough structural safety margin left before catastrophic failure occurs. Typical failures of the fish mouth type in pipe, due to a longitudinal crack formation, occur at a about 8% strain. This safety margin is further verified by comparing the expected pressures with the bursting pressure which is calculated utilizing the mean diameter formula which is empirical and agrees reasonably well with experiment for both thin and thick cylindrical vessels.