APS

Palo Verde Nuclear
Generating Station

Gregg R. Overbeck
Senior Vice President
Nuclear

Tel (623) 393-5148
Fax (623) 393-6077
e-mail: GOVERBEC@apsc.com

Mail Station 7602
PO Box 52034
Phoenix, Arizona 85072-2034

102-05292-GRO/TNW/GAM
June 15, 2005

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

Dear Sirs

Subject: Palo Verde Nuclear Generating Station (PVNGS)
Units 1, 2 and 3
Docket Nos. STN 50-528, 50-529, and 50-530
Redacted Version of Proprietary Submittal Dated February 24, 2005
Regarding ECCS Pump Testing and Safety Significance Assessment

In letter no. 102-05217, dated February 24, 2005, Arizona Public Service Company (APS) submitted to the NRC responses to a request for additional information regarding ECCS pump testing and safety significance. APS requested that Enclosure 2 of that submittal be withheld from public disclosure under 10 CFR 2.390(a)(4) because it contained information considered to be proprietary to APS. Since that time, NRC Region IV personnel have requested that APS submit a redacted version of Enclosure 2 of the February 24, 2005 submittal. The requested redacted version is enclosed.

There are no commitments in this letter. Should you have any questions, please contact Mr. Thomas N. Weber at (623) 393-5764.

Sincerely,

Gregg R. Overbeck

GRO/TNW/GAM/ca

Enclosure: Redacted Version of Proprietary Enclosure 2 of APS Letter No. 102-05217, dated February 24, 2005, Regarding ECCS Pump Testing and Safety Significance Assessment

cc:	T. W. Pruett	NRC Region IV	(w/ Enclosure)
	B. S. Mallett	NRC Region IV Regional Administrator	(w/o Enclosure)
	M. B. Fields	NRC NRR Project Manager	"
	G. G. Warnick	NRC Senior Resident Inspector for PVNGS	"

A001

Redacted Version of Proprietary Enclosure 2 of APS Letter No. 102-05217, Dated February 24, 2005, Regarding ECCS Pump Testing and Safety Significance Assessment

REDACTED VERSION

~~INFORMATION ON THIS PAGE IS CONSIDERED PROPRIETARY INFORMATION AND SHOULD BE WITHHELD FROM PUBLIC DISCLOSURE UNDER 10 CFR 2.390(a)(4)~~

Enclosure 2
Arizona Public Service Company
Responses to Request for Additional Information Regarding ECCS Pump Testing and Safety Significance Assessment

At the regulatory conference at NRC Region IV offices on February 17, 2005, APS presented a summary of the testing and analysis program that was performed to assess the risk significance of the ECCS voided piping concern. NRC staff members questioned various aspects of the program, particularly with respect to whether the testing program adequately represented the actual plant response and whether sufficient conservatism had been factored in to account for any differences. Below is additional information and clarification regarding the issues expressed by the NRC staff and additional information regarding the total conservatism contained within the testing program.

NRC Concern 1:

Provide a discussion on the affect of temperature on Froude number.

APS Response

As presented in previous submittals, the Froude number is defined as the ratio of the inertial and buoyancy forces, i.e.

$$N_{Fr}^2 = \frac{\rho_w U^2}{gD(\rho_w - \rho_g)} \qquad \text{Eq. (1)}$$

where:

- D is the diameter of the horizontal piping,
- g is the acceleration of gravity,
- U is the one-dimensional velocity of the flow in this line,
- ρ_g is the air density, and
- ρ_w is the water density.

Since the water density is far greater than that of air, this reduces to the familiar form

$$N_{Fr} = \frac{U}{\sqrt{gD}} \qquad \text{Eq. (2)}$$

Examination of the terms in Equation (1) yields the fact that only the density terms are a function of temperature. At both ambient and high temperatures, the density of water is much greater than the density of air and so the density terms in the numerator and the denominator cancel out. The remaining terms in Equation (2) are not a function of temperature; therefore the ratio of the two forces is independent of temperature.

[

] Other dimensionless parameters are potentially also influential in two-phase flow [Wallis, 1969] and these include the Reynolds number and Weber number. [

]

[

]

References for Response to Concern 1:

[ ]

<u>NRC Concern 2</u>:

Provide a discussion on the affects of high temperature on NPSH

<u>APS Response</u>:

[ ]

[ ]

Definition of NPSH and NPSH Calculation Methodology

The standard definition of NPSH is defined in the Hydraulic Institute Standard. The Net Positive Suction Head Available (NPSHA) is the total resultant head, less the head corresponding to the vapor pressure of the pumped fluid, taken relative to the pump datum. Ensuring that the NPSHA exceeds the NPSH required (NPSHR) provides assurance that the suction pressure will not be less than the vapor pressure, and cavitation (vapor coming out of solution) will not occur.

By definition then,

$$\text{NPSHA} = (h_a + h_{st} - h_{fs}) - h_{vpa} \qquad \text{Eq. (1)}$$

where the terms are defined as follows:

h_a absolute containment atmospheric pressure on the surface of the liquid supply level expressed in ft of water.

h_{st} static height that the liquid supply level is above the pump datum.

h_{fs} suction line losses (i.e. frictional losses).

h_{vpa} head corresponding to the vapor pressure of the liquid at the operational fluid temperature

Examination of the above terms identifies the fact that the containment pressure term and the vapor pressure term are a direct function of temperature. [

] This is consistent with the requirements of NRC Regulatory Guide 1.82, Revision 1 and the calculation methodology approved by the NRC for Palo Verde as documented in the NUREG 0800 (PVNGS SER, Section 6.2.2). [

]

[ ]

Palo Verde Design Basis NPSH

The NPSHR as specified by the vendor for the HPSI pump is 25 ft at pump runout conditions (1400 gpm). The design basis calculation conservatively evaluates NPSHA for recirculation with all 3 ECCS pumps at runout (even though LPSI is automatically stopped on RAS), minimum calculated containment flood level, no credit for containment over-pressure, and with a conservative sump suction screen debris loss. With these assumptions, the elevation head is 40' and the suction line losses total 11.2'. Thus

NPSHA = 40' – 11.2' = 28.8'

resulting in a design basis NPSH margin of (NPSHA – NPSHR) of 3.8 ft.

However, the several conservative assumptions used in the calculation in essence provide additional margin. [

]

[ ]

[ ]

[ ]

Based on the above assessment, it is concluded that there would have been sufficient suction head to the ECCS pumps (NPSHA>NPSHR) such that the suction pressure would have remained above the vapor pressure. Therefore, this aspect of the system response to the presence of air did not need to be explicitly tested.

Consideration for Pump Testing

NUREG/CR-2792 (Ref. 1) provides discussion and guidance regarding the affect of pump air ingestion on NPSH considerations. For example, Section 3.2.3 states that "the presence of air at the inlet.....increases the limiting NPSH required for satisfactory operation. The increased degradation at the pump inlet, as inlet NPSH or pressure is lowered, results from the increased volumetric expansion of air between the pump inlet flange and the impeller inlet. Thus pumps operating with air ingestion will have higher NPSH requirements than those required in single-phase operation."

Section 4.2 goes on to establish an "arbitrary relationship" for the purpose of minimizing this volumetric expansion that occurs between the inlet and the impeller eye. The relationship is:

$$NPSHR_{air/water} = NPSHR_{water} + (1 + 0.5\ AF)$$

Where AF is the air volume fraction in percent. It is noted that this relationship is only intended for use with air volume fractions less than 2%.

As discussed in the NUREG, the purpose of increasing the required NPSH in the presence of air is to insure satisfactory operation. Increasing the inlet pressure (i.e. the available NPSH), limits the increased volumetric expansion of the air at the impeller inlet. [ ]

[ ] Since the suction pressure would have remained above the vapor pressure, as discussed earlier, no additional vapor volume would have been produced. Therefore, it was not necessary to conduct this test at high temperature.

[ ]

NRC Concern 3:

Discuss the appropriateness for use of the Froude number to scale model test the 45 degree downward sloped CS branch connection.

APS Response:

As discussed during the regulatory conference, a non-conservative consequence of the use of Froude number scaling was observed. [ ] This non-conservative behavior was avoided in the Phase 2 integral tests by [ ]

[ ]

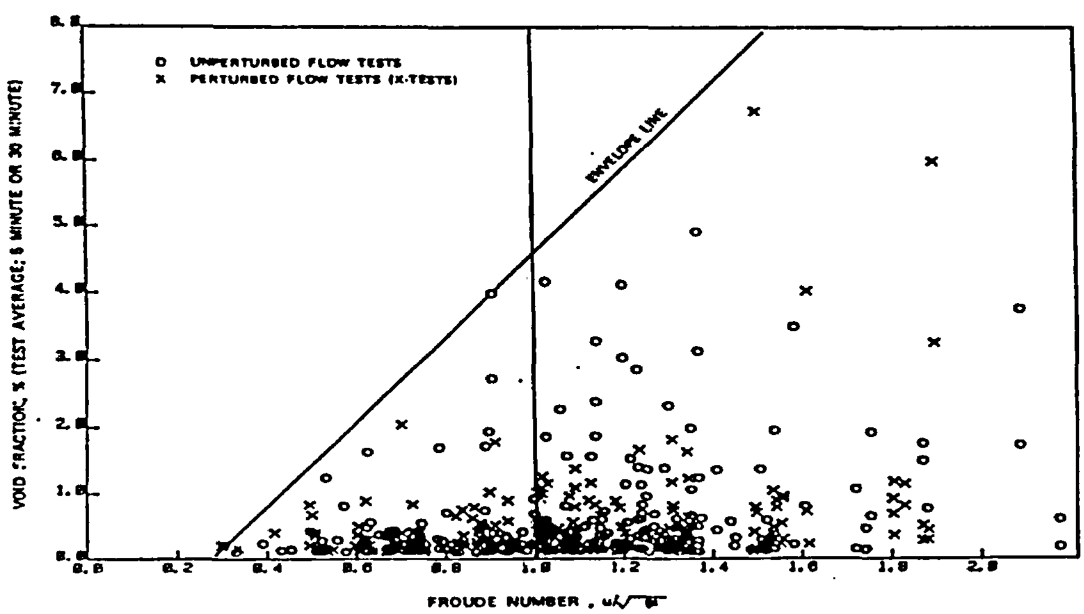
It was suggested by the NRC that a similar reduction in the CS branch connection would also seem necessary since the flow in this section of the piping was not horizontal. However, during the performance of the scale model testing, no such [ ] occurred in the 45 degree downward sloped segment of the CS branch connection. Without any observed non-conservative or non-prototypical behavior being exhibited in the tests, there was no need or justification to depart from the Froude number.

[ ]

demonstrates the necessity of maintaining the Froude number to ensure representative behavior of vortex formation and air entrainment into the CS line.

To obtain a perspective with respect to the large-scale sump studies that were performed and reported in NUREG/CR-2758, comparison can be made between the scale model test results and the NUREG results. [

]



References for Response to Concern 3:

[

]

[ ]

4. Weigand, G. G., et al., 1982, "Parametric Study of Containment Emergency Sump Performance," NUREG/CR-2758.

<u>**NRC Concern 4:**</u>

The NRC requested the information that was referred to in the conference regarding information from the Hydraulics Industry on air transport in large pipes.

<u>**APS Response**</u>:

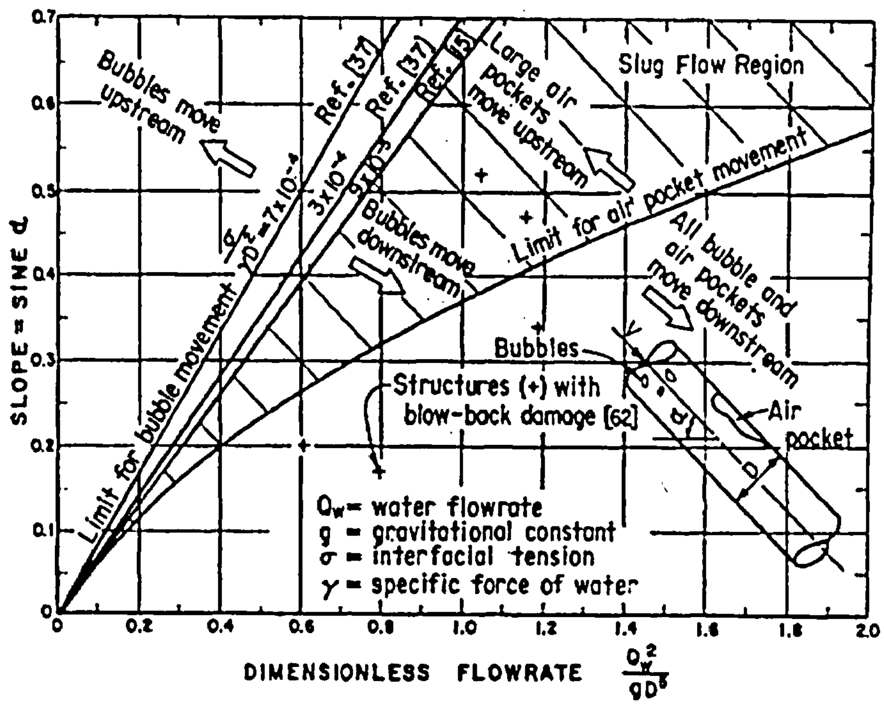
A good discussion regarding air transport in large pipes is provided in "Air-Water Flow in Hydraulic Structures", Engineering Monograph No. 41, United States Department of the Interior, Water and Power Resources Service. A copy of this paper is attached to this submittal.

[ ]

REDACTED VERSION

~~INFORMATION ON THIS PAGE IS CONSIDERED PROPRIETARY INFORMATION AND SHOULD BE WITHHELD FROM PUBLIC DISCLOSURE UNDER 10 CFR 2.390(a)(4)~~

CLOSED CONDUIT FLOW



The dimensionless flow rate is more conveniently expressed for their purposes as a function of flow rate, rather than velocity. The dimensionless flow rate is equivalent to the Froude number.

$$\text{Dimensionless Flowrate} = Q_w^2/(gD^5)$$

Since the volumetric flow rate divided by the square of the diameter is proportional to the velocity, the dimensionless flowrate used is proportional to the square of the Froude number.

Figure 27 on page 49 provides a correlation for air entrainment where a hydraulic jump closes the conduit. The correlation is a function of the Froude number as it is defined on the figure, which is reproduced below.

REDACTED VERSION

~~INFORMATION ON THIS PAGE IS CONSIDERED PROPRIETARY INFORMATION AND SHOULD BE WITHHELD FROM PUBLIC DISCLOSURE UNDER 10 CFR 2.390(a)(4)~~

CLOSED CONDUIT FLOW 49

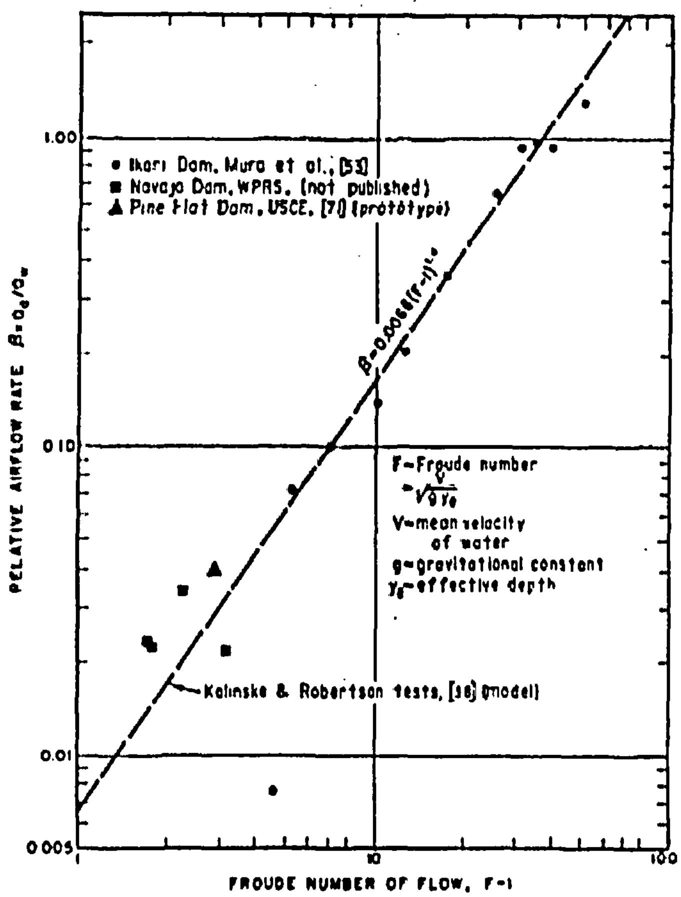


FIGURE 27.—Air entrainment with hydraulic jump closing conduit.

[ ]

Again, the correlations described are based on Froude number or on dimensionless water flow rates that are proportional to Froude number.

NRC Concern 5:

The NRC requested the MAAP analyses regarding the containment pressure and sump temperature at the time of RAS.

APS Response:

The February 15, 2005 submittal to the NRC contained as an attachment the summary report of the MAAP analyses. [ ]

[ ]

[ ]

[ ]

[ ]

NRC Concern 6:

The NRC expressed concern regarding the affects of high temperature on pump clearances and the associated impact on the pump test results.

APS Response:

Per input from the pump vendor, the pumps are manufactured with similar materials so that operation at temperatures other than ambient does not change the clearances significantly. [

] The actual change in clearance is thus less than the nominal variation in clearance due to machining tolerances.

[ ]

[ ]

NRC Concern 7:

The NRC expressed a general concern as to whether sufficient conservatism had been factored into the test program.

APS Response:

Through out the development and execution of the test program, specific selection of tests conditions were made where deemed appropriate and feasible such that conservatism would be built into the test conduct and test results. Conservative application of the test results, particularly with respect to the risk assessment, was also employed to ensure an ultimately conservative assessment of the risk significance. The following discussion provides our assessment of the primary conservative factors employed.

[ ]

[ ]

[ ]

[ ]

[ ]

CONCLUSION

APS and its consultants are convinced that the scale model test program, utilizing appropriate scaling techniques established by previous experts and investigators in the field of two-phase flow and confirmed in our tests, provided a conservative representation of the actual plant response to the initial air volume captured in the sump outlet piping. Selection of test conditions, [ ] were made so as to conservatively bound the actual plant conditions that would have existed in the event of an accident.

[ ]

From this assessment of the conservatisms factored into the test and analysis program, APS concludes there is more than reasonable assurance that the risk assessment results presented by APS at the regulatory conference is a conservative representation of the actual risk associated with this condition.