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SUBJECT: Final deficiency rept re reinforcing steel shown in Drawings 13-C-ZCS-108 & 115 not accurately reflecting actual design.Analysis of containment initiated & results show shell-basemat within allowable stress limits.

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Attention: Mr. G. S. Spencer, Chief
Reactor Construction and
Engineering Support Branch

Subject: A 50.55(e) Potentially Reportable Deficiency Relating to Reinforcing Steel Shown in Drawings that May Not Be Accurately Reflecting the Actual Design in Certain Areas (DER 80-19)
Final Report
File: 80-019-026

Reference: (1) Telephone Conversation between J. Eckhardt and B. S. Kaplan on July 1, 1980, same subject

(2) Interim Report ANPP-16016-JAR, dated July 28, 1980

Dear Sir:

Attached, is our final written report of the potentially reportable deficiency, under 10CFR50.55(e), for the subject noted above. An interim report was transmitted by Reference (2).

During a review and comparison of the containment shell calculations and drawings, an apparent discrepancy in the reinforcing steel was discovered in certain local segments of the circumferential joint between the containment shell and the basemat. This potential problem is not one which compromises containment integrity in an overall sense, but is one which could result in slight stress redistribution as a result of stresses in excess of allowables in local areas.

An analysis of the containment was initiated to verify design adequacy of the as-built containment for Units #1 and #2, as well as to provide recommendations for the Unit #3 containment. The results of the analyses show that taking into account concrete cracking and distribution of reinforcement, the stresses in the shell-basemat junction are all within the allowable stress limits.

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The results demonstrate that the reinforcement in the wall-basemat junction would not have reached the allowable limits had the condition remained undetected. Therefore, it is concluded that the shell-basemat junction would not have constituted a significant safety condition, and is not reportable under 10CFR50.55(e).

Very truly yours,

E. E. Van Brunt

E. E. Van Brunt, Jr.
APS Vice President
Nuclear Projects
ANPP Project Director

EEVBJr/BSK:skc

Attachment

cc: Victor Stello, Jr., Director
Office of Inspection and Enforcement
U. S. Nuclear Regulatory Commission
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FINAL REPORT

REPORTABLE DEFICIENCY 50.55(e)

ARIZONA PUBLIC SERVICE COMPANY (APS)

PVNGS UNITS #1, #2 AND #3

I. Description of Deficiency

During a review and comparison of the containment shell calculations (13-CC-ZC-055) with the design drawings (13-C-ZCS-108 and 115), an apparent discrepancy in the reinforcing steel was discovered in certain local segments of the circumferential joint between the containment shell and the basemat. The segments in question are those which have mechanical penetrations located 10 to 15 feet above the joint interrupting the reinforcing steel.

The amount of replacement reinforcement that was added in the vertical direction depended on the distance between the penetrations. In a few areas, the added reinforcement does not equal the calculated reinforcement. In many areas, the amount of added reinforcement exceeds the amount of calculated reinforcement.

The actual reinforcement of selected segments of the containment wall may be slightly over-stressed for certain load combinations based upon the conservative linear-elastic analysis used which does not take advantage of changes in stiffness due to concrete cracking.

This potential problem is not one which compromises containment integrity in an overall sense, but is one which could result in slight stress redistribution as a result of stresses in excess of allowables in local areas.

The status of construction of the containments for the three units is as follows:

Unit 1 - Containment concrete is complete. The installation of the post-tensioning system is ready to begin.

Unit 2 - Containment shell is placed nearly up to the springline. Dome liner plate is in place, with approximately 50% of the welding complete. Dome reinforcement has not been installed.

Unit 3 - Containment basemat is placed and the shell liner plate is installed for approximately 70 feet above the basemat. Installation of the vertical and horizontal rebar is in progress.

II. Analysis of Safety Implications

An analysis of the containment was initiated to verify design adequacy of the as-built containment for Units #1 and #2, as well as to provide recommendations for the Unit #3 containment. The following summarizes the results of this analysis for the shell-basemat junction and will be a part of the Design Report for the containment which is in preparation in accordance with the ASME Code, Section III, Division 2 (Calculation No. 13-CC-ZC-020).

The computer program used in the analysis was FINEL[a] for all loads except for seismic loads. (Resultant section forces due to seismic loads are taken from existing ASHSD seismic analysis.) The FINEL program is capable of taking into account material non-linearities such as concrete cracking and reinforcement yielding. The FINEL program was not used in the original design as it requires as input the actual reinforcement properties used in the structure.

A detailed finite element model of the containment was used for the FINEL analysis. This model is axisymetric (two-dimensional) and represents the as-built condition of the containment. The 4'-0" shell thickness used in the model for the critical area was obtained from as-built information for Units #1 and #2. SCN No. 2365 was issued July 18, 1980 to assure that the minimum shell thickness for the Unit #3 containment in the critical area will be at least 4'-0".

The vertical reinforcement used in the model was conservatively assumed to be equal to the minimum average reinforcement over a width of approximately 2½ times the thickness. This approximation was considered to be conservative since the equivalent inside veritical reinforcement thus modeled was only 2.12 in ^{2}/ft and corresponds to three small segments of the containment circumference. (Two segments are located between buttresses 1 and 2, and the other segment is located between buttresses 2 and 3.) The average vertical reinforcement which exists from buttress to buttress is 4.6 in ^{2}/ft.

(a) Refer to Appendix 3B of the FSAR for a discussion of the computer programs used in the analysis.

FINEL analysis results showed that, under the loading condition of Dead Load + Prestressing Force (at the end of 40-year life) + 150% of the Design Pressure Load, the maximum reinforcement stress (inside vertical bars at the shell-basemat junction) was 59.4 ksi (see Table 1). This stress is 10% greater than the allowable stress of 54 ksi and occurs only in three small segments of the containment circumference. The allowable stress of 54 ksi is based on specified design yield strength of 60 ksi. The actual average yield properties of the reinforcing steel obtained from the Certified Mill Tests Reports were 67.4 ksi. However, these properties (which were conservatively neglected for the analysis) would provide additional margins of safety.

FINEL results alone could have been used to disposition this DER if the stresses based on the conservative width of 2½ times the thickness were all within the allowable stress limit of 54 ksi. However, since this was not the case, FINEL analysis results were reviewed with Professor N. M. Newmark of the University of Illinois, a Bechtel consultant, to obtain his comments and recommendations. It was mutually concluded that the analysis was conservative and that, if the average vertical reinforcement were based on a wider strip such as 4 times the thickness, the resultant stresses would be lower than the allowable stresses. To support this assumption, it was decided to perform a three-dimensional finite element analysis, using cracked section properties which would provide better representation of the actual conditions, and would allow for a more realistic redistribution of the forces.

A three-dimensional model of a 90° segment of the containment shell in the area of interest was prepared. The shell was modeled with fixity at the shell-basemat junction and included 35 feet of shell height. In this analysis, cracked section properties of the shell were considered. Reinforcement in each element corresponds to the actual reinforcement that exists over the width represented by the element. The computer program used was BSAP which is a linear elastic program.

BSAP analysis showed that the moment at the shell-basemat junction is greatly reduced at the locations where minimum reinforcement exists. The analysis was done twice. First, with the assumption that all elements are cracked in both directions and second, with the assumption that only the elements adjacent to the shell-basemat junction are cracked in the vertical direction. Using the BSAP analysis, "reduction" and "increase" factors for moments were obtained at several sections. Both analyses resulted in similar reduction and increase factors. These factors were then applied

to the internal pressure moments obtained from the FINEL analysis to determine a more realistic moment at the junction. (These factors were applied to FINEL moments above 1.0 P_A since the FINEL analysis indicates that the concrete at the bottom of the shell is cracked at about the design pressure of 1.0 P_A.)

Modified total moments and corresponding axial forces (axial force due to internal pressure was not modified in order to be conservative) were then applied to sections to determine the state-of-stress in the reinforcement and concrete.

Details of the model, computer analyses and results for the overall containment structure will be included in the Design Report.

The most critical loading combinations for the shell-basemat junction were found to be the following:

$D + F + 1.5\ P_A$	Reference Loading Combination (RLC) 15
$D + F + 1.25\ P_A + 1.25\ E_o$	Reference Loading Combination (RLC) 18

Where D = Dead Load

F = Prestressing Forces (at the end of 40-year life)

P_A = Design Pressure (60 psi)

E_o = Operating Basis Earthquake

Section forces and stresses based on FINEL analysis and for the above loading combinations are given in Table 1. The values for RLC 15 are taken directly from the computer output. The values for RLC 18 are obtained as follows:

a. Analyze the structure for $D + F + 1.25\ P_A$.

b. Determine the section resultants for the combination in (a).

c. Superimpose, in the most conservative manner, section resultants due to seismic loads.

d. Analyze the section under the section resultants in (c) using the computer code OPTCON.

These steps are necessary since FINEL is an axisymmetric program and cannot deal with asymmetric seismic loads.

Section forces and stresses as modified by the factors based on BSAP analysis are shown in Table 2.

As noted above, FINEL analysis results indicate that, due to loading combination of D + F + 1.5 P_A, the stress in the inside vertical reinforcement, in localized areas, exceeds the allowable limit of 54 ksi by 10% but does not exceed the allowables based on actual average material yield properties.

However, review of Table 2 indicates that, if the actual vertical reinforcement magnitude and distribution is taken into account, all the stresses are within the allowable limits. This is due to the fact that once the concrete is cracked, the stronger sections (i.e., sections with greater reinforcement) will resist a greater portion of the loads. This result is expected since, under the axisymmetric loads, radial displacements of the shell will be nearly uniform and each vertical strip, acting as cantilever, will resist (and develop internal forces) loads in proportion to their stiffnesses.

III. Corrective Action

The results of the analyses show that taking into account concrete cracking and distribution of reinforcement, the stresses in the shell-basemat junction are all within the allowable stress limits as shown on Table 2.

Since the shell wall for Unit 3 is not complete, there are techniques for drilling and grouting rebar into the basemat that could be utilized to add selected local reinforcing steel, if required, provided that extreme care is exercised in maintaining the integrity of the basemat reinforcement. The results have shown that this technique is not necessary for Unit #3.

The results demonstrate that the reinforcement in the wall-basemat junction would not have reached the allowable limits had the condition remained undetected. Therefore, it is concluded that the shell-basemat junction would not have constituted a significant safety condition, and is not reportable under 10CFR50.55(e).

TABLE 1
Shell-Basemat Junction Section Forces and Stresses Based on FINEL and ASHSD Analysis[a]

LOADING COMBINATION	CONCRETE STRESSES MERIDIONAL PRIMARY		REINFORCEMENT STRESSES MERIDIONAL PRIMARY		SECTION RESULTANTS	
	Membrane lb/in^2	Membrane & Bending lb/in^2	Inside ksi	Outside ksi	P kips	M ft-kips
Allowable	-3600	-4500	± 54	± 54	---	---
$D + F + 1.5\ P_A$	- 310	-3570	59.4	-19.4	-179	-704
$D + F + 1.25\ P_A + 1.25E_o$	- 153	-3580	54.9	- 9.7	- 88	-567

[a] Applicable to three small segments of the containment circumference.

NOTE: Secondary stresses (i.e., stresses due to accident thermal loads) are not included in the above Table since thermal loads tend to reduce the actual critical stresses.

TABLE 2

Shell-Basemat Junction Section Forces and Stresses Based on FINEL, ASHSD and BSAP Analysis[(a)]

LOADING COMBINATION	CONCRETE STRESSES		REINFORCEMENT STRESSES		SECTION RESULTANTS	
	MERIDIONAL		MERIDIONAL			
	PRIMARY		PRIMARY			
	Membrane lb/in^2	Membrand & Bending lb/in^2	Inside ksi	Outside ksi	P kips	M ft-kips
Allowable	-3600	-4500	± 54	± 54	---	---
$D + F + 1.5\ P_A$	- 310	-3410	42.4	-10.9	-179	-550
$D + F + 1.25\ P_A + 1.25\ E_o$	- 153	-3260	50.8	- 8.1	- 88	-484

[(a)] Applicable to three small segments of the containment circumference.

NOTE: Secondary stresses (i.e., stresses due to accident thermal loads) are not included in the above Table since thermal loads tend to reduce the actual critical stresses.