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DCP/NRC1343
NSD-NRC-98-5667
Docket No.: 52-003

April 14, 1998

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

ATTENTION: T. R. QUAY

SUBJECT: NRC REQUEST FOR ADDITIONAL INFORMATION 640.155 REV. 1

Dear Mr. Quay:

Enclosed is the Westinghouse response to RAI 640.155 Revision 1 (OITS 6055) related to the basis for the concrete-to-steel gap assumed in the AP600 WGOTHIC Evaluation Model.

This response closes this item, from the Westinghouse perspective.

Please contact Bruce Rarig on (412) 374-4358 if you have any questions concerning this transmittal.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

jml

Enclosure

cc: D. C. Scaletti, NRC (w/ Enclosure)
N. J. Liparulo, Westinghouse (w/o Enclosure)

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ENCLOSURE
WESTINGHOUSE LETTER DCP/NRC1343

APRIL 14, 1998

RAI: 640.155(R1) (OITS 6055)

2.2.2 - Passive Containment Cooling System

Your response to RAI 640.57(g) is unacceptable. The steel jacket-to-concrete air gap is a key assumption in your safety analyses. Provide an ITAAC that verifies the air gap (refer to your response to RAI 480.636). This verification should be based on the expected shrinkage of the concrete over plant life, the type and pour of the concrete, and other key construction features.

For reference, RAI 640.57(g) is shown below.

The following comments relate to Section 2.2.2, "Passive Containment Cooling System," of the CDM.

(g) The design basis performance of the PCS is also based on adequate heat removal from the containment atmosphere by internal, structural heat sinks. The design basis analyses of the performance is based on a maximum steel jacket-to-concrete air gap thickness which accounts for shrinkage of the concrete over the life of the plant. An increased air gap thickness will reduce the effective heat transfer and result in an increase in the containment pressure response following a design basis accident. To assure that this maximum air gap thickness is not exceeded over the life of the plant, the concrete composition (for example aggregate size and moisture content), steel T-pin length and initial pour need to be controlled and verified. The ITAAC does not address the minimum air gap thickness.

Suitable requirements concerning the concrete composition, steel T-pin design and initial pour need to be included in the Design Description. Figure 2.2.2-1 and Table 2.2.2-1 should also be modified as appropriate.

Supplemental Question:

It is our assessment that the steel-jacketed concrete air gap under normal operation is zero, the concrete is likely in contact with the steel walls. For the staff to conclude that your analysis with the 20 mil gap, as used in the WGOTHIC evaluation model, is conservative, please address the following:

Assuming that the initial air gap is zero, for the limiting LOCA demonstrate that the heat transfer into the concrete through the initial contact with the wall and through the headed studs and other steel structures embedded in the concrete (attached to the walls) will not result in vaporization of moisture in the concrete sufficient to pressurize the structure such that the resulting loading on the steel wall would result in an average gap in excess of 20 mils as a result of the accident. The containment pressure can be considered in determining the overall movement of the steel walls in evaluating the gap dimension.

Westinghouse Response to Supplemental Question:

GAP FORMATION IN STEEL-JACKETED CONCRETE DUE TO HEATUP OF FREE MOISTURE IN THE CONCRETE

1.0 Introduction

Concrete walls in the AP600 containment are lined with either carbon or stainless steel plates. The plates are the form for placement of the concrete. In many cases the concrete wall is partially capped with a steel plate making it difficult for the free water in the concrete to escape during curing. During the curing process, the concrete shrinks leaving a gap between the steel and concrete which can fill with water that has escaped the concrete during the curing process. There is a concern that during a mass and energy release to containment event, the free water inside the form may be heated and vaporize, increasing the pressure within the steel form above the containment pressure. This pressure increase could potentially deform the liner plate and create a gap between the concrete and the steel greater than the maximum gap assumed in the AP600 DBA containment pressure analysis (See Figure 640.155(R1)-1). An evaluation of the AP600 LOCA and Steamline break cases was performed to determine the maximum postulated temperature of the free water within the assumed concrete/steel gap, and the resulting pressure within the steel-jacketed concrete. This evaluation conservatively assumed that the steel encasement was completely airtight, thus maximizing the pressure increase.

2.0 Evaluation Method

The limiting MSLB and LOCA SSAR analyses were used to determine the maximum gap temperature. For the purpose of this evaluation, it was assumed that the liquid within the gap reached the same temperature as the surface of the steel liner. Thus, the steam pressure in the gap would equal the saturation pressure at the prescribed temperature. This assumption is considered to be conservative since it ignores 1) the temperature gradient across the steel liner, 2) the heat capacity of the water in limiting the heatup of the water trapped in the gap, and 3) heat removal by the concrete. Thus, the temperature of the water is over-predicted. Walls in the CMT room and SG rooms were chosen since these walls are exposed to the mass and energy releases from either the postulated LOCA or Steamline break.

3.0 LOCA Transient

For the LOCA, the maximum wall temperature occurred in a SG room wall, and had a temperature of 270.09°F with a containment pressure of 59.02 psia @ 1000 seconds. This would result in a gap pressure of 58.61 psia, the sum of the saturation pressure associated with 270.09°F and the air partial pressure. Thus, the containment pressure of 59.02 psia is greater than the pressure within the steel-jacketed concrete and the net delta-P would push in on the steel liner plates.

4.0 Steamline Break

For MSLB, two steamline break cases were evaluated. The 30% power case results in the highest containment pressure, and the 102% power case results in the highest containment vapor temperature. Both cases were examined to determine which case resulted in the highest wall surface temperature for the steel-jacketed concrete walls. The 30% power case was found to have a slightly higher wall temperature. The maximum wall temperature again occurred in an SG room. The maximum wall temperature was 192.39°F with a containment pressure of 53.90 psia at 750.6 seconds. The saturation pressure for a temperature of 192.39°F is 9.82 psia. The gap would be at 24.74 psia which reflects the fact that the water never exceeded 212°F. Therefore, the pressure difference across the steel liner will always be in the direction to push the liner closer to the concrete.

5.0 Conclusion

A review of the AP600 LOCA and Steamline Break containment response calculations showed that the maximum steel lined concrete surface temperature was 270.09°F for the LOCA case. Assuming that the water in the gap between the steel and concrete could reach this maximum temperature, the maximum pressure within the steel-lined concrete would be 58.61 psia, at a time when the containment pressure is at 59.02 psia. Therefore, the force exerted on the steel liner would tend to push the liner closer to the concrete, in all cases. This evaluation demonstrates that the pressure developed within steel-jacketed concrete during either a postulated LOCA or steamline break event is not sufficient to develop a pressure differential with the containment atmosphere. Therefore, there is no impact on the assumed gap between the concrete and the steel liner plate.

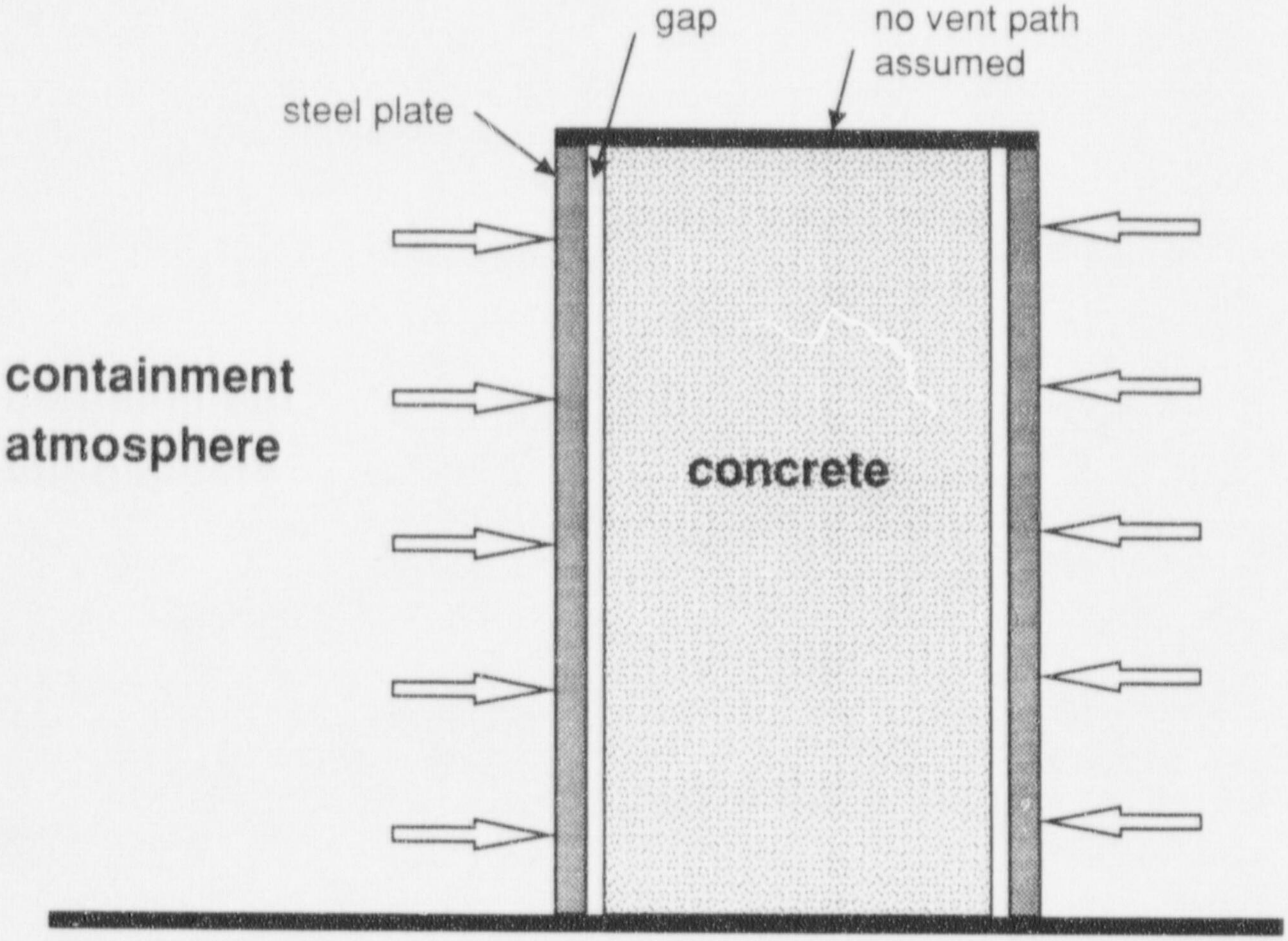

Figure 640.155(R1)-1 Steel-Jacketed Concrete Form with Airtight Boundary

Westinghouse Response to original question:

The design basis performance of the containment considers concrete inside the containment as a heat sink. Some of the concrete heat sinks are enclosed in steel plates and an air gap may be present between the steel plate and concrete. The maximum gap is conservatively estimated herein based on the expected shrinkage of the concrete over plant life, the type and pour of the concrete, and differential thermal expansion of the steel and concrete. The design basis analyses are based on a uniform steel jacket-to-concrete air gap thickness of 0.020 inches which exceeds the conservative estimate of the maximum gap size.

There is no need to provide an ITAAC since the magnitude of air gap used in the design basis analyses bounds the conservatively estimated value for construction which is controlled in accordance with the codes specified for module construction in SSAR subsection 3.8.3.

The maximum gap size was estimated for the structural module walls which represent the largest steel jacketed surfaces in the design basis analyses. The typical configuration of a structural module wall is shown in Figure 640.155-1 (SSAR Figure 3.8.3-2). The walls are either 30 or 48 inches thick and have ½ inch thick surface plates with welded studs and trusses embedded in the concrete at 30 inch centers. The vertical trusses have angles welded to the surface plates with through-wall channels connecting the vertical angles at 48 inch centers. These walls have the greatest potential for gaps since the through-wall embedded steel channels may hold the surface plates apart as the concrete volume reduces. The gap size was estimated for shrinkage and differential temperatures as follows:

- The expected shrinkage for concrete meeting the specifications identified in the SSAR is 350 microstrain (350×10^{-6} in/in) as discussed in attachment 1. This shrinkage for the concrete in the structural modules is lower than shrinkage in exposed concrete due to the surface steel plates which prevent significant drying of the concrete. The shrinkage was conservatively increased to 500 microstrains for evaluation of its effect on the gap.

- Thermal analyses of the design basis LOCA transient show that the embedded steel is at a higher temperature than the concrete during the initial heatup. This results in thermal growth of the embedded steel relative to the concrete. The differential growth is evaluated at the time of the peak containment pressure.

Table 1 AP600 Structural Module Heat Sink Maximum Gaps

	Stud location	Channel location	
		48" wall	30" wall
Gap size due to 500 microstrain shrinkage	0.003	0.010	0.006
Gap size due to LOCA thermal transient at 30 minutes	0.003	0.006	0.006
Total gap size	0.006	0.016	0.012

The gap size is summarized in Table 1. The gap is influenced by the truss configuration and is shown in the table at the plan locations of the studs and channels. The gaps were conservatively evaluated by neglecting the benefits of bond between the concrete and steel as well as the tension strength of concrete resisting bearing loads.

- At the studs, the gap due to shrinkage is conservatively calculated equal to the shrinkage over the length of the stud. Slip is assumed along the shank of the stud. The stud head moves with the center portion of the wall. The gap due to thermal growth is equal to the increase in length of the stud relative to the adjacent concrete obtained from a finite element thermal analysis. This gap would be less at some distance away from the studs due to preload of the surface plate during concrete placement; calculations show that there would still be contact of the surface plate with the concrete midway between studs.

- At the embedded channels, the gap due to shrinkage is conservatively calculated equal to the shrinkage over one half of the thickness of the wall. The gap due to thermal growth is equal to the increase in length of the channel relative to the adjacent concrete obtained from a finite element thermal analysis. This gap is only expected beside the vertical angle of the truss since the surface concrete at the truss itself is trapped within the vertical angle and moves with the angle and surface plate. The gap is conservatively assumed constant over the full height of the truss. However, due to concrete tension and to the preload of the angle during concrete placement, the gap midway between the channels would be smaller.

The maximum gap size of 0.0016 inches is conservatively predicted and occurs at the end of the through wall channels. The channels are placed at 30-inch centers horizontally and 48-inch centers vertically. At other locations the gaps will be smaller and are expected to be zero at mid panel due to initial loading during concrete placement. The channel affects the gap over about 25 percent of the surface (one half of the horizontal distance from the edge of the truss to the adjacent line of studs).

Assuming that the gap over the rest of the surface is that predicted for the studs, the average gap is 0.008 inches. Thus, the assumption of a gap of 0.020 inches at all locations in the design basis containment analyses is extremely conservative.

See response to 640.155 for Attachment 1.

SSAR Revisions: None

ITAAC Revisions: None