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May 28, 2010

Subject: AP1000 Standard COL Technical Report Submittal of APP-GW-GLR-133, Revision 1 (TR 133)

Westinghouse is submitting Revision 1 of AP1000 Standard Combined License Technical Report Number 133, "Summary of Automobile Tornado Missile 30' Above Grade."

This report is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information provided in this report is generic and is expected to apply to all Combined Operating License (COL) applicants referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application. This document is provided in support of the response to RAI-COL03.05.01-04 Revision 2.

Pursuant to 10 CFR 50.30(b), APP-GW-GLR-133, Revision 1, "Summary of Automobile Tornado Missile 30' Above Grade," is submitted as Enclosure 1.

Questions or requests for additional information related to the content and preparation of this report should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

D. A. Lindgren /FOR

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/Enclosure

1. AP1000 Standard COL Technical Report Submittal of APP-GW-GLR-133, Revision 1 (TR 133)

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ENCLOSURE 1

APP-GW-GLR-133 Revision 1

"Summary of Automobile Tornado Missile 30' Above Grade"

Technical Report Number 133

WESTINGHOUSE NON-PROPRIETARY CLASS 3

APP-GW-GLR-133
Revision 1

May 2010

AP1000 Standard Combined License Technical Report

Summary of Automobile Tornado Missile 30' above Grade

(TR 133)

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AP1000 RECORD OF CHANGES

Rev	Date	Revision Description
0	8/2007	Original Issue
1	3/2010	Per NRC request the following revisions were made: • Added that the evaluation includes the shield building up to the elevation of the PCS tank (El. 293' 9"); • Added that the automobile impact forcing function is based on a rigid target; • Corrected "Y" axis heading ("Force-kips") so that it is readable.

Introduction / Background

This Technical Report (TR) has been generated to address whether or not the AP1000 DCD provides sufficient information related to protecting safety-related structures consistent with DG-1143 and Draft Standard Review Plan (SRP) 3.5.1.4 Draft Rev. 3, January 2006. Westinghouse notes that DG-1143 has since been formally issued as Regulatory Guide (RG) 1.76 Rev. 1, March 2007. The issue is automobiles located in parking lots within a half mile radius of the nuclear island and at plant grade elevation that could affect the nuclear island, which is the safety-related structure of concern. The information contained herein can be used by any Combined License applicant to justify that the nuclear island structure remains satisfactorily intact after being impacted at any elevation by an automobile.

Westinghouse has reviewed the information and NRC guidance pertaining to this subject and offers the following comments:

- The AP1000 Design Control Document (DCD) does not and need not consider RG 1.76 Rev. 1, proposed Revision 3 to SRP Section 3.5.1.4 and formally issued SRP Section 3.5.1.4, Revision 3 as these document revisions were not issued six months prior to the docketing of the AP1000 DCD. The NRC is also invoking the backfit rule on the RG update.

- Although DG-1143 appeared to be introducing a change in that the draft guidance did not limit the consideration of tornado missiles with respect to height, the formally issued guidance RG 1.76 Rev. 1, March 2007 did not follow through with the change. Thus the new guidance does not impose new requirements in the area.

- The AP1000 DCD assumes a green field site. Thus 30 feet above grade (with grade being defined as the ground level within a half mile radius of the safety-related structure being considered, which is consistent with SRP3.5.1.4 Rev. 2, July 1981), is limited to elevation 130 feet on the AP1000 general arrangement drawings. (Grade is defined as elevation 100 feet on the AP1000 general arrangement drawings.)

Westinghouse has been made aware that there may be automobile parking lots within a half mile radius of the nuclear island and at elevations significantly above elevation 100', which could impact the nuclear island, which is the safety-related structure of concern.

Automobile impact at all elevations above grade to the nuclear island (the safety-related structure) up to the elevation of the passive containment cooling system tank (El. 293' 9") has been considered in the calculation. A summary of the calculation follows.

Automobile Tornado Missile

The automobile is defined as a massive high kinetic energy missile for the tornado event. The AP1000 Civil Design Criteria, Reference 2, defines this missile as: "a massive high kinetic energy missile which deforms on impact, assumed to be a 4000 lb automobile impacting the structure at normal incidence with a horizontal velocity of 105 mph or a vertical velocity of 74 mph."

In Reference 5, the forcing function associated with the impact of the automobile onto the structure is defined as a quarter sine wave. The basis of this formulation is that "the automobile is considered as a deformable missile and the structure as a rigid target." This formulation is given below:

$F_t = 0.625\ V_c\ W\ \text{Sin}\ (20t) \qquad 0 < t \leq 0.0785$ sec

$F_t = 0 \qquad t > 0.0785$ sec

Where

V_c = ~~change of~~ impact velocity during impact (fps)
Conservatively assumed to be equal to:

V_c = 154 fps for horizontal impact
V_c = 108.5 fps for vertical impact

W = weight of automobile = 4000 lbs

Ft = 385 Sin (20t), kips for horizontal impact
Ft = 271 Sin (20t), kips for vertical impact

It is noted that the velocities given in Revision 1 to Regulatory Guide 1.76 (Reference 3) have reduced the velocities to be considered during impact. The new velocities are 135 fps for horizontal impact, and 90.45 fps for vertical. This reduces Ft to a maximum load of 338 kips and 226 kips for the horizontal and vertical impacts respectively. The automobile impact for which the AP1000 nuclear island was analyzed uses the higher values that are consistent with the AP1000 Civil Design Criteria. The plot of this forcing function considering horizontal impact is shown in Figure 1. The frontal impact is 6.6' x 4.3' per Reference 3.

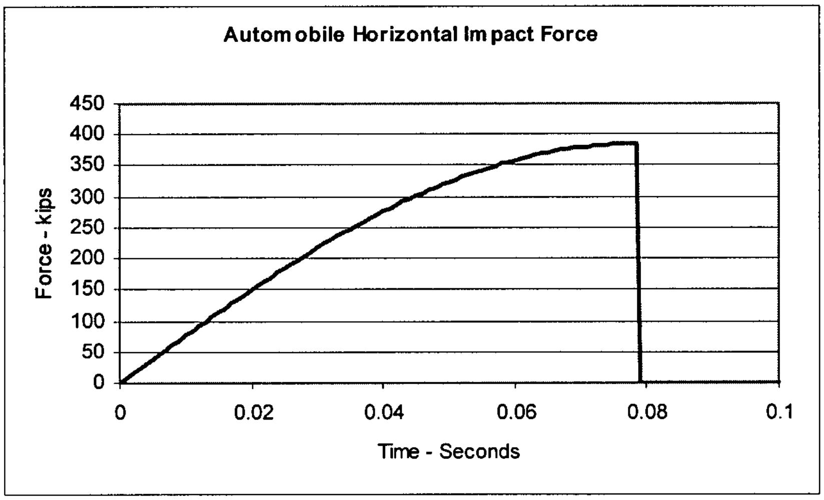

Figure 1 – Automobile Horizontal Impact Force

Selection of Walls and Roof Segments for Analysis

Five typical walls and three typical roof slabs are selected for evaluation. The wall segments and location are identified in Table 1 along with the reinforcing steel. All these locations are associated with the Auxiliary Building. The Shield Building wall is thicker than the Auxiliary Building walls (3' versus 2') and has more reinforcement. Therefore, the Shield Building is shown adequate by demonstrating that the Auxiliary Building structural integrity is maintained for the automobile tornado missile.

Table 1 – Critical Walls and Roofs for Evaluation

Wall/Roof ID Number	Wall / Roof Segment	Elevation	Span	Span	Reinforcement	Thickness T
Walls						
1W	Along wall 1 between walls N & I	135' 3" to 180' 0"	Vertical: 44' 9"	Horizontal: 87' 6"	**Horizontal:** North & South face: #11@6" **Vertical:** North face: #11@6" South face: #11@6" + #8@12"	2' 3"
2W	Along wall N between walls 1 & 4	135' 3" to 180' 0"	Vertical: 44' 9"	Horizontal 66' 0"	**Horizontal:** East & West face: #10@6" + #10@12" **Vertical:** East & West face: #11@12" + #11@12"	2' 0"
3W	Along wall I between 1 & 4	153' 0" to 180' 0"	Vertical 27' 0"	Horizontal 66' 0"	**Horizontal:** East & West face: #11@12" + #10@12" **Vertical:** East & West face: #10@12" + #9@12"	2' 0"
4W	Along wall I between walls 4 & 5	145' 9" to ~162' 0"	Vertical: 16' 3"	Horizontal 57'	**Horizontal:** East & West face: #10@12" + #9@12" **Vertical:** East & West face: #9@12" + #9@12"	2' 0"
5W	Along wall I between 7.3 & 11	135' 3" to 155' 6"	Vertical 20' 3"	Horizontal 71' 3"	**Horizontal:** East & West face: #11@12" + #10@12" **Vertical:** East & West face: #11@12" + #9@12"	2' 0"
Roof						
1R	Representative segment within area defined by walls 1 to 4 & I to N	180' 0"	NS: 66' 0"	EW: 14' 2" Measured between steel beams	**Horizontal Running NS:** Top face: #9@12" Bottom face: #9@12" with metal deck supported on steel beams running NS. **Horizontal Running EW:** Top face: #11@12" Bottom face: #11@12" with metal deck supported on steel beams	1' 3"

Wall/Roof ID Number	**Wall / Roof Segment**	**Elevation**	**Span**	**Span**	**Reinforcement**	**Thickness T**
					running NS.	
2R	Representative segment within area defined by walls 5 to 7 & I to J	160' 6"	NS: 11' 6" Measured between steel beams	EW: 13' 0"	**Horizontal Running NS:** Top face: #10@12" Bottom face: #10@12" with metal deck supported on steel beams running EW. **Horizontal Running EW:** Top face: #10@12" Bottom face: #10@12" with metal deck supported on steel beams running EW.	1' 3"
3R	Representative segment within area defined by walls 10 to 11 & I to K	155' 0"	NS: 11' 9" Measured between steel beams	EW: 36' 0"	**Horizontal Running NS:** Top face: #11@12" Bottom face: #11@12" with metal deck supported on steel beams running EW. **Horizontal Running EW:** Top face: #9@12" Bottom face: #9@12" with metal deck supported on steel beams running EW.	1' 3"

Shear Capacity

The shear stress in the concrete caused by the impact of the automobile on the structural segment is checked against the allowable shear stress defined by the ACI code (Reference 4, ACI 349, Section 11.3). The allowable shear stress is 112.77 psi.

The shear stress that the impact of the automobile imparts to the wall or roof is determined using the effective parameter about the zone of impact. It is conservatively assumed that the impact is next to the edge or corner of the wall or roof. A corner impact is considered since this will have the smallest effective perimeter that supports the shear load by the concrete.

When performing equivalent static analyses for the automobile impact, a dynamic load factor is used to reflect the dynamic amplification effect of the forcing function of the automobile impact. For calculating shear, or overturning effect, it is conservatively assumed that the impact load is amplified by a dynamic load factor of 2 that is the maximum that it can be. The equivalent horizontal static loads become 770 kips (maximum horizontal load of 385 kips times 2) and a vertical equivalent load of 542 kips (maximum vertical load of 271 kips times 2). In addition to the missile impact load, the wind and differential pressure, inward, on the walls act over the area within the shear perimeter. The roof is subjected to dead load as well as wind and differential pressure. It is noted that the tornado wind loading on the roof results in uplift. Therefore, it is conservatively assumed that only the dead weight of the 15" thick roof slab acts.

It was found that the stresses on the analyzed walls and roof segments are under the allowable stress of 112.77 psi.

Ductility due to Flexure from Missile Impact

Based on ACI 349 (Appendix C), Reference 4, and the AP1000 design, a ductility factor of 10 can be used as the allowable.

A dynamic analysis is performed using a one-mass dynamic model and the time history forcing function defined in Section 2.0. The resistance (Rm) associated with each of the wall and roof segments identified in Table 1 is determined, then time history analyses are performed that allows the wall or floor to deform in an elastic-perfectly plastic manner as shown in Figure 2. From these analyses, ductility factors are determined. These ductility factors are adjusted for the added deflection due to the tornado and dead weight. All of the wall and roof segments analyzed had ductility factors below 10.

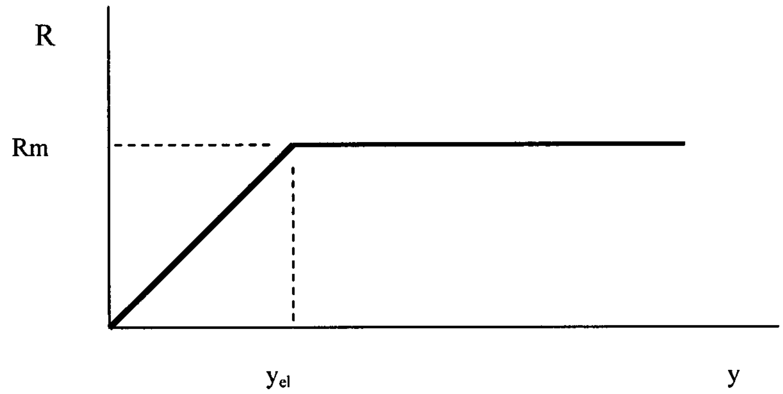

Figure 2 – Elastic Perfectly Plastic Resistance Function

Automobile Global Missile Impact

The analysis of the postulated automobile missile on the enhanced shield building was performed using a force-moment calculation:

$$M = F\,d$$

where

M	moment, kips-ft.
F	shear force (horizontal impact of automobile)
d	distance

The same load as described above under Shear Capacity is used. The equivalent horizontal static loads is 770 kips (maximum horizontal load of 385 kips times 2). The distance d reflects the difference between the impact elevation and the location of the reinforced and steel composite (RC/SC) joint elevation. The calculated moment and shear due to the horizontal impact of the automobile is:

F = 770 kips

M = 114,538 kips-ft.

Using the seismic demand defined by the maximum shear and moment from the six site soil conditions considered in design (Table 2), it is seen that the postulated automobile missile impact shear load is approximately 30 times smaller than the seismic shear load and the moment is approximately 25 times smaller.

Table 2 - Seismic Loads

	Shear (10^3 kips)	Moment (10^3 kips-ft.)
Hard Rock (HR)	38.24	4246
Firm Rock (FR)	37.79	4204
Soft Rock (SR)	37.61	4349
Upper Bound Soft to Medium (UBSM)	41.04	4831
Soft to Medium (SM)	44.11	4874
Soft Soil (SS)	23.4	2898

Therefore, seismic loads govern the design of the shield building with respect to the postulated automobile missile and the global impact of the automobile on the shield building will not affect the reinforced concrete/steel composite connection or design. Further, if the maximum tornado wind load is considered to occur concurrently with the impact of the automobile this conclusion will not be changed because the seismic load is also dominant (over 5 times greater) as seen by the comparison of factors of safety for sliding and overturning as documented in RAI-TR85-SEB1-10, R4, that gives the revised DCD Table 3.8.5-2 (minimum sliding factor of safety for tornado is 5.9, and for seismic is 1.1; minimum overturning factor of safety for tornado is 9.6, and for seismic is 1.17).

Summary/Conclusion

The postulated automobile tornado missile impact above the height of 30 feet above grade on the nuclear island was evaluated. It was determined that the nuclear island structural integrity is maintained. The shear stress due to the automobile impact is within the allowable stress of 112.8 psi. All ductility factors are below 10, which is the acceptable limit, with the largest being ~2.6.

Based on the results of the performed calculation, it can be stated that the massive high-kinetic-energy missile (4000-pound automobile) identified in DCD Section 3.5.1.4 is no longer limited to 30 feet above grade. The evaluation of the automobile tornado missile has considered the impact up to the elevation of the passive containment cooling system tank (El. 293' 9"). The PCS tank in the roof of the shield building is above postulated elevation of tornado auto missiles for known sites. Evaluation of the impact of the missile on the tank is more complicated than evaluation of simple barrier. Although the thickness of concrete for the outside wall and roof of the tank exceed the minimum concrete thickness in Standard Review Plan Section 3.5.3 those minimum thicknesses do not factor in the effect on the stainless steel liner of the tank.

The information contained herein can be used by any Combined License applicant to justify that the nuclear island structure remains satisfactorily intact after being impacted at any elevation by an automobile.

References

1. NOT USED
2. APP-GW-C1-001, "Civil/Structural Design Criteria," Revision 1.

3. Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Revision 1, March 2007.
4. ACI Standard 349, "Code Requirements for Nuclear Safety Related Concrete Structures."
5. R.B. Linderman, et. al., Design of Structures for Missile Impact, BC-TOP-9-A., Rev. 2, Bechtel Power Corporation, San Francisco, California, September 1974.