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Docket No.: STN-52-003

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

ATTENTION: T. R. QUAY

SUBJECT: INPUT ASSUMPTIONS FOR CALCULATION OF AEROSOL REMOVAL  
COEFFICIENTS IN AP600 CONTAINMENT

- References:
1. Westinghouse Letter to NRC: NSD-NRC-96-4807, 8/29/96, "Surface Areas in the AP600 Containment that are Available for Aerosol Sedimentation Collection"
  2. Westinghouse Letter to NRC: NSD-NRC-95-4430, 4/7/95, "Information Requested by RAI 470.23 Regarding Input Parameters for the Calculation of Aerosol Removal Coefficients"
  3. "Summary of February 11 and 12, 1997, Meeting with Westinghouse to Discuss Issues Related to the AP600 Source Term," 3/14/97, USNRC
  4. Westinghouse Letter to NRC: NSD-NRC-97-4978, 2/7/97, "Position Paper in Support of the Assumption of Complete Mixing of Aerosols in the AP600 Containment Atmosphere following a Loss of Coolant Accident"

Dear Mr. Quay:

A number of input assumptions for calculation of the post-LOCA aerosol removal coefficients for the AP600 were discussed in the telecon of April 2, 1997. The participants in the telecon were:

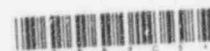
Nuclear Regulatory Commission:	Tom Kenyon, Rich Emch, and Jay Lee
Westinghouse Electric:	Brian McIntyre, Jim Grover, and Jim Scobel
Polestar Applied Technology:	Dave Leaver, Jun Li, and Rudy Sher

This letter provides documentation of the information provided in the telecon plus additional discussion on issues as requested by the staff.

#### Sedimentation Surface Area

The surface area that is available for sedimentation processes in the AP600 containment was identified by Westinghouse as 2900 m<sup>2</sup>. This value is a reduction from the 3500 m<sup>2</sup> reported in

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Reference 1. The determination of available surface area does not include any surfaces that are in dead-ended volumes (e.g., accumulator rooms and CVS room) or flooded areas (e.g., reactor cavity). Also, the surfaces in and directly above the steam generator compartments were excluded due to concerns about potential resuspension of deposited aerosols by the super-heated steam plume. The Westinghouse review of the surfaces areas showed that there was adequate separation between the various surfaces such that "shadowing" of one surface by another would not be expected to be a factor in the sedimentation removal process.

#### Mixing Volume for Aerosols in Containment

The volume in the containment that is available for mixing of aerosols was identified by Westinghouse as 45,900 m<sup>3</sup>. This value is slightly lower than the 47,927 m<sup>3</sup> that was reported in Reference 2. The determination of aerosol mixing volume does not include any volumes that are dead-ended (e.g., accumulator rooms and CVS room) or that are flooded (e.g., reactor cavity).

#### Ratio of Inert Aerosol Mass to Mass of Fission Product Aerosol Mass

The previous determination of aerosol removal coefficients performed by Polestar for the AP600 used a ratio for inert material to fission products of 3:1. Additional review of available literature indicates that a ratio of 1.5:1 better models the core degradation event. This lower ratio is being used in the reanalysis of aerosol removal coefficients.

#### Shape Factors

Shape factors are derived from the assumed packing fraction. In the analysis performed by Sandia for the NRC, a fractal aggregate simulation approach was used to model the agglomeration of particles. From our review of the Sandia material, it appears that a packing factor range of 0.0028 to 0.28 was used with the result that the shape factor could be as high as 2.2.

The fractal aggregate approach does not appear to be appropriate. Review of scanning electron microscope photographs of deposited aerosol particles from actual core melt and fission product vaporization and aerosolization experiments (the Argonne STEP-4 test and the INEL Power Burst Facility SFD 1-4 test) indicates that the processes are fundamentally different from the fractal model. The deposited particles appear relatively dense. A packing fraction of 0.8 is being used in the reanalysis of aerosol removal coefficients. This is expected to result in a shape factor of the order of 1.1.

#### Use of Shape Factor in the Thermophoresis Equation

As discussed in the telecon, we believe that the Sandia thermophoresis equation for aerosol removal, which includes the shape factor in the denominator, is not correct. The shape factor would not have a significant impact on the thermophoretic removal of aerosols. In the reanalysis of the aerosol removal coefficients, we will not include the shape factor in the thermophoretic removal equation.

Mixing of Aerosols in the AP600 Containment - Air Entrainment in the Rising Plume

This item was discussed only briefly during the telecon and without any details provided. By addressing it in this letter, action item A.1 from Reference 3 is fully addressed.

At the meeting with the NRC at Polestar offices on February 11 & 12, 1997, a question was raised regarding the validity of the mixing time of one full volume in ~350 seconds that was reported in Reference 4; this is equivalent to a mixing constant of  $10.3 \text{ hr}^{-1}$ . Based on a rough calculation by Sandia at the meeting (as shown in Enclosure 4 to Reference 3), a mixing time of one full volume in ~3000 seconds was arrived at. This is equivalent to a mixing constant of  $1.2 \text{ hr}^{-1}$ .

The determination of 3000 seconds to mix one full volume is based on the incorrect identification of 1.8 kg/sec of steam production due to decay heat. At a steam production of 1.8 kg/sec, the decay heat input would be 4 Mw which is about 0.2% of the rated thermal power. During the early stages of the accident which are of concern relative to aerosol removal processes (i.e., the first 6 to 12 hours), the decay heat is far greater than 0.2% of rated core power. The approximate decay heat production at different times after reactor trip are:

time (hr)	decay heat (Mw)
0.5	40.0
1.0	26.0
2.0	21.5
4.0	18.0
8.0	15.0
12.0	13.5

The model described in Reference 4 identifies a steam plume flow rate of 400 ft<sup>3</sup>/sec. Based on an assumed pressure in the containment of 30 psig, this is the equivalent of 20.4 kg/sec of steam and a decay heat production rate of 44 Mw. This is appropriate to a time very early in the accident (note that this is inconsistent with the statement in Reference 4 that the 400 ft<sup>3</sup>/sec is based on 19 Mw of decay heat production).

Neither the 44 Mw nor the 4 Mw decay heat production rate is representative of the time of concern for which aerosol mixing in the containment is to be demonstrated. The time of concern is the period between the onset of release of activity from the core (for the AP600 this is 50 minutes into the accident) and the time at which most of the aerosols would have been removed from the containment atmosphere (this would be at about 12 hours). The limiting case would be at 12 hours when the decay heat production is lower.

The discussion of aerosol mixing in containment that was provided in Reference 4 will be revised and submitted to the NRC. The review and comments provided at the meeting of February 11 & 12, 1997, plus further internal review have shown the need for refinement of the report. The following changes will be made to the model:

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- The mixing rate will be determined for 12 hours after reactor trip. The decay heat production rate and containment conditions associated with this times will be used.
- The decay heat production in the reactor vessel will be appropriately reduced to reflect the portion of core activity assumed to be released to the containment.
- Instead of releasing the steam in one plume, two steam plumes will be assumed. This is consistent with the AP600 design which has two locations for the stage-4 discharge from the automatic depressurization system (ADS).
- The volume assumed for aerosol mixing will be increased from the 40,360 m<sup>3</sup> (which is the volume above the operating deck only) to 45,900 m<sup>3</sup>. This larger volume includes the volume below the operating deck that would readily participate in the mixing process but does not include the volumes that are flooded (e.g., the reactor cavity) or those that are dead-ended (e.g., the accumulator rooms and the CVS room).

It is expected that after making these changes the results will be similar to those currently reported in Reference 4.

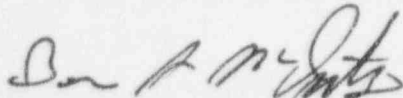
#### Presence of Hydrogen in the Containment Atmosphere

This item was discussed only briefly in the telecon with the point being made that, since there is assumed to be a core melt, there is also assumed to be a large hydrogen production due to zirconium reaction with water. As a result, it is assumed that the ignitors initiate hydrogen burning and the hydrogen concentration remains near the lower flammability limit. Including steam effects, the hydrogen concentration would be typically 4 to 6 percent. The presence of hydrogen in the containment atmosphere is included in the MAAP modeling of the thermal-hydraulics.

#### Thermal-Hydraulics

As stated during the telecon, the containment thermal-hydraulics data that was transmitted by Reference 2 has been superseded by a new MAAP analysis and this revised data is being used in the recalculation of aerosol removal coefficients.

If there are any questions on the above, contact Brian McIntyre at (412) 374-4334.



Brian A. McIntyre, Manager  
Advanced Plant Safety and Licensing

jml

cc: N. J. Liparulo, Westinghouse  
J. Sebrosky, NRC