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Energy Systems

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NSD-NRC-96-4839
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Docket No.: STN-52-003

October 11, 1996

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

ATTENTION: T. R. QUAY

SUBJECT: WESTINGHOUSE RESPONSES TO NRC REQUESTS FOR ADDITIONAL INFORMATION ON THE AP600

Dear Mr. Quay:

Enclosed are three copies of the Westinghouse responses to NRC requests for additional information on AP600 topics. Responses to 280.14 through 280.19 and 280.31 provide additional information on Section 9.5.1 of the SSAR. Responses to 480.290 and 480.293 respond to questions on the WGOTHIC computer code.

The NRC technical staff should review these responses as a part of their review of the AP600 design.

Please contact Brian A. McIntyre on (412) 374-4334 if you have any questions concerning this transmittal.

Brian A. McIntyre

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

Enclosures
Attachments

cc: T. Kenyon, NRC (w/o enclosures)
D. Jackson, NRC (1E1)
E. Throm, NRC (w/o enclosures)
J. Kudrick, NRC (w/o enclosures)
P. Boehnert, ACRS (4E1)
N. Liparulo, Westinghouse (w/o attachments and enclosures)

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Question 280.14

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.2 Protection of Safe Shutdown Capability for a Fire Outside the Containment and the Main Control Room.

On SSAR Page 9A-63, Westinghouse states that fire areas within the Annex I and Annex II buildings are separated from safety-related areas of the Nuclear Island by a 3-hour fire barrier wall, except for those fire areas which include portions of the auxiliary building. The staff is concerned that the Fire Area 4031 AF 02 (SSAR Section 9A.3.4.6) which contains safety-related Division A electrical cables (it is not clear whether these are required for safe shutdown) may not be separated by 3-hour fire barrier walls, ceilings or floors from adjoining annex building fire areas. The staff is further concerned that the fire areas in the annex buildings may not be separated by 3-hour structural fire barriers from auxiliary building fire areas which contain safe shutdown components (i.e., equipment, cabling, instrument and controls). During its meeting with the staff on April 12 and 13, 1995, Westinghouse told the staff that the Annex I and Annex II buildings are now considered as one Annex Building and that the Annex building fire areas do not contain safe shutdown components including cables and that the above position will be reflected in a future revision of the SSAR. The staff considers that the proposed revision does not clearly resolve staff's two concerns identified above (for example, it is not clear where the Division A electrical cables, supposedly protected by 3-hour fire barrier in the Fire Area 4031 AF 02 will be relocated). For the above reason, the above concerns are identified as RAI # 280.14 and is designated as Open Item 9.5.1.6-3.

Response:

SSAR Appendix 9A, subsection 9A.3.4.8 and Figure 9A-3 (Sheet 1 of 3), Revision 8, properly shows the location and contents of Fire Area 4031 AF 02. As stated, there are no Division A cables in Fire Area 4031 AF 02. The cables addressed by this Request for Additional Information, as well as others, have been relocated to be within a fire area associated with their division. Note that for other fire areas, as indicated in Note 3 on Figure 9A-1 (Sheet 2, et al.), electrical cable chases for one division that pass through a fire area of another division are separated from those fire areas by three-hour fire barriers. Although these chases are not shown on Figure 9A-1, the space within the chases is considered part of the fire area at their ends, not a part of the fire area on the outside of the three-hour fire barrier.

SSAR Revision: None

Question 280.15

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.2 Protection of Safe Shutdown Capability for a Fire Outside the Containment and the Main Control Room.

For a number of fire areas outside the containment that contain safe shutdown components, Westinghouse states in SSAR Section 9A that the fire resistance of the boundaries of the fire areas are greater than the equivalent fire duration in those areas as shown in SSAR Table 9A-6. The staff is concerned about this position, since equivalent fire duration does not relate to the actual performance of a fire barrier assembly when exposed to the standard time-temperature fire endurance test as defined by American Society for Testing and Materials (ASTM) E-119. The above concern is RAI # 280.15 and is designated as Open Item 9.5.1.6-4.

Response:

The "Equivalent Fire Duration" portion of SSAR Appendix 9A, subsection 9A.2.4, Revision 8, provides a description of the basis and use of the comparison of estimated fire duration to fire area boundary resistance times. These comparisons, which are summarized in Table 9A-3, are based on Figures 7-9A and 7-9B of the NFPA Fire Protection Handbook and normalized. Although not based on ASTM E-119 tests, they are considered adequate and appropriate for determining the adequacy of fire boundary resistance values identified in Appendix 9A.

SSAR Revision: None

Question 280.16

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

1. The SSAR information on separation between redundant safe shutdown components inside the containment/shield building fire area zones lacks details. The staff needs details on the separation between redundant safe shutdown components (instrumentation and controls and power and control cables are also considered as components) provided in the form of structural walls (their types, thickness, fire rating), containment penetrations (fire rating), horizontal distances with no intervening combustibles, cable trays (fire rating of the cables and distances between divisional cable trays), equipment such as pressurizer or steam generator. The staff needs the above information for each of the fire zones containing any safe shutdown component for which redundant safe shutdown component is credited in the safe shutdown analysis. This concern is RAI # 280.16 and is designated as Open Item 9.5.1.6-5.

Response:

SSAR Appendix 9A, subsection 9A.3.1.1, Revision 8, and its subsections address each of the 19 fire zones within the containment/shield building. In each case, details on the separation between redundant safe shutdown components is provided.

SSAR Revision: None

Question 280.17

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

2. In SSAR Section 9A, Westinghouse states that fire damage to any single valve does not affect the adjacent valve since the valves are sufficiently separated from one another in the following zones: Fire Zones 1100 AF 11206, 11207, 11208, 11209, 11300A and 11300C. This section does not define what sufficient separation means. Further, it is not clear whether any safety function (e.g., containment isolation needed to maintain safe shutdown over an extended period of time, when only safety-related equipment are used for safe shutdown) will be compromised in the event fire damages all the valves in any zone listed above. If so, it is not clear how the safety function will be performed. Also, it is not clear whether following a fire in any one of the fire zones 1100 AF 11206, 11207, 11300A and 11300C, safe shutdown can be achieved without relying on any safe shutdown component located in the affected fire zone. The above concern arises since SSAR Section 9A refers only to the performance of some specific safe shutdown function (i.e., providing adequate cooling to the reactor vessel) by redundant components in an unaffected fire zone and does not refer to ensuring safe shutdown capability in entirety without relying on any safe shutdown component in the affected fire zone. The above concerns are collectively classified as RAI # 280.17 and is designated as Open Item 9.5.1.6-6.

Response:

SSAR Appendix 9A, Revision 8, subsections 9A.3.1.1.3 through 9A.3.1.1.7 and 9A.3.1.1.9. as well as, Table 9A-2 provide the information determine the safe shutdown capability of the plant given a fire in a designated fire zone. The "Safe Shutdown Evaluation" portion of a subsection provides a description of the functions that are disabled in the fire zone with the fire. It then delineates the fire zone(s) containing redundant safe shutdown equipment. A definitive listing of the safe shutdown equipment in each fire zone is contained in Table 9A-2. As a result, it can be shown that safe shutdown can be achieved without relying on any components in the fire zone affected by the fire.

SSAR Revision:

NONE

Question 280.18

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

3. The safe shutdown evaluations for a number of fire zones contain statements listed below:

"The horizontal separation between the termination boxes for different divisions is at least three feet. Fire in one division does not damage the adjacent division" (Fire Zone 1100 AF 11300B - this area encompasses passive residual heat removal (PRHR) valve area and north quadrant mechanical penetration area)."

"The horizontal runs of Divisions B and D cable trays are routed adjacent to each other (side by side) approximately 26 feet above the operating deck. A fire in either division of cable trays does not propagate to the other division of cable trays (Fire Zone 1100 AF 11500)."

"The minimum distance between the instrumentation and control cabling for separate divisions is approximately 3 feet. Adequate protection is provided between the four divisions of cabling to prevent a fire in one bundle of cabling from propagating to an adjacent cable bundle of another division" (Fire Zone 1200 AF 12356)."

"The cable for these divisions (A and B) is separated from each other and from nonsafety-related cable such that a fire cannot affect both safety-related raceways" (Fire Zone 1200 AF 12556 - this area contains PCS air flow baffles, PCS piping, instrumentation and cables outside of the PCS valve room)."

"The divisional cable and valves are separated from each other and protected such that a fire cannot affect both divisions" (Fire Zone 1200 AF 12701 - PCS valves and cables in this fire zone are assigned to Divisions A and B)."

Based on the above statements, the staff is concerned that horizontal separation of at least 3 feet between safe shutdown cables of different (i.e., redundant) divisions in accordance with Institute of Electrical and Electronics Engineers (IEEE) 384 requirement does not necessarily eliminate fire-induced associated circuit problems which may compromise safe shutdown capability. This is because the 3 feet divisional cable separation eliminates only the problems internally generated due to electrical faults. Furthermore, the staff is concerned that the loss of all PRHR heat exchanger discharge valves of different divisions due to a fire in Fire Zone 1100 AF 11300B will result in loss of safe shutdown capability, particularly, since there is only one PRHR heat exchanger. The above concerns are collectively classified as RAI # 280.18 and is designated as Open Item 9.5.1.6-7 (resolution of Open Item 9.5.1.6-5 will provide partial resolution of this open item).

Response:

SSAR Section 9.5.1.6, Revision 8, does not include the descriptions provided in this Request for Additional Information.

SSAR Appendix 9A, Revision 8, includes "Safe Shutdown Evaluations" for the fire zones within the Containment/Shield Building. These evaluations do not rely on 3 feet horizontal separation of safe shutdown cables of different (i.e., redundant) divisions. The evaluations indicate that redundant divisions or functions are in separate fire zones and that they are separated by physical barriers as well as distance. In the case of the single passive residual heat removal heat exchanger, a fire in the zone that disables the heat exchanger will have no effect on the valves necessary for feed and bleed operations which are available for decay heat removal.

SSAR Revision: None

Question 280.19

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

4. In SSAR Section 9A, Westinghouse does not explain why a fire in either Fire Zone 1100 AF 11303A or AF 11303B can result in loss of only one of the three ADS vent paths in the affected zone. Also, SSAR Section 9A does not clarify whether following a fire in any one of the zones listed above, the first, second and third stages of ADS valves in the unaffected fire zone (the above fire zones contain redundant first, second and third stages of ADS valves) and fourth stage ADS valves in either Fire Zone 1100 AF 11301 or AF 11302 can provide sufficient depressurization capability, should the ADS be required to achieve safe shutdown. The above concerns are classified as RAI # 280.19 and is designated as Open Item 9.5.1.6-8.

Response:

SSAR Appendix 9A, Revision 8, subsections 9A.3.1.1.13 and 9A.3.1.1.14 describe how the two groups of stage 1, 2 and 3 ADS valves and their control are each protected from a fire in the other. It also states that either group is sufficient for safe shutdown. In addition, subsections 9A.3.1.1.10 and 9A.3.1.1.11 state that either set of fourth stage ADS valves is sufficient for safe shutdown and that they are separated by distance and fire barriers from other ADS valves.

Note that, consistent with SSAR subsection 9A.2.7.1, a fire in one of the fire zones identified here will not cause the opening of valves sufficient to become an inadvertent ADS event. This reenforces the conclusion that unaffected ADS valve groups are sufficient for safe shutdown. ADS response during applicable events is later in the event thus requiring less vent area.

SSAR Revision:

NONE

Question 280.31

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.5 Additional Features to Ensure Safe Shutdown Capability.

Regarding safe shutdown functions, SSAR Section 7.4 (Page 7.4-1 lists the following as needed for safe shutdown: decay heat removal, RCS inventory control, RCS pressure control and reactivity control. Though SSAR Section 7.4 describes how safe shutdown is achieved and maintained, it does not clearly state how the reactivity control function and reactor coolant makeup function (needed to maintain reactor coolant inventory control) are ensured. The staff is particularly concerned regarding ensuring the reactor coolant makeup function to maintain safe shutdown over long-term, once it has been achieved (see SECY-94-084, Pages 13 and 14). The above concerns which deal with the performance goals of safe shutdown capability, namely, ensuring reactivity control function and reactor coolant makeup function, particularly over long-term, are collectively classified as RAI # 280.31 and is designated as Open Item 9.5.1.6-20.

Response:

SSAR subsection 7.4.1.1, Revision 5, provides a description of safe shutdown using safety-related systems, including a discussion of maintenance of final long term safe shutdown conditions. Initial response is insertion of control rods. Following this initial reactivity control function, borated water is used to maintain reactivity control and reactor coolant inventory control. Borated water makeup, which provides reactivity control, is provided first by the core makeup tanks. Then borated water makeup is provided by the accumulators and the in-containment refueling water storage tank, if needed because of LOCA or ADS actuation or both. If required following a loss of coolant accident, borated water is recirculated through the reactor from the flooded reactor cavity via the recirculation sump. With containment isolation established, the water inventory inside containment provides an indefinite reactor coolant makeup inventory of borated water. The systems providing reactivity control and reactor coolant makeup are located within containment. As described in SSAR Appendix 9A, the capability to achieve and maintain safe shutdown is preserved with a fire in any one fire zone within containment.

SSAR Revision: NONE

Question 480.290

Re: (WGOTHIC MODELS AND PHENOMENA) FLOW RESISTANCES AND VELOCITIES;
A detailed description needs to be provided showing how intercell flow resistances are calculated for cells in an open volume. The LST model could serve as an example.

Response: In an open volume, the flow field is determined by the relative magnitude of the wall and form drag, inertia, momentum fluxes, body forces and viscous and turbulent stresses. If a WGOTHIC network of lumped volumes and junctions is used to model the open region, then only wall and form drag, inertia and body forces are considered. In a subdivided model, all of the mentioned force terms can be included. These two modeling options are discussed below.

In a lumped volume network model, a collection of volumes is used to represent the region of interest. Mass and energy balances are maintained for each of these volumes. The volumes can be connected together in any meaningful fashion with flow junctions. Momentum balances are maintained for each junction that include terms for the inertia, body force and drag forces. If, for example, a particular volume represents a rectangular volume in an open region, with adjacent volumes at each of the 6 volume faces, then junctions would be used to model the flow connector for each of the volume faces. The flow area of these connectors would be consistent with the volume face area. The inertia is controlled by a user specified inertia length. The recommended value of the center-to-center distance of the adjoined cells is typically used. If there is a wall parallel to the junction connection, then the wall friction can be modeled by specifying appropriate values for the junction hydraulic diameter and friction length. The hydraulic diameter should be specified as

$$D_h = \frac{4AL}{W}$$

where A is the junction area, L is the friction length and W is the wall area exposed to the junction. Wall drag will then be calculated using a smooth tube friction factor. If there are some obstacles in the region represented by the flow path, e.g. piping runs, cable trays, equipment, then an appropriate loss coefficient can be specified for the junction. The resulting drag force is added to the wall drag force. If there is no adjacent wall and no obstacles, then the input value for the friction length and the forward and reverse loss coefficients would be set to zero. However, to maintain numerical stability, WGOTHIC sets the minimum form loss coefficient to 0.001. In this case of minimal flow resistance, the velocity and pressure fields will be determined by a balance of inertia and body forces. The flow field will adjust to eliminate buoyancy forces and local pressure variations resulting from inertia and the time to adjustment will be controlled by the specified inertia lengths.

In a subdivided model the region is divided into a number of subvolumes by a series of grid planes arranged to form rectangular volumes. Mass and energy balances are maintained for each of these subvolumes. Momentum balances are maintained for the momentum control volumes that are arranged in what is commonly referred to as a staggered grid. For each subvolume face that is shared by two subvolumes, there is a momentum control volume for the momentum perpendicular to the subvolume face. (Refer to the diagrams in Section 11 of Reference 480.290-1). For each of these momentum control volumes, the user can specify the flow area, the hydraulic diameter and a form loss coefficient. Typically, the flow area is the face area of the subvolume. If one or more sides of the control volume

are formed by a wall, then wall friction can be included by specifying an appropriate hydraulic diameter. The hydraulic diameter should be calculated from

$$D_h = \frac{4AL}{W}$$

where A is the flow area, L is length of the wall in the flow direction and W is the wall area exposed to the momentum control volume. For momentum control volumes for vertical flow, the hydraulic diameter is input directly. For momentum control volumes for horizontal flow, the hydraulic diameter is related to the user specified value for the wall factor, λ_w, by

$$\lambda_w = \frac{2s}{D_h}$$

where s is the width of the transverse connection. The wall drag is calculated according to Equations 8.83 through 8.86 of Reference 480.290-1 assuming a friction factor for a smooth tube. If a form loss coefficient is specified for the control volume, then the drag is calculated according to Equation 8.81 and added to the wall drag. If there are no walls bounding the control volume, then the hydraulic diameter is set to a large value (relative to the cell dimensions). This effectively eliminates any wall drag. To maintain numerical stability, the minimum loss coefficient for horizontal connections is set to 0.01.

The other mechanism for intercell flow resistance in a subdivided model is viscous and turbulent shear. Both of these models were activated for the subdivided model of the LST. In this model the stress terms were calculated only for the vapor phase. The viscous shear force depends on the local viscosity and the velocity gradients. The shear force is calculated for each face of the momentum control volume that is parallel to the direction of flow according to Equations 9.1 through 9.4 of Reference 480.290-1. When the turbulence model is activated, the viscosity coefficient in the stress calculations is augmented by the eddy viscosity. The eddy viscosity is calculated from the local strain rates using a one parameter mixing length model. The value of the mixing length used in the LST calculations was very small (0.01 ft) relative to the cell size making the impact of turbulent shear negligible.

Please also see the response to RAI 480.294 for a description of how friction losses are input in the WGOTHIC evaluation model.

References:

480.290-1 NTD-NRC-95-4563, "GOTHIC Version 4.0 Documentation Enclosure 2: Technical Manual," September 1995.

SSAR Revision: NONE

Question 480.293

Re: (WGOTHIC MODELS AND PHENOMENA)FLOW RESISTANCES AND VELOCITIES:
Is there a missing factor of two in the equation for the vertical component of the velocity (Equation 8.16 on page 8-5 of EPRI TR-1030503-V1, or page A-107 of WCAP-13246)? Do these equations properly represent what is actually used in the code?

Response:

Equation 8.16 (Reference 480.293-1) is incorrect and does not represent what is actually in the code. The vertical component of the velocity for phase i as calculated in WGOTHIC is

$$U_{\Phi}=\frac{(F_{\Phi}^{below}+F_{\Phi}^{above}+\sum_{vertjuncs}\xi_j F_{\Phi j})}{(A^{below}+A^{above}+\sum_{vertjuncs}A_j)(\alpha_{\phi}\rho_{\phi})}$$

References:

480.293-1 NTD-NRC-95-4563, "GOTHIC Version 4.0 Documentation, Enclosure 2: Technical Manual", September 1995.

SSAR Revision: NONE

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The NRC technical staff should review these responses as a part of their review of the AP600 design.

Please contact Brian A. McIntyre on (412) 374-4334 if you have any questions concerning this transmittal.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

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2950A

Question 280.14

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9.5.1.6.2 Protection of Safe Shutdown Capability for a Fire Outside the Containment and the Main Control Room.

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Response:

SSAR Appendix 9A, subsection 9A.3.4.8 and Figure 9A-3 (Sheet 1 of 3), Revision 8, properly shows the location and contents of Fire Area 4031 AF 02. As stated, there are no Division A cables in Fire Area 4031 AF 02. The cables addressed by this Request for Additional Information, as well as others, have been relocated to be within a fire area associated with their division. Note that for other fire areas, as indicated in Note 3 on Figure 9A-1 (Sheet 2, et al.), electrical cable chases for one division that pass through a fire area of another division are separated from those fire areas by three-hour fire barriers. Although these chases are not shown on Figure 9A-1, the space within the chases is considered part of the fire area at their ends, not a part of the fire area on the outside of the three-hour fire barrier.

SSAR Revision: None

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For a number of fire areas outside the containment that contain safe shutdown components, Westinghouse states in SSAR Section 9A that the fire resistance of the boundaries of the fire areas are greater than the equivalent fire duration in those areas as shown in SSAR Table 9A-6. The staff is concerned about this position, since equivalent fire duration does not relate to the actual performance of a fire barrier assembly when exposed to the standard time-temperature fire endurance test as defined by American Society for Testing and Materials (ASTM) E-119. The above concern is RAI # 280.15 and is designated as Open Item 9.5.1.6-4.

Response:

The "Equivalent Fire Duration" portion of SSAR Appendix 9A, subsection 9A.2.4, Revision 8, provides a description of the basis and use of the comparison of estimated fire duration to fire area boundary resistance times. These comparisons, which are summarized in Table 9A-3, are based on Figures 7-9A and 7-9B of the NFPA Fire Protection Handbook and normalized. Although not based on ASTM E-119 tests, they are considered adequate and appropriate for determining the adequacy of fire boundary resistance values identified in Appendix 9A.

SSAR Revision: None

Question 280.16

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9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

1. The SSAR information on separation between redundant safe shutdown components inside the containment/shield building fire area zones lacks details. The staff needs details on the separation between redundant safe shutdown components (instrumentation and controls and power and control cables are also considered as components) provided in the form of structural walls (their types, thickness, fire rating), containment penetrations (fire rating), horizontal distances with no intervening combustibles, cable trays (fire rating of the cables and distances between divisional cable trays), equipment such as pressurizer or steam generator. The staff needs the above information for each of the fire zones containing any safe shutdown component for which redundant safe shutdown component is credited in the safe shutdown analysis. This concern is RAI # 280.16 and is designated as Open Item 9.5.1.6-5.

Response:

SSAR Appendix 9A, subsection 9A.3.1.1, Revision 8, and its subsections address each of the 19 fire zones within the containment/shield building. In each case, details on the separation between redundant safe shutdown components is provided.

SSAR Revision: None

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2. In SSAR Section 9A, Westinghouse states that fire damage to any single valve does not affect the adjacent valve since the valves are sufficiently separated from one another in the following zones: Fire Zones 1100 AF 11206, 11207, 11208, 11209, 11300A and 11300C. This section does not define what sufficient separation means. Further, it is not clear whether any safety function (e.g., containment isolation needed to maintain safe shutdown over an extended period of time, when only safety-related equipment are used for safe shutdown) will be compromised in the event fire damages all the valves in any zone listed above. If so, it is not clear how the safety function will be performed. Also, it is not clear whether following a fire in any one of the fire zones 1100 AF 11206, 11207, 11300A and 11300C, safe shutdown can be achieved without relying on any safe shutdown component located in the affected fire zone. The above concern arises since SSAR Section 9A refers only to the performance of some specific safe shutdown function (i.e., providing adequate cooling to the reactor vessel) by redundant components in an unaffected fire zone and does not refer to ensuring safe shutdown capability in entirety without relying on any safe shutdown component in the affected fire zone. The above concerns are collectively classified as RAI # 280.17 and is designated as Open Item 9.5.1.6-6.

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SSAR Revision:

NONE

Question 280.18

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9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

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"The horizontal runs of Divisions B and D cable trays are routed adjacent to each other (side by side) approximately 26 feet above the operating deck. A fire in either division of cable trays does not propagate to the other division of cable trays (Fire Zone 1100 AF 11500)."

"The minimum distance between the instrumentation and control cabling for separate divisions is approximately 3 feet. Adequate protection is provided between the four divisions of cabling to prevent a fire in one bundle of cabling from propagating to an adjacent cable bundle of another division" (Fire Zone 1200 AF 12356)."

"The cable for these divisions (A and B) is separated from each other and from nonsafety-related cable such that a fire cannot affect both safety-related raceways" (Fire Zone 1200 AF 12556 - this area contains PCS air flow baffles, PCS piping, instrumentation and cables outside of the PCS valve room)."

"The divisional cable and valves are separated from each other and protected such that a fire cannot affect both divisions" (Fire Zone 1200 AF 12701 - PCS valves and cables in this fire zone are assigned to Divisions A and B)."

Based on the above statements, the staff is concerned that horizontal separation of at least 3 feet between safe shutdown cables of different (i.e., redundant) divisions in accordance with Institute of Electrical and Electronics Engineers (IEEE) 384 requirement does not necessarily eliminate fire-induced associated circuit problems which may compromise safe shutdown capability. This is because the 3 feet divisional cable separation eliminates only the problems internally generated due to electrical faults. Furthermore, the staff is concerned that the loss of all PRHR heat exchanger discharge valves of different divisions due to a fire in Fire Zone 1100 AF 11300B will result in loss of safe shutdown capability, particularly, since there is only one PRHR heat exchanger. The above concerns are collectively classified as RAI # 280.18 and is designated as Open Item 9.5.1.6-7 (resolution of Open Item 9.5.1.6-5 will provide partial resolution of this open item).

Response:

SSAR Section 9.5.1.6, Revision 8, does not include the descriptions provided in this Request for Additional Information.

SSAR Appendix 9A, Revision 8, includes "Safe Shutdown Evaluations" for the fire zones within the Containment/Shield Building. These evaluations do not rely on 3 feet horizontal separation of safe shutdown cables of different (i.e., redundant) divisions. The evaluations indicate that redundant divisions or functions are in separate fire zones and that they are separated by physical barriers as well as distance. In the case of the single passive residual heat removal heat exchanger, a fire in the zone that disables the heat exchanger will have no effect on the valves necessary for feed and bleed operations which are available for decay heat removal.

SSAR Revision: None

Question 280.19

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

4. In SSAR Section 9A, Westinghouse does not explain why a fire in either Fire Zone 1100 AF 11303A or AF 11303B can result in loss of only one of the three ADS vent paths in the affected zone. Also, SSAR Section 9A does not clarify whether following a fire in any one of the zones listed above, the first, second and third stages of ADS valves in the unaffected fire zone (the above fire zones contain redundant first, second and third stages of ADS valves) and fourth stage ADS valves in either Fire Zone 1100 AF 11301 or AF 11302 can provide sufficient depressurization capability, should the ADS be required to achieve safe shutdown. The above concerns are classified as RAI # 280.19 and is designated as Open Item 9.5.1.6-8.

Response:

SSAR Appendix 9A, Revision 8, subsections 9A.3.1.1.13 and 9A.3.1.1.14 describe how the two groups of stage 1, 2 and 3 ADS valves and their control are each protected from a fire in the other. It also states that either group is sufficient for safe shutdown. In addition, subsections 9A.3.1.1.10 and 9A.3.1.1.11 state that either set of fourth stage ADS valves is sufficient for safe shutdown and that they are separated by distance and fire barriers from other ADS valves.

Note that, consistent with SSAR subsection 9A.2.7.1, a fire in one of the fire zones identified here will not cause the opening of valves sufficient to become an inadvertent ADS event. This reenforces the conclusion that unaffected ADS valve groups are sufficient for safe shutdown. ADS response during applicable events is later in the event thus requiring less vent area.

SSAR Revision:

NONE

Question 280.31

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.5 Additional Features to Ensure Safe Shutdown Capability.

Regarding safe shutdown functions, SSAR Section 7.4 (Page 7.4-1) lists the following as needed for safe shutdown: decay heat removal, RCS inventory control, RCS pressure control and reactivity control. Though SSAR Section 7.4 describes how safe shutdown is achieved and maintained, it does not clearly state how the reactivity control function and reactor coolant makeup function (needed to maintain reactor coolant inventory control) are ensured. The staff is particularly concerned regarding ensuring the reactor coolant makeup function to maintain safe shutdown over long-term, once it has been achieved (see SECY-94-084, Pages 13 and 14). The above concerns which deal with the performance goals of safe shutdown capability, namely, ensuring reactivity control function and reactor coolant makeup function, particularly over long-term, are collectively classified as RAI # 280.31 and is designated as Open Item 9.5.1.6-20.

Response:

SSAR subsection 7.4.1.1, Revision 5, provides a description of safe shutdown using safety-related systems, including a discussion of maintenance of final long term safe shutdown conditions. Initial response is insertion of control rods. Following this initial reactivity control function, borated water is used to maintain reactivity control and reactor coolant inventory control. Borated water makeup, which provides reactivity control, is provided first by the core makeup tanks. Then borated water makeup is provided by the accumulators and the in-containment refueling water storage tank, if needed because of LOCA or ADS actuation or both. If required following a loss of coolant accident, borated water is recirculated through the reactor from the flooded reactor cavity via the recirculation sump. With containment isolation established, the water inventory inside containment provides an indefinite reactor coolant makeup inventory of borated water. The systems providing reactivity control and reactor coolant makeup are located within containment. As described in SSAR Appendix 9A, the capability to achieve and maintain safe shutdown is preserved with a fire in any one fire zone within containment.

SSAR Revision: NONE

Question 480.290

Re: (WGOTHIC MODELS AND PHENOMENA) FLOW RESISTANCES AND VELOCITIES;
A detailed description needs to be provided showing how intercell flow resistances are calculated for cells in an open volume. The LST model could serve as an example.

Response: In an open volume, the flow field is determined by the relative magnitude of the wall and form drag, inertia, momentum fluxes, body forces and viscous and turbulent stresses. If a WGOTHIC network of lumped volumes and junctions is used to model the open region, then only wall and form drag, inertia and body forces are considered. In a subdivided model, all of the mentioned force terms can be included. These two modeling options are discussed below.

In a lumped volume network model, a collection of volumes is used to represent the region of interest. Mass and energy balances are maintained for each of these volumes. The volumes can be connected together in any meaningful fashion with flow junctions. Momentum balances are maintained for each junction that include terms for the inertia, body force and drag forces. If, for example, a particular volume represents a rectangular volume in an open region, with adjacent volumes at each of the 6 volume faces, then junctions would be used to model the flow connector for each of the volume faces. The flow area of these connectors would be consistent with the volume face area. The inertia is controlled by a user specified inertia length. The recommended value of the center-to-center distance of the adjoined cells is typically used. If there is a wall parallel to the junction connection, then the wall friction can be modeled by specifying appropriate values for the junction hydraulic diameter and friction length. The hydraulic diameter should be specified as

$$D_h = \frac{4AL}{W}$$

where A is the junction area, L is the friction length and W is the wall area exposed to the junction. Wall drag will then be calculated using a smooth tube friction factor. If there are some obstacles in the region represented by the flow path, e.g. piping runs, cable trays, equipment, then an appropriate loss coefficient can be specified for the junction. The resulting drag force is added to the wall drag force. If there is no adjacent wall and no obstacles, then the input value for the friction length and the forward and reverse loss coefficients would be set to zero. However, to maintain numerical stability, WGOTHIC sets the minimum form loss coefficient to 0.001. In this case of minimal flow resistance, the velocity and pressure fields will be determined by a balance of inertia and body forces. The flow field will adjust to eliminate buoyancy forces and local pressure variations resulting from inertia and the time to adjustment will be controlled by the specified inertia lengths.

In a subdivided model the region is divided into a number of subvolumes by a series of grid planes arranged to form rectangular volumes. Mass and energy balances are maintained for each of these subvolumes. Momentum balances are maintained for the momentum control volumes that are arranged in what is commonly referred to as a staggered grid. For each subvolume face that is shared by two subvolumes, there is a momentum control volume for the momentum perpendicular to the subvolume face. (Refer to the diagrams in Section 11 of Reference 480.290-1). For each of these momentum control volumes, the user can specify the flow area, the hydraulic diameter and a form loss coefficient. Typically, the flow area is the face area of the subvolume. If one or more sides of the control volume

are formed by a wall, then wall friction can be included by specifying an appropriate hydraulic diameter. The hydraulic diameter should be calculated from

$$D_h = \frac{4AL}{W}$$

where A is the flow area, L is length of the wall in the flow direction and W is the wall area exposed to the momentum control volume. For momentum control volumes for vertical flow, the hydraulic diameter is input directly. For momentum control volumes for horizontal flow, the hydraulic diameter is related to the user specified value for the wall factor, λ_w, by

$$\lambda_w = \frac{2s}{D_h}$$

where s is the width of the transverse connection. The wall drag is calculated according to Equations 8.83 through 8.86 of Reference 480.290-1 assuming a friction factor for a smooth tube. If a form loss coefficient is specified for the control volume, then the drag is calculated according to Equation 8.81 and added to the wall drag. If there are no walls bounding the control volume, then the hydraulic diameter is set to a large value (relative to the cell dimensions). This effectively eliminates any wall drag. To maintain numerical stability, the minimum loss coefficient for horizontal connections is set to 0.01.

The other mechanism for intercell flow resistance in a subdivided model is viscous and turbulent shear. Both of these models were activated for the subdivided model of the LST. In this model the stress terms were calculated only for the vapor phase. The viscous shear force depends on the local viscosity and the velocity gradients. The shear force is calculated for each face of the momentum control volume that is parallel to the direction of flow according to Equations 9.1 through 9.4 of Reference 480.290-1. When the turbulence model is activated, the viscosity coefficient in the stress calculations is augmented by the eddy viscosity. The eddy viscosity is calculated from the local strain rates using a one parameter mixing length model. The value of the mixing length used in the LST calculations was very small (0.01 ft) relative to the cell size making the impact of turbulent shear negligible.

Please also see the response to RAI 480.294 for a description of how friction losses are input in the WGOTHIC evaluation model.

References:

480.290-1 NTD-NRC-95-4563, "GOTHIC Version 4.0 Documentation Enclosure 2: Technical Manual," September 1995.

SSAR Revision: NONE

Question 480.293

Re: (WGOTHIC MODELS AND PHENOMENA)FLOW RESISTANCES AND VELOCITIES:
Is there a missing factor of two in the equation for the vertical component of the velocity (Equation 8.16 on page 8-5 of EPRI TR-1030503-V1, or page A-107 of WCAP-13246)? Do these equations properly represent what is actually used in the code?

Response:

Equation 8.16 (Reference 480.293-1) is incorrect and does not represent what is actually in the code. The vertical component of the velocity for phase j as calculated in WGOTHIC is

$$U_{\phi} = \frac{(F_{\phi}^{below} + F_{\phi}^{above} + \sum_{vertjuncs} \xi_j F_{\phi j})}{(A^{below} + A^{above} + \sum_{vertjuncs} A_j)(\alpha_{\phi} \rho_{\phi})}$$

References:

480.293-1 NTD-NRC-95-4563, "GOTHIC Version 4.0 Documentation, Enclosure 2: Technical Manual", September 1995.

SSAR Revision: NONE

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Electric Corporation

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NSD-NRC-96-4839
DCP/NRC0621
Docket No.: STN-52-003

October 11, 1996

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

ATTENTION: T. R. QUAY

SUBJECT: WESTINGHOUSE RESPONSES TO NRC REQUESTS FOR ADDITIONAL INFORMATION ON THE AP600

Dear Mr. Quay:

Enclosed are three copies of the Westinghouse responses to NRC requests for additional information on AP600 topics. Responses to 280.14 through 280.19 and 280.31 provide additional information on Section 9.5.1 of the SSAR. Responses to 480.290 and 480.293 respond to questions on the WGOTHIC computer code.

The NRC technical staff should review these responses as a part of their review of the AP600 design.

Please contact Brian A. McIntyre on (412) 374-4334 if you have any questions concerning this transmittal.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

Enclosures
Attachments

cc: T. Kenyon, NRC (w/o enclosures)
D. Jackson, NRC (1E1)
E. Throm, NRC (w/o enclosures)
J. Kudrick, NRC (w/o enclosures)
P. Boehnert, ACRS (4E1)
N. Liparulo, Westinghouse (w/o attachments and enclosures)

2950A

Question 280.14

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.2 Protection of Safe Shutdown Capability for a Fire Outside the Containment and the Main Control Room.

On SSAR Page 9A-63, Westinghouse states that fire areas within the Annex I and Annex II buildings are separated from safety-related areas of the Nuclear Island by a 3-hour fire barrier wall, except for those fire areas which include portions of the auxiliary building. The staff is concerned that the Fire Area 4031 AF 02 (SSAR Section 9A.3.4.6) which contains safety-related Division A electrical cables (it is not clear whether these are required for safe shutdown) may not be separated by 3-hour fire barrier walls, ceilings or floors from adjoining annex building fire areas. The staff is further concerned that the fire areas in the annex buildings may not be separated by 3-hour structural fire barriers from auxiliary building fire areas which contain safe shutdown components (i.e., equipment, cabling, instrument and controls). During its meeting with the staff on April 12 and 13, 1995, Westinghouse told the staff that the Annex I and Annex II buildings are now considered as one Annex Building and that the Annex building fire areas do not contain safe shutdown components including cables and that the above position will be reflected in a future revision of the SSAR. The staff considers that the proposed revision does not clearly resolve staff's two concerns identified above (for example, it is not clear where the Division A electrical cables, supposedly protected by 3-hour fire barrier in the Fire Area 4031 AF 02 will be relocated). For the above reason, the above concerns are identified as RAI # 280.14 and is designated as Open Item 9.5.1.6-3.

Response:

SSAR Appendix 9A, subsection 9A.3.4.8 and Figure 9A-3 (Sheet 1 of 3), Revision 8, properly shows the location and contents of Fire Area 4031 AF 02. As stated, there are no Division A cables in Fire Area 4031 AF 02. The cables addressed by this Request for Additional Information, as well as others, have been relocated to be within a fire area associated with their division. Note that for other fire areas, as indicated in Note 3 on Figure 9A-1 (Sheet 2, et al.), electrical cable chases for one division that pass through a fire area of another division are separated from those fire areas by three-hour fire barriers. Although these chases are not shown on Figure 9A-1, the space within the chases is considered part of the fire area at their ends, not a part of the fire area on the outside of the three-hour fire barrier.

SSAR Revision: None

Question 280.15

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.2 Protection of Safe Shutdown Capability for a Fire Outside the Containment and the Main Control Room.

For a number of fire areas outside the containment that contain safe shutdown components, Westinghouse states in SSAR Section 9A that the fire resistance of the boundaries of the fire areas are greater than the equivalent fire duration in those areas as shown in SSAR Table 9A-6. The staff is concerned about this position, since equivalent fire duration does not relate to the actual performance of a fire barrier assembly when exposed to the standard time-temperature fire endurance test as defined by American Society for Testing and Materials (ASTM) E-119. The above concern is RAI # 280.1. and is designated as Open Item 9.5.1.6-4.

Response:

The "Equivalent Fire Duration" portion of SSAR Appendix 9A, subsection 9A.2.4, Revision 8, provides a description of the basis and use of the comparison of estimated fire duration to fire area boundary resistance times. These comparisons, which are summarized in Table 9A-3, are based on Figures 7-9A and 7-9B of the NFPA Fire Protection Handbook and normalized. Although not based on ASTM E-119 tests, they are considered adequate and appropriate for determining the adequacy of fire boundary resistance values identified in Appendix 9A.

SSAR Revision: None

Question 280.16

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

1. The SSAR information on separation between redundant safe shutdown components inside the containment/shield building fire area zones lacks details. The staff needs details on the separation between redundant safe shutdown components (instrumentation and controls and power and control cables are also considered as components) provided in the form of structural walls (their types, thickness, fire rating), containment penetrations (fire rating), horizontal distances with no intervening combustibles, cable trays (fire rating of the cables and distances between divisional cable trays), equipment such as pressurizer or steam generator. The staff needs the above information for each of the fire zones containing any safe shutdown component for which redundant safe shutdown component is credited in the safe shutdown analysis. This concern is RAI # 280.16 and is designated as Open Item 9.5.1.6-5.

Response:

SSAR Appendix 9A, subsection 9A.3.1.1, Revision 8, and its subsections address each of the 19 fire zones within the containment/shield building. In each case, details on the separation between redundant safe shutdown components is provided.

SSAR Revision: None

Question 280.17

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

2. In SSAR Section 9A, Westinghouse states that fire damage to any single valve does not affect the adjacent valve since the valves are sufficiently separated from one another in the following zones: Fire Zones 1100 AF 11206, 11207, 11208, 11209, 11300A and 11300C. This section does not define what sufficient separation means. Further, it is not clear whether any safety function (e.g., containment isolation needed to maintain safe shutdown over an extended period of time, when only safety-related equipment are used for safe shutdown) will be compromised in the event fire damages all the valves in any zone listed above. If so, it is not clear how the safety function will be performed. Also, it is not clear whether following a fire in any one of the fire zones 1100 AF 11206, 11207, 11300A and 11300C, safe shutdown can be achieved without relying on any safe shutdown component located in the affected fire zone. The above concern arises since SSAR Section 9A refers only to the performance of some specific safe shutdown function (i.e., providing adequate cooling to the reactor vessel) by redundant components in an unaffected fire zone and does not refer to ensuring safe shutdown capability in entirety without relying on any safe shutdown component in the affected fire zone. The above concerns are collectively classified as RAI # 280.17 and is designated as Open Item 9.5.1.6-6.

Response:

SSAR Appendix 9A, Revision 8, subsections 9A.3.1.1.3 through 9A.3.1.1.7 and 9A.3.1.1.9. as well as, Table 9A-2 provide the information determine the safe shutdown capability of the plant given a fire in a designated fire zone. The "Safe Shutdown Evaluation" portion of a subsection provides a description of the functions that are disabled in the fire zone with the fire. It then delineates the fire zone(s) containing redundant safe shutdown equipment. A definitive listing of the safe shutdown equipment in each fire zone is contained in Table 9A-2. As a result, it can be shown that safe shutdown can be achieved without relying on any components in the fire zone affected by the fire.

SSAR Revision:

NONE

Question 280.18

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

3. The safe shutdown evaluations for a number of fire zones contain statements listed below:

"The horizontal separation between the termination boxes for different divisions is at least three feet. Fire in one division does not damage the adjacent division" (Fire Zone 1100 AF 11300B - this area encompasses passive residual heat removal (PRHR) valve area and north quadrant mechanical penetration area)."

"The horizontal runs of Divisions B and D cable trays are routed adjacent to each other (side by side) approximately 26 feet above the operating deck. A fire in either division of cable trays does not propagate to the other division of cable trays (Fire Zone 1100 AF 11500)."

"The minimum distance between the instrumentation and control cabling for separate divisions is approximately 3 feet. Adequate protection is provided between the four divisions of cabling to prevent a fire in one bundle of cabling from propagating to an adjacent cable bundle of another division" (Fire Zone 1200 AF 12356)."

"The cable for these divisions (A and B) is separated from each other and from nonsafety-related cable such that a fire cannot affect both safety-related raceways" (Fire Zone 1200 AF 12556 - this area contains PCS air flow baffles, PCS piping, instrumentation and cables outside of the PCS valve room)."

"The divisional cable and valves are separated from each other and protected such that a fire cannot affect both divisions" (Fire Zone 1200 AF 12701 - PCS valves and cables in this fire zone are assigned to Divisions A and B)."

Based on the above statements, the staff is concerned that horizontal separation of at least 3 feet between safe shutdown cables of different (i.e., redundant) divisions in accordance with Institute of Electrical and Electronics Engineers (IEEE) 384 requirement does not necessarily eliminate fire-induced associated circuit problems which may compromise safe shutdown capability. This is because the 3 feet divisional cable separation eliminates only the problems internally generated due to electrical faults. Furthermore, the staff is concerned that the loss of all PRHR heat exchanger discharge valves of different divisions due to a fire in Fire Zone 1100 AF 11300B will result in loss of safe shutdown capability, particularly, since there is only one PRHR heat exchanger. The above concerns are collectively classified as RAI # 280.18 and is designated as Open Item 9.5.1.6-7 (resolution of Open Item 9.5.1.6-5 will provide partial resolution of this open item).

Response:

SSAR Section 9.5.1.6, Revision 8, does not include the descriptions provided in this Request for Additional Information.

SSAR Appendix 9A, Revision 8, includes "Safe Shutdown Evaluations" for the fire zones within the Containment/Shield Building. These evaluations do not rely on 3 feet horizontal separation of safe shutdown cables of different (i.e., redundant) divisions. The evaluations indicate that redundant divisions or functions are in separate fire zones and that they are separated by physical barriers as well as distance. In the case of the single passive residual heat removal heat exchanger, a fire in the zone that disables the heat exchanger will have no effect on the valves necessary for feed and bleed operations which are available for decay heat removal.

SSAR Revision: None

Question 280.19

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.3 Protection of Safe Shutdown Capability for a Fire Inside the Containment/Shield Building.

4. In SSAR Section 9A, Westinghouse does not explain why a fire in either Fire Zone 1100 AF 11303A or AF 11303B can result in loss of only one of the three ADS vent paths in the affected zone. Also, SSAR Section 9A does not clarify whether following a fire in any one of the zones listed above, the first, second and third stages of ADS valves in the unaffected fire zone (the above fire zones contain redundant first, second and third stages of ADS valves) and fourth stage ADS valves in either Fire Zone 1100 AF 11301 or AF 11302 can provide sufficient depressurization capability, should the ADS be required to achieve safe shutdown. The above concerns are classified as RAI # 280.19 and is designated as Open Item 9.5.1.6-8.

Response:

SSAR Appendix 9A, Revision 8, subsections 9A.3.1.1.13 and 9A.3.1.1.14 describe how the two groups of stage 1, 2 and 3 ADS valves and their control are each protected from a fire in the other. It also states that either group is sufficient for safe shutdown. In addition, subsections 9A.3.1.1.10 and 9A.3.1.1.11 state that either set of fourth stage ADS valves is sufficient for safe shutdown and that they are separated by distance and fire barriers from other ADS valves.

Note that, consistent with SSAR subsection 9A.2.7.1, a fire in one of the fire zones identified here will not cause the opening of valves sufficient to become an inadvertent ADS event. This reenforces the conclusion that unaffected ADS valve groups are sufficient for safe shutdown. ADS response during applicable events is later in the event thus requiring less vent area.

SSAR Revision:

NONE

Question 280.31

Re: STAFF FOLLOW ON QUESTIONS AND REVIEW STATUS, SSAR SECTION 9.5.1 - FIRE PROTECTION (June 24, 1996 letter).

9.5.1.6.5 Additional Features to Ensure Safe Shutdown Capability.

Regarding safe shutdown functions, SSAR Section 7.4 (Page 7.4-1) lists the following as needed for safe shutdown: decay heat removal, RCS inventory control, RCS pressure control and reactivity control. Though SSAR Section 7.4 describes how safe shutdown is achieved and maintained, it does not clearly state how the reactivity control function and reactor coolant makeup function (needed to maintain reactor coolant inventory control) are ensured. The staff is particularly concerned regarding ensuring the reactor coolant makeup function to maintain safe shutdown over long-term, once it has been achieved (see SECY-94-084, Pages 13 and 14). The above concerns which deal with the performance goals of safe shutdown capability, namely, ensuring reactivity control function and reactor coolant makeup function, particularly over long-term, are collectively classified as RAI # 280.31 and is designated as Open Item 9.5.1.6-20.

Response:

SSAR subsection 7.4.1.1, Revision 5, provides a description of safe shutdown using safety-related systems, including a discussion of maintenance of final long term safe shutdown conditions. Initial response is insertion of control rods. Following this initial reactivity control function, borated water is used to maintain reactivity control and reactor coolant inventory control. Borated water makeup, which provides reactivity control, is provided first by the core makeup tanks. Then borated water makeup is provided by the accumulators and the in-containment refueling water storage tank, if needed because of LOCA or ADS actuation or both. If required following a loss of coolant accident, borated water is recirculated through the reactor from the flooded reactor cavity via the recirculation sump. With containment isolation established, the water inventory inside containment provides an indefinite reactor coolant makeup inventory of borated water. The systems providing reactivity control and reactor coolant makeup are located within containment. As described in SSAR Appendix 9A, the capability to achieve and maintain safe shutdown is preserved with a fire in any one fire zone within containment.

SSAR Revision: NONE

Question 480.290

Re: (WGOTHIC MODELS AND PHENOMENA) FLOW RESISTANCES AND VELOCITIES:
A detailed description needs to be provided showing how intercell flow resistances are calculated for cells in an open volume. The LST model could serve as an example.

Response: In an open volume, the flow field is determined by the relative magnitude of the wall and form drag, inertia, momentum fluxes, body forces and viscous and turbulent stresses. If a WGOTHIC network of lumped volumes and junctions is used to model the open region, then only wall and form drag, inertia and body forces are considered. In a subdivided model, all of the mentioned force terms can be included. These two modeling options are discussed below.

In a lumped volume network model, a collection of volumes is used to represent the region of interest. Mass and energy balances are maintained for each of these volumes. The volumes can be connected together in any meaningful fashion with flow junctions. Momentum balances are maintained for each junction that include terms for the inertia, body force and drag forces. If, for example, a particular volume represents a rectangular volume in an open region, with adjacent volumes at each of the 6 volume faces, then junctions would be used to model the flow connector for each of the volume faces. The flow area of these connectors would be consistent with the volume face area. The inertia is controlled by a user specified inertia length. The recommended value of the center-to-center distance of the adjoined cells is typically used. If there is a wall parallel to the junction connection, then the wall friction can be modeled by specifying appropriate values for the junction hydraulic diameter and friction length. The hydraulic diameter should be specified as

$$D_h = \frac{4AL}{W}$$

where A is the junction area, L is the friction length and W is the wall area exposed to the junction. Wall drag will then be calculated using a smooth tube friction factor. If there are some obstacles in the region represented by the flow path, e.g. piping runs, cable trays, equipment, then an appropriate loss coefficient can be specified for the junction. The resulting drag force is added to the wall drag force. If there is no adjacent wall and no obstacles, then the input value for the friction length and the forward and reverse loss coefficients would be set to zero. However, to maintain numerical stability, WGOTHIC sets the minimum form loss coefficient to 0.001. In this case of minimal flow resistance, the velocity and pressure fields will be determined by a balance of inertia and body forces. The flow field will adjust to eliminate buoyancy forces and local pressure variations resulting from inertia and the time to adjustment will be controlled by the specified inertia lengths.

In a subdivided model the region is divided into a number of subvolumes by a series of grid planes arranged to form rectangular volumes. Mass and energy balances are maintained for each of these subvolumes. Momentum balances are maintained for the momentum control volumes that are arranged in what is commonly referred to as a staggered grid. For each subvolume face that is shared by two subvolumes, there is a momentum control volume for the momentum perpendicular to the subvolume face. (Refer to the diagrams in Section 11 of Reference 480.290-1). For each of these momentum control volumes, the user can specify the flow area, the hydraulic diameter and a form loss coefficient. Typically, the flow area is the face area of the subvolume. If one or more sides of the control volume

are formed by a wall, then wall friction can be included by specifying an appropriate hydraulic diameter. The hydraulic diameter should be calculated from

$$D_h = \frac{4AL}{W}$$

where A is the flow area, L is length of the wall in the flow direction and W is the wall area exposed to the momentum control volume. For momentum control volumes for vertical flow, the hydraulic diameter is input directly. For momentum control volumes for horizontal flow, the hydraulic diameter is related to the user specified value for the wall factor, λ_w, by

$$\lambda_w = \frac{2s}{D_h}$$

where s is the width of the transverse connection. The wall drag is calculated according to Equations 8.83 through 8.86 of Reference 480.290-1 assuming a friction factor for a smooth tube. If a form loss coefficient is specified for the control volume, then the drag is calculated according to Equation 8.81 and added to the wall drag. If there are no walls bounding the control volume, then the hydraulic diameter is set to a large value (relative to the cell dimensions). This effectively eliminates any wall drag. To maintain numerical stability, the minimum loss coefficient for horizontal connections is set to 0.01.

The other mechanism for intercell flow resistance in a subdivided model is viscous and turbulent shear. Both of these models were activated for the subdivided model of the LST. In this model the stress terms were calculated only for the vapor phase. The viscous shear force depends on the local viscosity and the velocity gradients. The shear force is calculated for each face of the momentum control volume that is parallel to the direction of flow according to Equations 9.1 through 9.4 of Reference 480.290-1. When the turbulence model is activated, the viscosity coefficient in the stress calculations is augmented by the eddy viscosity. The eddy viscosity is calculated from the local strain rates using a one parameter mixing length model. The value of the mixing length used in the LST calculations was very small (0.01 ft) relative to the cell size making the impact of turbulent shear negligible.

Please also see the response to RAI 480.294 for a description of how friction losses are input in the WGOTHIC evaluation model.

References:

480.290-1 NTD-NRC-95-4563, "GOTHIC Version 4.0 Documentation Enclosure 2: Technical Manual," September 1995.

SSAR Revision: NONE

Question 480.293

Re: (WGOTHIC MODELS AND PHENOMENA) FLOW RESISTANCES AND VELOCITIES:
Is there a missing factor of two in the equation for the vertical component of the velocity (Equation 8.16 on page 8-5 of EPRI TR-1030503-V1, or page A-107 of WCAP-13246)? Do these equations properly represent what is actually used in the code?

Response:

Equation 8.16 (Reference 480.293-1) is incorrect and does not represent what is actually in the code. The vertical component of the velocity for phase j as calculated in WGOTHIC is

$$U_{\phi} = \frac{(F_{\phi}^{below} + F_{\phi}^{above} + \sum_{vertfaces} \xi_j F_{\phi})}{(A^{below} + A^{above} + \sum_{vertfaces} A_j)(\alpha_{\phi} \rho_{\phi})}$$

References:

480.293-1 NTD-NRC-95-4563, "GOTHIC Version 4.0 Documentation, Enclosure 2: Technical Manual", September 1995.

SSAR Revision: NONE