UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

August 29, 1995 52-003

APPLICANT: Westinghouse Electric Corporation

FACILITY: AP600

SUBJECT: SUMMARY OF MEETING TO DISCUSS CONTAINMENT AND HYDROGEN ISSUES ON THE AP600

On April 10 and 11, 1995, representatives of the Nuclear Regulatory Commission and Westinghouse Electric Corporation met to discuss issues concerning the containment and hydrogen production for the AP600 design. The purpose of the meeting was to obtain a more thorough understanding of the AP600's hydrogen igniter system and the latest information on the evolving design of the hydrogen recombiner system. In addition, a discussion on the analysis and evaluation of the AP600 large scale test data took place. Attachment 1 is a list of attendees. Attachment 2 is the status of the followon questions that were discussed at the meeting. Both proprietary and non-proprietary versions of the slides and information presented by Westinghouse were submitted by letter dated April 18, 1995.

Hydrogen Igniter Placement

Westinghouse provided the staff with a series of general arrangement drawings, a demonstration of their computer generated 3-D model, and an overview of the containment layout using their scaled model. These presentations will be an integral part of the staff's final evaluation of the number and location of hydrogen igniters. As a result of these discussions with Westinghouse, the staff indicated that it will concentrate the remainder of it's review on the major subcompartments. These subcompartments, such as the IRWST, reactor cavity, A and B accumulator and core make-up tank volumes, chemical and volume control system (CVCS) compartment and the reactor coolant system loop, are restricted volumes and currently have igniter coverage. The staff will assess the ability of this igniter coverage to burn the hydrogen relatively close to it's source and prevent flame acceleration.

Power Supplies to Hydrogen Igniters

The present design includes an igniter system that will be powered by two non-safety-related diesel generators or offsite power. Westinghouse indicated that they do not plan on providing battery power to a subset of igniters so that the igniters would be available during a station blackout (SBO) event sequence. The staff has indicated that SBO is one of the more likely severe accident challenges as described in SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor Designs". The Commission paper states, in part, that the containment should maintain its role as a reliable, leak-tight barrier for approximately 24 hours following the onset of core damage under the more likely severe accident challenges. Therefore, the staff indicated that battery power should be available to the hydrogen igniter system for at least the first 24 hours

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following the onset of core damage to preclude the failure of containment due to hydrogen combustion. Westinghouse indicated that this design change is unwarranted because SBO sequences represent such a small percentage of the core damage frequency.

Issues

Other issues discussed during the meeting include:

- The staff is concerned over what the impact of lightoff pressures, due to hydrogen ignition initiated at the IRWST vents, is on the IRWST.
- Westinghouse indicated that they will continue to evaluate the possibility of adding IRWST vents along the wall separating Steam Generator 1 from the IRWST closest to the spargers.
- Westinghouse indicated that they will provide design loadings for specific igniter locations.
- Westinghouse indicated that they will provide a rationale for why the CVCS room is not a primary hydrogen source term or reevaluate the hydrogen igniter locations for this compartment.
- Westinghouse indicated that they will provide an evaluation of the effects of diffusion flames, anchored to the IRWST vents, on the containment wall.

Original signed by

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Docket No. 52-003

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As stated

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W AP600/NRC HYDROGEN GENERATION AND CONTROL MEETING
ATTENDANCE SHEET
MONDAY APRIL 10, 1995

NAME	ORGANIZATION
CINDY HAAG	WESTINGHOUSE
JIM SCOBEL	W RISK ASSESSMENT
BOB HAMMERSLY	FAI
ASIMIOS MALLIAKOS	USNRC
J. KUDRICK	USNRC
M. SNODDERLY	USNRC
EDWARD D. THROM	USNRC
THOMAS KENYON	USNRC
DAN SPENCER	W CONTAINMENT ANALYSIS
DAN MCDERMOTT	W FLUID SYSTEMS
RICHARD ORR	W PLANT ENGINEERING
DOUGLAS STAMPS	SNL

Attachment 1

STATUS OF FOLLOW-ON QUESTIONS FOR THE WESTINGHOUSE AP600 DESIGN

SEVERE ACCIDENT HYDROGEN GENERATION AND CONTROL

480.116 10 CFR 50.63(a)(2), "Loss of All AC Power," requires that the reactor core and associated coolant, control, and protection systems, including station batteries and any necessary support systems, must provide sufficient capacity and capability to ensure that the core is cooled and appropriate containment integrity is maintained in the event of a station blackout for the specified duration. The PRA for the AP600 shows that station blackout sequences are a significant contributor to overall plant risk. The staff believes that hydrogen igniters are necessary to ensure containment integrity during a station blackout. Therefore, discuss the availability of the igniter system during various sequences, including station blackout.

STATUS: ACTION W (Westinghouse to provide paper that describes its position on power and igniters)

480.117 In previously reviewed designs, the staff has viewed power diversity and redundancy as important elements to demonstrate availability of the igniters. However, the AP600 igniter system is single train, and, besides the normal onsite and offsite power supplies, the non-safety-related diesel generator is the sole emergency power source. Discuss why this design provides sufficient quality, redundancy, and diversity in accordance with past practice established during the review of the evolutionary designs.

STATUS: ACTION W (Same as response to Q480.116)

480.118 The hydrogen control system includes recombiners for design-basis events. The staff views equipment needed for design-basis events as safety-related. Discuss why the proposed non-safety-related power supplies are acceptable for a design basis event.

STATUS: RESOLVED (Need to get formal submittal of PARS, then can close this follow-on item)

480.119 The staff is concerned about the effect of diffusion flames anchored to the IRWST vents on the containment shell.

STATUS: ACTIVE

480.120 Lumped-parameter codes have limitations when used to predict hydrogen distribution in containments. Lumped-parameter codes tend to over-predict the rate of mixing that can result in under-predicting local hydrogen concentrations. For example, in Test E11.2 performed at the HDR test facility, the actual helium gas concentration in the upper dome region of the containment was 3 times larger than the value the

CONTAIN code (a lumped parameter code) predicted at the point of largest discrepancy (25 percent measured versus 8 percent calculated concentration). On what basis does Westinghouse conclude that lumped parameter codes are adequate to predict hydrogen mixing? Also, how is the subnodal physics model capable of sufficiently predicting hydrogen stratification?

STATUS: ACTION W (Westinghouse to provide written response to follow-on item)

480.121 Mark III and ice condenser containments have specifically designed flowpaths. Mark III containments have been designed to force flow from the drywell to the wetwell through the suppression pool, and ice condenser containments force flow to the bottom of the containment through the ice stacks to the containment dome. What are the flowpaths in the AP600? What is the database that supports these flowpaths? Provide drawings to assist in understanding the overall layout of containment, and where the igniters are located relative to the dominant accident flowpaths.

STATUS: ACTION W / ACTION N (pending 4/10/95 meeting summary) The staff indicated that it would state what source areas it has identified. Drawings have been provided by Westinghouse. Westinghouse has database that supports the flow paths. The locations of credible break locations were determined by evaluation.

480.122 The first three stages of the atmospheric dump system vent into the IRWST. The fourth stage valves vent into the containment atmosphere. They appear to exhaust into the lower containment, either in the core makeup tank room or the steam generator room. Describe in more detail where the fourth stage valves vent into the containment? What igniter locations have been provided for a release through this pathway? What affect do the elevated temperatures of this type of release have on the possible combustion loads?

STATUS: ACTION W / ACTION N (pending 4/10/95 meeting summary, see also Q480.121)

480.123 The response to Q480.35 dated September 3, 1993, addresses the issue of impulsive loads from subsonic accelerated flames. The response referred to tests conducted by KfK in Germany were flame acceleration occurred as the burn front passed from region to region through restricted interconnecting areas. Westinghouse concludes that "a small number of interconnected regions exists in the AP600 containment configuration and they are connected by large flow areas which would not be expected to result in significant floor acceleration between the various regions." Describe in more detail the basis for this conclusion, and why flame acceleration due to junction-induced turbulence in multi-compartment burns is not a concern for the AP600. Also, the response does not address other mechanisms of flame acceleration and their associated pressure loads (e.g., flame acceleration could also occur in long subcompartments that have venting or obstacles).

STATUS: ACTION W (Westinghouse to respond to the follow-on item based on discussions in 4/11/95 meeting)

480.124 The staff is concerned about the possibility of detonable conditions when combustible gases are released through the IRWST. Near stoichiometric concentrations of hydrogen are predicted to exist at various times throughout the release of hydrogen based on separate work performed by Sandia[1] and the AP600 PRA. Steam concentrations are generally between 10-20 percent during times of high hydrogen concentrations. The transition of a deflagration to a detonation is the most likely mode of detonation initiation. Peraldi[2] has proposed a criterion for deflagration to detonation transition (DDT) which relates the detonation cell size of a mixture to a characteristic geometric length scale. Sandia used this criteria to give an estimate of the range of hydrogen concentrations that may detonate in the IRWST. Peraldi's criterion states that if a flame speed is near the sound speed in the combustion products, DDT will occur if the detonation cell size is on the order of, or less than, the minimum transverse dimension of the channel. The distance between the surface of the water and the top of the IRWST was estimated to be 0.5 m, based on the input for MAAP calculations. Sandia estimated, according to Peraldi's criterion, what mixtures having detonation cell sizes on the order of 0.5 m or less may undergo a DDT. This corresponded to hydrogen-air-steam mixtures having hydrogen concentrations between approximately 18 percent and 56 percent for mixtures with 10 percent steam and 19 percent and 42 percent for mixtures with 20 percent steam. These conditions can occur for relatively long periods of time, as was noted in the containment analysis report by Sandia.

STATUS: ACTION W (same as Q480.123)

480.125 WCAP-13388 addresses the likelihood of a deflagration-to-detonation transition (DDT) in the AP600 design. No structural analysis response is presented. However, the abstract states that "it is concluded that such detonations will not challenge the integrity of the AP600 containment." This statement gives the impression that if a DDT were to occur in the AP600, the containment (structurally)

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[1]Tills, J. and Murata, K.K., "Letter Report on Containment Analysis of the AP600 Plant," proprietary letter report submitted to A. Notafrancesco, U.S. NRC, October 30, 1992.

[2]Peraldi, O., Knystautas, R., and Lee, J.H., "Criteria for Transition to Detonation in Tubes," Twenty-first Symposium (International) on Combustion, The Combustion Institute, pp. 1629-1637, 1986.

would not be challenged. Provide a more detailed explanation of the containment's structural capability to withstand impulsive loadings due to hydrogen detonation.

STATUS: RESOLVED (pending Westinghouse response. Information is in the AP600 PRA decomposition event tree).

480.126 Besides DDT, hot jet initiation is another mechanism that could initiate a detonation. Address how this mechanism affects the AP600 design.

STATUS: PROPOSED (Westinghouse to provide follow-on item response)

480.127 Figure 2-11 of WCAP-13388 was used to calculate the likelihood of DDT by defining cell-width dependency based on steam and hydrogen concentrations. The data from Figure 2-11 are at a different temperature than the one used to define the likelihood of DDT in the AP600 design. What is the impact of the temperature differences between the data taken from the plots and the AP600 data?

STATUS: PROPOSED (Westinghouse to provide follow-on item response)

480.128 Figure 2-11 from WCAP-13388 presents some experimental data and plots of hydrogen and steam concentrations versus cell width. The plots are based on theoretical models and, therefore, can be misleading and non-conservative when used to determine cell size. Caution should be exercised when using Figure 2-11 because the cell width is on a log scale, and at the hydrogen concentration used to determine cell size the plot has a very steep slope. The value chosen for cell width is lower than the value provided by the plots and higher than the value the experimental data provides. Why wasn't the experimental data value used to define cell size? Discuss this concern.

STATUS: PROPOSED (Westinghouse to provide follow-on item response. The staff indicated that the verbal response sounded reasonable).

480.129 To calculate the likelihood of DDT in the AP600 design, WCAP-13388 uses a set of initial conditions derived from severe accident analyses. Discuss why these initial conditions are appropriate for these calculations.

STATUS: PROPOSED (Westinghouse to provide follow-on item response. The staff indicated that Westinghouse's response about DETs is fine) NRC wants global and local response discussed.

480.130 In WCAP-13388, the equation that defines the scale factor uses a safety factor parameter. This parameter is not mentioned in the methodology introduced by Sherman and Berman. What is the purpose of the safety factor (e.g., to account for cell measurement uncertainties, provide conservatism, etc.)?

STATUS: PROPOSED (Westinghouse to provide follow-on item response. The staff agreed FAI response is fine)

480.131 Tables 4-3 and 4-4 of WCAP-13388 list the steam generator compartment, steam generator annulus, CMT, and equipment bay as geometric class 3. Immediately after the geometric class determination in Tables 4-3 and 4-4, the report concludes that there is "no potential for DDT." It is not clear how this conclusion was reached. Proper use of this methodology has the analyst define a mixture class. Then the geometric class is combined with the mixture class to define a result class. These steps are missing from the report. In addition, the conclusion reached in the report does not appear to represent any of the result classes mentioned in the methodology used. Provide a more detailed justification for this conclusion.

STATUS: PROPOSED (Westinghouse to provide follow-on item response. Westinghouse showed staff where the information is) Steps are not missing from the report, it's in the text, not in the table where NRC was looking.

480.132 The geometric class assigned to the IRWST and steam generator subcompartments appears to be non-conservative. It appears that a qualitative method was used to assign these geometric classes. Describe in more detail the process used to assign the geometric classifications for the subcompartments stated above.

STATUS: PROPOSED (Westinghouse to provide follow-on item response. The staff indicated that verbal response is acceptable)

480.133 DDT has been observed in hydrogen-air mixtures at hydrogen concentrations as low as 12.5 percent, which is less than the value of 15 percent reported in WCAP-13388. A mixture of 11.7 percent hydrogen in air at STP was also observed to be intrinsically detonable in the HDT[3] as compared to the 13 percent value quoted on page 2-8 of WCAP-13388. Also, the detonation limit observed in a stoichiometric hydrogen-air-steam mixture at 100 °C and 1 atm initial pressure is between 38.8 percent and 40.5 percent steam, and will increase with increasing scale. This is greater than the conclusion reported on page 2-1 of WCAP-13388 that mixtures with 30 percent steam may be immune to detonations. Discuss this concern.

STATUS: ACTION N (Sandia to provide available information to Westinghouse via NRC on flame acceleration)

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[3]Stamps, D.W. and Berman, M., "Hydrogen-Air-Diluent Detonation Study for Nuclear Reactor Safety Analyses," Sandia National Laboratories report, SAND89-2398, NUREG\CR-5525, January 1991.

480.134 WCAP-13388 states that in the case of ex-vessel combustible gas generation (i.e., a dry cavity), the gas temperature in the reactor cavity would be sufficiently high to promote recombination of the combustible gas. Even if some of the combustible gas leaves the reactor cavity, it could be safely burned in the steam generator compartment or in the tunnel connecting the steam generator compartments. Therefore, Westinghouse states that no igniters are located in the reactor cavity. Provide a more detailed discussion of the basis for this conclusion. Also, are there any other restricted volumes within the containment that do not have igniter coverage?

STATUS: ACTION W (NRC wants justification for why igniters not placed in cavity.) Westinghouse recommended that the NRC review response to Q480.40.

480.135 The following criteria was used by previously reviewed designs to locate hydrogen igniters, and does not appear to be applied to the AP600 design. Discuss the differences between this criteria and the criteria listed in Chapter 16 of the AP600 PRA.

- Placement of igniters in closed and less well vented regions.
- Igniter locations are supported by an igniter pair in the same general vicinity.
- All igniter pairs are powered via independent power sources.
- Compartments adjacent to the break compartment should have igniter coverage.
- Computer analyses, such as MAAP and WGOTHIC, are a valuable tool in assessing general trends. However, they are not sufficient in determining whether or not igniters are needed in a specific location.
- Detonation calculations have an important role in the overall assessment of the design.
- Equipment survivability should be addressed by determining the environment in the burning zones.

STATUS: PROPOSED (Westinghouse to provide information on igniter siting criteria in response).