52-003

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NUCLEAR REGULATORY COMMISSION
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January 18, 1996

Mr. Nicholas J. Liparulo
Nuclear Safety and Regulatory Activities
Westinghouse Electric Corporation
P.O. Box 355
Pittsburgh, Pennsylvania 15230

SUBJECT: COMMENTS ON WESTINGHOUSE PLAN TO RESOLVE AP600 PROBABILISTIC RISK ASSESSMENT (PRA) MAAP4 SUCCESS CRITERIA ISSUES

Dear Mr. Liparulo:

Westinghouse letter NTD-NRC-95-4606, dated December 8, 1995, submitted a plan to resolve AP600 PRA MAAP4 success criteria issues. The letter states that the plan addresses outstanding MAAP4 issues, including benchmarking and thermal-hydraulic uncertainty concerns related to the AP600 certification effort.

This letter was in response to an NRC request for a plan on benchmarking the MAAP4 computer code. The staff was expecting a submittal which would outline how Westinghouse intended to demonstrate the sufficiency of the MAAP4 through the benchmarking of output results and important phenomenology against other validated ECCS codes (e.g., NOTRUMP) and experimental data. However, the Westinghouse submittal goes beyond MAAP4 benchmarking concerns and appears to propose a completely new strategy addressing all issues related to the thermal-hydraulic uncertainties involved in the analysis of passive system performance.

The evolution of the thermal-hydraulic uncertainty issue has been a consequence of the philosophy inherent in advanced passive reactor designs. The AP600 design employs both active and passive systems for accident prevention and mitigation but only passive systems are safety related. Since passive systems rely on natural forces such as gravity and stored energy to perform their functions, the net driving forces are small compared to active systems and are subject to large uncertainties - especially when considering multiple system failure scenarios contained in PRAs. These uncertainties potentially affect the thermal-hydraulic performance reliability of the passive systems and must be accounted for in the PRA. Quantification of these uncertainties involves a prohibitively large number of computations. For this reason, Westinghouse had developed a conservative PRA success criteria bounding approach which would eliminate the need to quantify thermal-hydraulic uncertainties.

In a meeting on July 27, 1995, Westinghouse presented their bounding approach plan for resolving thermal-hydraulic uncertainty issues. Although the Westinghouse approach was not formally submitted to the staff, it was our understanding that the methodology involved had received high level management review and agreement within Westinghouse. In an August 14, 1995, letter from

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the NRC to Westinghouse, the staff approved the Westinghouse bounding approach provided five concerns could be satisfied. The plan approval received high level review and concurrence within the NRC.

The Westinghouse December 8, 1995, submittal contains a substantial change to the thermal-hydraulic uncertainty resolution plan approved by the staff in August of 1995. Specifically, it eliminates the analysis of bounding sequences using an approved ECCS evaluation model (NOTRUMP with Appendix K requirements) to show that peak cladding temperatures remain less that 2200°F. Additionally, the Westinghouse plan minimizes the number of NOTRUMP analyses to be performed (total of four). This is significantly fewer than what the staff would prefer in order to obtain confidence in the adequacy of MAAP4. It should be noted that the staff plans to run approximately 15 confirmatory RELAP and TRAC cases based on selected MAAP4 sequences.

The staff has provided detailed comments on the Westinghouse submittal which are enclosed with this letter. However, it is unlikely that this revised approach would be approved by us. Westinghouse should reexamine the intent of this submittal and make adjustments, as appropriate, to bring it back in line with the plan approved by the staff in August of 1995. Westinghouse is reminded that ultimately, resolution of thermal-hydraulic uncertainty issues factor into determining the scope of systems which will be subject to regulatory treatment of non-safety systems (RTNSS). If Westinghouse were to agree to regulatory oversight of certain important defense-in-depth active systems, the process required to reach closure on passive system thermal-hydraulic uncertainty could be simplified considerably.

If you have any questions regarding this matter, please contact me at (301)-415-1118, or the responsible AP600 project manager, Bill Huffman, at (301) 415-1141.

Sincerely,

original signed by:

Theodore R. Quay, Project Director
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Division of Reactor Program Management
Office of Nuclear Reactor Regulation

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Docket No. 52-003
AP600

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COMMENTS ON WESTINGHOUSE AP600 MAAP4 BENCHMARK PLAN (12/8/95)

In the July 27, 1995, meeting, Westinghouse presented an approach for addressing the issue of passive system thermal-hydraulic uncertainties by demonstrating robustness of the PRA success criteria that have adequate margin to bound the effects of passive system thermal-hydraulic uncertainties. The essence of this approach includes: (1) selecting a small set of sequences which bound the T/H response for all other success sequences analyzed using the MAAP4 code, (2) analyzing the bounding sequences using an approved ECCS evaluation model (NOTRUMP with Appendix K requirements) to show a PCT of less than 2200°F, and (3) performing benchmarking comparison of the MAAP4 with the NOTRUMP for a few sequences to show appropriateness of MAAP4 analyses in selecting the bounding sequences. The staff in an August 14, 1995, letter of the meeting summary stated that it considers this approach to be acceptable provided that Westinghouse addresses five concerns laid out in the letter. To address part of these issues, the staff required Westinghouse to (1) demonstrate that MAAP4 is adequate to provide an understanding of all the important T/H phenomena associated with the AP600 design in sufficient detail to identify the bounding PRA sequences, (2) describe and justify the process used to select the least margin or bounding sequences for subsequent NOTRUMP/DBA-like analysis, and explain why the success of the associated sequence success criteria ensures that all other PRA sequences would be expected to succeed if analyzed using the same DBA-like analyses, and (3) justify why the use of Appendix K inputs and models is sufficient to bound the thermal hydraulic uncertainties for all AP600 PRA sequences.

Subsequently the staff met with Westinghouse to address these issues. A meeting was held on September 12 through 14, 1995, to discuss the accident sequence analysis, including a review of numerous baseline accident sequence progressions, specific system responses and the integrated system behavior and phenomenology as predicted by MAAP4, and the process and sensitivity studies used to discard marginal success criteria and to sort the various accident sequences to a set of baseline sequences. Another meeting was held on October 24 and 25, 1995, to discuss details and limitations of the use of the MAAP4 code in the analysis of AP600 Level 1 PRA accident sequence success criteria, including an overview of MAAP4 basic modelling, input parameters conservatism, effect of input parameter variations, and application guidelines. Because MAAP4 uses many simplified models to address thermal-hydraulic phenomena in the accident sequences, the staff emphasized the importance of careful benchmarking to determine the adequacy of the MAAP4 application in the analysis of the success criteria and in selecting the bounding PRA success sequences. The staff requested Westinghouse to provide a written benchmarking plan.

On December 8, 1995, Westinghouse provided a document entitled "Plan to Resolve AP600 PRA MAAP4 Success Criteria Issues," which included a proposed benchmarking plan for MAAP4 but also discussed an approach to closeout the T/H uncertainty issues. This approach appears to be different from the one presented in the July 27, 1995, meeting.

Enclosure

In a telecon on December 14, Westinghouse indicated that while there were some differences in the approach relative to the July 27 presentation, the approach was basically the same. The staff committed to provide its comments on the Westinghouse submittal using the July 27th presentation as the basis, discuss how we see the revised approach to be different, and to specifically discuss our concerns with regard to the adequacy of the proposed benchmarking plan and revised approach.

I REVISED APPROACH FOR RESOLUTION OF T/H UNCERTAINTY ISSUE:

1. Significance of Change in T/H Uncertainty Resolution Approach:

The "Introduction" in the submittal indicates that the purpose of the MAAP4 benchmarking plan is to describe the process for bringing the issue of thermal-hydraulic uncertainties for passive system reliability to closure. However, the NOTRUMP/DBA-like analysis to demonstrate the success of the bounding sequences is not included in either the three major components for addressing the T/H uncertainty issue (Section 3), or the 11 step process (Section 5 and Figure 2). Nor is there a discussion of how Westinghouse plans to address the issue of justifying that use of Appendix K inputs and models is sufficient to bound the T/H uncertainties for all AP600 PRA sequences.

Eliminating the use of NOTRUMP/DBA-like analysis of the bounding sequences to demonstrate robustness of success criteria is a significant change from the T/H uncertainty resolution approach presented in the July 27, 1995, meeting. Since NOTRUMP is verified and validated against test data from various AP600 test facilities, the staff's review and approval of its AP600 application in the design basis analysis of small break LOCAs will provide sufficient basis for the validity of its analysis of the AP600 PRA success sequences, provided that Westinghouse can demonstrate that no new and significant thermal-hydraulic phenomena could be encountered in the PRA success sequences to invalidate the NOTRUMP applicability. The DBA-like analysis also eliminates the need to quantify the effects of thermal-hydraulic uncertainties. In this approach, MAAP4 is used primarily to perform "preliminary analysis" of PRA sequences to determine success criteria, select baseline sequences and bounding sequences. The MAAP4 benchmarking will be focused on demonstrating that MAAP4 is adequate for identification of the bounding sequences, including determining the limiting break size and location, and operator action times. In the "revised" approach, MAAP4 is also used for final analysis to demonstrate adequacy of success criteria. If MAAP4 is used in this manner, its validity for AP600 application will require more strict scrutiny.

2. Comments on Revised Resolution Approach of T/H Uncertainty Issue:

Section 3 states that the issue of thermal-hydraulic uncertainty and its effect on the reliability of the passive systems is addressed with three major component, i.e., MAAP4 benchmarking, significant margin to the 2200°F PCT criterion, and sensitivity studies. The staff finds that these three major components as implemented by Westinghouse do not properly address the passive system thermal-hydraulic uncertainty issue.

MAAP4 Benchmarking:

As will be discussed on MAAP4 Benchmarking below, MAAP4 lacks appropriate models to address many important phenomena in the accident sequences. The MAAP4 benchmarking plan relies on tuning of model parameters to provide good comparison of only a few runs against NOTRUMP on a few selected parameters, which gives no assurance that MAAP4 will perform well for other cases not used in the tuning process. There is insufficient basis for saying that "the benchmarking of MAAP4 provides assurance that the models and the methodology applied in the success criteria analysis produce accurate results with respect to predicting the system behavior and core damage."

PCT Margin:

The MAAP4 analysis of peak core temperature is based on lumped radial peaking factors, which are quite small compared to the hot pin peaking factors. No result has been given for the peak cladding temperature calculated with appropriate hot pin peaking factors. There is insufficient basis to say that "significant margin (on the order of hundreds of degrees) to the 2200°F PCT used to define core damage is provided for the most thermal-hydraulically restrictive accident sequence represented on the success path in the PRA." In addition, there is no quantification of the PCT margin required to bound the effects of uncertainties associated with thermal-hydraulic parameters in the plant, operator action time, various T/H models in MAAP4, and lack of MAAP4 models to address many important phenomena in the accident sequences. Therefore, there is little evidence that the "significant margin" from the MAAP4 calculation is sufficient to bound the T/H uncertainties.

Sensitivity Studies:

It is not clear how the T-H uncertainty will be covered with MAAP4 sensitivity studies. The MAAP4 sensitivity study of the few parameters indicated in the report, including the sensitivity study using LOCTA to show the effect of varying the core peaking factors, appear to be too limited in scope, and do not necessarily cover the T/H uncertainty. "Small uncertainties related to the physical plant" are not the only areas of concern. The extent to which user-selected parameters can affect the performance of code models is also an issue. To illustrate with a simple example: as the plant depressurizes, through both the break (depending on size) and the ADS, there may be a transition from critical flow to subsonic flow. The pressure at which this occurs and the way in which the flow changes as a function of the transition will have an impact on inventory loss, system pressure, and related parameters. Code models need to be assessed as to their ability to represent this transition; it may be a matter of internal code logic, user-selected parameter(s), or both. It has been amply demonstrated in previous code validation/benchmarking exercises (for instance, the series of International Standard Problems sponsored by the OECD/NEA) that relatively small variations in user-selected parameters (and, by extension, in the internal logic of different computer codes) can have a profound effect on just the type of analyses being performed in this benchmarking study. The range over which MAAP4 models have been validated is also an issue in this regard (and is also related to the MAAP4/OSU comparison).

Also, it is stated that sensitivity analysis will be performed with LOCTA to show the effect of varying the core peaking factors that impact the calculation of PCT for the hot pin. It also states that because of the difficulty in defining the nominal values of the overall peaking factor and axial power shapes as they vary during a fuel cycle, the benchmarking cases will be defined to have a conservative core model, but not necessarily the worst possible conditions that are assumed for Chapter 15 safety analyses. It is not clear whether the "conservative core model" used in the benchmarking is also used in the success criteria analysis, and what values of the peaking factors will be considered adequately conservative.

II MAAP4 BENCHMARKING PLAN:

1. MAAP4 Key Models and Important Phenomena:

Section 2.2 states that the MAAP4 benchmarking plan is developed around the need to test key models within the MAAP4 code as they are applied for the AP600 success criteria analyses. The staff believes this major premise only addresses half of the issue. In addition to test adequacy of the MAAP4 key models, it would also be important to identify and evaluate impact of lack of appropriate models in MAAP4 to address the important phenomena occurring in the AP600 during accident sequences.

Though Section 2.2 states that a review of the small LOCA PIRT was performed so that no important phenomena would be excluded from the benchmarking, many of the "high importance" components/phenomena for SBLOCA (Table 2) are either not modeled or modeled very simplistically in the MAAP4 code. There is no discussion on why these high importance phenomena can be excluded, how these important phenomena become unimportant, or how the MAAP4 results can be trusted and the adequacy of MAAP4 justified in light of these shortcomings.

Additional Comments:

a. It is understood that, in the success criteria analysis of PRA sequences, failure of containment isolation is assumed by Westinghouse so that the containment remains at atmospheric pressure. If this assumption is not made, Westinghouse would need to model containment pressurization as well as the passive containment cooling system, and demonstrate that disregarding it leads to more conservative results. If containment integrity is assumed to have failed, then the phenomena related to the long-term cooling phase may be important to demonstrate the core will continue to receive an adequate supply of coolant from the sump as time proceeds, since operation of the PCCS relies on an intact containment.

b. Table 1 indicates that the passive residual heat removal system is not applicable because ADS success criteria with the PRHR operable are not directly supported by the MAAP4 analyses. While the assumption of PRHR failure does minimize heat removal capability, it also tends to reduce the heat load to the IRWST. Westinghouse should look at the assumptions made about the temperature of the IRWST liquid flowing to the core, since that could have an impact on the core two-phase flow behavior and possibly uncovery.

2. Parameters of Interest:

The criteria for comparing the two codes in the benchmarking are extremely broad. This is no doubt driven, in part, by the need to find a standard to judge the performance of two vastly different computer codes. However, focusing as these criteria do on gross differences between the two codes (the implication is that the two main criteria are peak core temperatures and the timing of certain events during the accident sequences.) could lead to overlooking the reasons for these differences; or, if the predictions appear to agree reasonably well, the possibility and impact of compensating errors could be overlooked. Therefore, the MAAP4/NOTRUMP comparison should not be limited to the parameters of interest of the MAAP4 models provided in the last column in Table 1. Physical phenomena of the agreements and differences in the comparison should be explored and understood to judge their impacts on sequences which will not be used in the benchmarking. In addition, the following are some specific comments related to the parameters of interest in Table 1.

a. For the core uncovery and heatup model, the core heat transfer coefficient would be an important parameter, but is not mentioned. The calculation of core heatup would seem to be directly influenced by the heat transfer model(s) used leading up to and after core uncovery, as well as those predicting rewet and post-rewet heat transfer. Since LOCTA is actually used for these calculations when the core uncovers (as opposed to NOTRUMP itself), another potential source of uncertainty is introduced. There is no description in this document as to how output from NOTRUMP is configured into input to LOCTA, nor how LOCTA results may have an impact on NOTRUMP calculations as the mixture level in the core drops below the top of active fuel and then (presumably) recovers.

b. The time that the core makeup tank (CMT) makes the transition from recirculation to draining is cited as a key parameter, but the mechanism for that transition is not cited as an element of the comparison. The CMT can begin draining by virtue of an in-flow of vapor as the cold leg uncovers, or the hot layer in the CMT can flash as the system depressurizes (due to the break, since ADS has not been actuated).

c. The core collapsed level or inventory would be an important parameter in addition to the mixture level.

3. PIRT for Other accidents:

MAAP4 is also used to analyze steam generator tube rupture, steamline break, and other heatup transients in addition to small break LOCA. There is no PIRT to identify important phenomena, and benchmarking of MAAP4 for these other sequences. Westinghouse should discuss whether additional PIRTs for specific accident initiators are needed, or the SBLOCA PIRT covers all other initiating events where MAAP4 is used in the success criteria analysis with the rationale for this conclusion.

4. Use of MAAP4 AP600 Model for Assessment of OSU Tests:

Section 2.6 indicates that the MAAP4/OSU test assessment will be performed with the MAAP4 AP600 model, with its output being scaled against the OSU semi-scale tests. It states that the output from MAAP4 will be scaled (e.g., 1/2 time, 1/96 mass flowrates) to assess the ability of the code to predict the same general conclusions found in the tests, and the focus will be on water inventory and MAAP4's ability to predict core uncovery. The staff has some serious questions about scaling the MAAP4 AP600 model results to the OSU tests. The OSU scaling was based largely upon a set of assumptions about facility response during events up to and including the design basis of the AP600. It is true that the approximate timing and mass flow rate scale factors are 1/2 and 1/96. However, there are distortions that occur as a natural result of the reduced size of the test facility that impact the loop response. No simple one-to-one correspondence between plant and test loop response that can be assessed just by applying the scaling factors for various parameters to an AP600 calculation. At best, the comparison would have to be made on the basis of the appropriate dimensionless parameters that represent "high-importance" phenomena (from the OSU/AP600 PIRTs) during these events. In addition, a superficial application of the "scaling factors" overlooks fundamental aspects of the performance of scaled tests. For instance, post-test evaluation of OSU facility response and a re-examination of the scaling analysis performed for Westinghouse (by J. Reyes) indicates that the appropriate scaling ratios may actually change as a function of time during the event and as a function of the event itself (e.g., break size). Furthermore, extending this "scaling" to core heatup is beyond the scope of the original scaling analysis for the OSU facility, and could lead to erroneous conclusions. Not only is OSU's power also scaled (since time is "shortened" in OSU by a factor of 2, the power input must be increased to account for the compression of events), but the response of the fuel rod simulators in OSU was not designed to represent AP600 fuel rods. It is not at all clear that a simple set of "scaling factors" could be applied to the post-uncovery portion of the event. It is also not clear how the initial conditions would be "scaled" from OSU to an AP600-model calculation; and these conditions could have a significant impact on the analysis.

The staff believes that the use of MAAP4 AP600 model to perform MAAP4 assessment against OSU tests is inadequate. The appropriate means to benchmark MAAP4 would be to run MAAP4 with an OSU-loop model and compare directly to the test results. If core heatup is to be included in the assessment, then a valid fuel pin simulator heatup model should be included as well.

Additional Comments Related to OSU Tests:

a. The two OSU tests (SB26 and SB28) that will be analyzed have high or significant system redundancy and lead to only limited core uncovery. Therefore, the MAAP4 benchmarking against the OSU tests should not be expected to provide global coverage of phenomena that might be encountered in the multiple failure PRA sequences.

b. Section 2.6 states that phenomena observed at OSU test facility will be reviewed for potential applicability to MAAP4 success criteria. (e.g., thermal stratification, rapid condensation, and flow reversal in the IRWST injection lines). It is not clear (1) what the criteria are to determine whether a phenomenon from a test facility simulating AP600 plant is applicable to AP600 success criteria analysis, and (2) what would be done if a phenomenon is applicable, but the MAAP4 code does not have an appropriate model to address the phenomenon.

5. Tuning of MAAP4:

The 11-step closure process (p.10-11) includes a determination of adequacy of the EPRI-recommended MAAP4 model parameters or a need to modify the code model parameters to provide good comparison between the MAAP4 results and the NOTRUMP results and OSU data (step 7). It indicates that any modification of the MAAP4 model parameter will be done in a systematic manner that either changes the values for all cases, or is based on phenomena that are specific to a set of cases. It should be noted that the data on which the "EPRI-recommended" values for MAAP4 model parameters are based may or may not be broad enough to encompass the conditions expected in the AP600. If parameters are to be kept at current values, the rationale for choosing those values needs to be documented for application to the AP600; if parameters are changed, a systematic means for determining how they should be changed needs to be established. However, there is no description of how the "systematic manner" will be determined, or the systematic process to be used for tuning the model parameters that would assure that good comparisons are not because of some compensating errors especially when MAAP4 lacks models to address many important phenomena. In addition, if the benchmark cases will be used to adjust MAAP parameters, it must be shown that these adjustments work well for cases that were not used in the adjustment process. The process as proposed, provides no basis to assure that the model parameters tuned from the limited runs are good for other sequences not used in the tuning process.

6. Number of Benchmark Comparison with NOTRUMP:

Sections 2.3 selects four PRA sequences to be used to benchmark MAAP4 to NOTRUMP results. Three of the PRA sequences will be analyzed through IRWST injection to compare the parameters of the key models, and the fourth one would only be used to show that the cold leg break uncovers the core later than the hot leg break. There are essentially 3.5 MAAP4/NOTRUMP benchmarking cases in light of the inadequacy of the proposed approach for the MAAP4 benchmarking against the OSU data (see Item 4 above). Section 2.4 states one of the key questions as "Is there a major difference between MAAP4 and NOTRUMP's prediction that would give reason to doubt MAAP4's successful core cooling prediction of other accident scenarios?" The staff believes these limited MAAP4/NOTRUMP comparisons are insufficient to identify all major differences in predictions between MAAP4 and NOTRUMP, and to demonstrate that MAAP provides adequate predictions for the whole spectrum of events sequences. This is because (1) there are a large number of high importance phenomena (as shown in Table 2 and by the OSU tests), (2) there are many important phenomena not properly modeled by MAAP4, and (3) these sequences are used to tune the MAAP4 model parameters to provide good comparisons. The number of cases needed to provide a confidence of the adequacy of

MAAP4 cannot be pre-determined, but will depend on how well the code predicts various phenomena during the benchmarking comparison.

Additional Comments on MAAP4/NOTRUMP Benchmarking:

a. Though the actual models and required input parameters may be different between the MAAP4 and NOTRUMP codes, consistent values (including uncertainties) of the plant parameters, initial conditions, decay heat, and core peaking factors, etc., should be used for the two codes to provide meaningful comparison of the results.

b. It is said (p. 5) that Case 4, which is an 8.74" cold leg break, will be analyzed with MAAP4 and NOTRUMP to confirm that the cold leg break is not limiting as an identical hot leg break case 3 by showing that the cold leg break uncovers the core later than the hot leg break, and that once this is demonstrated, the purpose of case 4 is fulfilled. It should be noted that later uncovery does not mean lower PCT. Thus, time to uncovery may not be an adequate criterion.

c. It is stated (p. 6) that "ADS parameters will remain at conservative values to minimize the depressurization capability, which is the same assumption used in the MAAP4 analyses for success criteria and for benchmarking." It should be shown that higher ADS flow always give lower PCT.

III RECIRCULATION:

Page 8 states that the lessons learned at the OSU test facility will be reviewed for potential applicability to the MAAP4 success criteria analysis. One of the phenomena observed in the OSU tests is the flow reversal in the IRWST injection line occurred during sump cooling. The staff is not sure that MAAP4 appropriately models this phenomenon. In the September 12 through 14, 1995, meeting, the staff questioned adequacy of stopping success criteria analysis at stabilized IRWST injection conditions, because long term recirculation conditions could be subject to greater uncertainty due to small head differences involved. This is especially true because Westinghouse assumes containment integrity failure in the success criteria analyses, and there is no assurance that the core will continue to receive an adequate supply of coolant from thesump as time proceeds. Though Westinghouse staff indicated that they felt the long term interval to recirculation reduced decay heat levels to the point where recirculation thermal-hydraulics is not a significant concern, the staff requires that a clear technical justification be provided showing that analysis through the recirculation phase is not needed.

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