July 27, 2000

Mr. W. E. Cummins, Director
Advanced Plant Development Unit
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355

SUBJECT: AP1000 PRE-APPLICATION REVIEW - PHASE ONE

Dear Mr. Cummins:

This letter provides the results of the U.S. Nuclear Regulatory Commission (NRC) staff's phase one assessment of Westinghouse's AP1000 pre-application review. You requested the NRC to proceed with phase one in your letter of May 4, 2000, so that the scope of a design certification review could be determined (phase two). The results of the NRC's phase one assessment and estimates of the professional staff hours needed to perform the phase two review are given in Enclosure 1. A summary is provided in Enclosure 2. Our confidence in the accuracy of these estimates depends upon the schedule for the phase two review and the availability of the AP600 reviewers.

If Westinghouse chooses to proceed with the phase two assessment, it must submit a written request specifying the items that the NRC should evaluate. Westinghouse should also provide information that NRC can use to determine the priority for the phase two review, as part of the NRC's Fiscal Year 2001 workload. We will use the following performance goals to prioritize your request and any information that you choose to provide will assist us in developing a schedule for the phase two review.

1. Maintain safety, protection of the environment, and the common defense and security.
2. Increase public confidence.
3. Make NRC activities and decisions more effective, efficient, and realistic.
4. Reduce unnecessary regulatory burden on stakeholders.

An explanation of these goals is provided in the NRC's Strategic Plan (NUREG-1614, Vol. 2, Part 2). If you have any questions on this matter, please contact Jerry N. Wilson of my staff.

Sincerely,

/***RA***/

Samuel J. Collins, Director
Office of Nuclear Reactor Regulation

Project No. 711

Enclosures: As stated

cc w/encls: See next page

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PHASE ONE RESULTS

The following assessment addresses the five items proposed by Westinghouse in its letter of May 31, 2000, and an additional item (exemptions) proposed by the NRC staff for evaluation in phase two of the AP1000 pre-application review. The resource estimates assume that Westinghouse will provide complete, high-quality submittals to support the phase two review and that NRC will not need to make any written requests for additional information. Our confidence in the accuracy of these estimates depends upon the schedule for the phase two review and the availability of the AP600 reviewers.

Item 1 - Scope of NRC Review

The purpose of this item is to determine the scope of the NRC's design certification review of an AP1000 application, specifically, which sections of the AP600 design control document (DCD) will not require re-review for the AP1000 DCD. In order to perform this evaluation, the NRC staff expects Westinghouse to provide the following:

1. A description of its proposed design changes containing a level of detail comparable to that provided in Section 1.2 of the AP600 DCD.

2. An annotated Table of Contents for the DCD, Tier 2, identifying unchanged sections.

3. A rationale for why no change is needed in that section of the AP600 DCD.

The NRC's review of Item 1 will require about 30 staff members for about 1 month and will consume about 1000 professional staff hours, depending on the availability of former AP600 reviewers. This estimate does not include a review of Tier 1 information or NUREG-1512, "Final Safety Evaluation Report related to Certification of the AP600 Standard Design."

Items 2 and 3 - Test Program and Analysis Plan

The purpose of these items is to determine if the AP600 test program meets the requirements of 10 CFR 52.47(b)(2)(i) for the AP1000 design and if the analytical codes used for AP600, with changes proposed by Westinghouse, are acceptable for analyzing the AP1000. Specifically, the question is will the NRC require Westinghouse to perform additional tests or make further modifications to the analytical codes to support an AP1000 application for design certification. In order to determine whether the AP600 test program (including test matrices) and code validation are sufficient for the AP1000, Westinghouse must develop a Phenomena Identification and Ranking Table (PIRT) for the AP1000, identify key thermal-hydraulic (T/H) phenomena and parameter ranges, and identify any new phenomena or differences from the AP600 PIRTs for large- and small-break loss-of-coolant accidents (LOCAs) and non-LOCA transients. It is also expected that Westinghouse will provide the following:

1. AP1000 Analysis Plan and Scaling Assessment of the AP600 Test Program
2. AP1000 Passive Core Cooling System Design Margins Assessment

The following discussion identifies additional information that the NRC staff expects to be addressed by Westinghouse in its submittal for Items 2 and 3 and provides estimates of the staff effort needed to review these issues.

Separate Effects Tests

Westinghouse must demonstrate that the existing separate effects tests of the passive residual heat removal system (PRHR) heat exchanger (HX), automatic depressurization system (ADS), and core makeup tank (CMT) sufficiently cover the ranges of key T/H phenomena and parameters or acquire additional test data. For example:

1. Westinghouse must demonstrate that the ADS test conditions provide sufficient coverage of the operating conditions expected in the AP1000 design. Westinghouse must provide justification as to why the range of T/H conditions covered by the AP600 ADS test program and the data acquired therefrom, provide an adequate basis for validation of code models for ADS performance analysis for the AP1000.

2. The PRHR behavior has a significant effect on reactor coolant system behavior over a wide range of design basis accidents. The PRHR HX tests were performed with three straight tubes compared to the C-tube HX in the AP600 and AP1000 designs. Although the staff concluded that the straight tube based heat transfer model did an adequate job of predicting C-tube performance for the AP600, the AP1000 PRHR system has larger pipe connections to the HX, higher flow and heat transfer, and possibly new T/H phenomena such as vapor blanketing the HX tubes during both natural circulation and forced convection modes. Westinghouse must demonstrate that the straight tube test bundle adequately simulates the C-tube HX design, whether the ROSA PRHR design, which was used for confirmatory tests, is adequate to simulate the AP1000, and whether the test data cover the ranges of PRHR HX T/H phenomena and parameters. It is possible that additional PRHR tests in a substantially upgraded test facility may be required.

3. The CMT tests were performed with the test article that is half of the height and 1/7.8 of the diameter of the AP600 CMT design. Westinghouse must demonstrate that the AP600 CMT tests are adequate for the AP1000 design, including scaling, test matrix, and data.

Integral System Tests

Westinghouse must submit a scaling report for the integral system tests, such as OSU/APEX and SPES-2 (high pressure, full vertical scale), for the AP1000 and demonstrate that the test matrices of OSU/APEX and SPES-2 provided adequate coverage of the break sizes and locations to address important system-related phenomena identified in the AP1000 design. It is possible that additional integral system tests may be required, especially for validation of the NOTRUMP code for small-break LOCA analysis and the WCOBRA/TRAC code for long-term cooling analysis.

The NRC's review of the separate effect and integral system tests will be performed by one staff member for about 30 weeks and will consume about 1200 professional staff hours. This estimate assumes that the AP600 test program reviewer will not be available to evaluate these tests, and a new staff member will have to spend a significant amount of time reviewing the AP600 test program to prepare for the phase two assessment.

Critical Heat Flux Test

The AP1000 will use a fuel design of a 14-foot active fuel length compared to the 12-foot VANTAGE-5H used in the AP600, and it will have a higher power density than in the AP600 fuel design. Therefore, the NRC staff believes that Westinghouse should include a review of test data necessary to ensure that the WRB-2 critical heat flux (CHF) correlation used for the AP600 is applicable to the ranges of T/H and geometric parameters of the AP1000 fuel design. Westinghouse will have to either (1) provide justifications on the applicability of the WRB-2 CHF correlation to the new fuel design by demonstrating that sufficient test data exist to cover the geometrical and T/H conditions of the new fuel design or (2) acquire additional CHF data to cover the new fuel design and T/H conditions and demonstrate that the WRB-2 correlation adequately predicts the new data, or develop a new CHF correlation (including WRB-2 modification). The NRC's review of the CHF correlation will require one staff member and consume about 40 professional staff hours.

WCOBRA-TRAC

WCOBRA-TRAC was benchmarked for a long term cooling (LTC) application to four experiments in the OSU/APEX facility. In the AP600 review, the power density limit that could be supported by natural circulation in the primary system was not established. Since the AP1000 has higher power density than the AP600, some analysis (or even testing) is required to establish that the OSU/APEX results used in the AP600 WCOBRA-TRAC LTC validation are valid for the AP1000 design. The resource estimate assumes that the AP600 reviewer will evaluate WCOBRA-TRAC for LTC and large-break LOCA and will consume about 320 professional staff hours for 2 to 3 months.

LOFTRAN/LOFTTR2

The LOFTRAN code that was used for transient analyses is hardwired specifically for the AP600 design and has models for each AP600 component that are very hardware specific. The code will have to be modified for the different AP1000 components. Conditions for the main steamline break (MSLB) and steam generator tube rupture events will be significantly different. Westinghouse needs to explain how LOFTRAN has been or will be changed to model AP1000 and why these changes are appropriate.

NOTRUMP

The AP600 Final Safety Evaluation Report (NUREG-1512) concludes that the approval of NOTRUMP for use in the small-break LOCA analysis is given specifically for the AP600, which means it is restricted to that configuration and power level. There were numerous problems with the AP600 analysis that would require the whole code and analysis qualification to be re-evaluated. For example, the code does not calculate non-condensable gas in the system, as required by NUREG-0737, "Clarification of TMI Action Plan Requirements," item II.K.3.30. It would have to be shown that non-condensable gas would not be injected into the system for the AP1000 design. The AP600 test program was unable to track the gas in the system.

The AP600 small-break LOCA analysis did not predict uncovery of the core, but the predicted level was very close to the top of the core. In fact, there was a two-phase mixture in the core for some of the breaks. The AP1000 core is 2 feet longer, with a higher linear heat generation rate and a higher power density. If the AP1000 analysis predicts core uncovery, there can be little doubt that transition boiling will occur. That is another problem because the transition boiling correlation was found to be unacceptable in the AP600 review. Therefore, the heat transfer package review will have to be reopened.

The NRC's review of LOFTRAN and NOTRUMP will require one staff member for 2 to 4 months and will consume 300 - 600 professional staff hours, depending on the availability of the former AP600 reviewer. The NRC's review effort will require going back over the testing program to determine the validity of the tests for this new configuration.

WGOTHIC

The large-scale test (LST) facility was a proof-of-principle test and not a scaled test facility and exhibited shortcomings in both scaling and prototypicality (mass and energy inputs, heat sinks - both short term and long term - compartments, etc.). Therefore, it could only address some portions of the evaluation model and could not be used as an integral test. At the scale of the AP1000 design, these issues are likely to be more significant. In addition, the physical modeling of the AP600 design was based on scaling the model used in the WGOTHIC calculations of the LST.

The mass and heat transfer correlations used in WGOTHIC came from separate effects tests or technical journal references. The applicable ranges of these correlations need to be examined at the scale of the AP1000. In addition, the passive containment cooling system (PCS) water flow characteristics were developed in the cold water distribution test (WDT) facility. The WDT modeled the range of the AP600 PCS water flow rates, although the actual flow rates in the AP600 are higher than tested. The WDT also modeled the expected surface conditions of the AP600 (material, coating, and surface defects). The AP1000 PCS water flow rates and surface conditions may not be adequately represented by the WDT.

Westinghouse is expected to provide the following information in its phase two submittal:

1. A PIRT evaluation that addresses the parameter ranges of the heat and mass transfer correlations and the PCS water (film) correlations used in WGOTHIC to justify their use at the scale of the AP1000 design or if new or additional experimental programs are needed to extend their ranges. Westinghouse also needs to address the multipliers approved for the AP600 as related to the AP1000.

2. A scaling evaluation of the LST facility to accomplish the following:

    a. Demonstrate that the AP1000 model (lumped-parameter nodalization - node sizes, boundaries, etc.) is justified.

b. Demonstrate that the PCS water flow characteristics (flow rate, delay time, cover areas, film stability, surface defects, loss coefficient in the external annulus, etc.) are justified and within the correlation ranges developed for the AP600.

c. Demonstrate that the mass and energy (LOCA and MSLB) driving forces as they would influence jet characteristic, plume rise, wall boundary layers, and so on, are justified and within the mass and heat transfer correlation ranges.

3. The “Limitations and Restrictions” (see NUREG-1512, Section 21.6.5.8.3) on the AP600 evaluation model need to be justified or modified accordingly for the AP1000.

The NRC’s review of WGOTHIC will use the former AP600 reviewer for 1 to 2 months and will consume about 120 professional staff hours.

Item 4 - AP1000 Probabilistic Risk Assessment

The purpose of this item is to determine if the AP1000 design certification application can utilize the AP600 probabilistic risk assessment (PRA), Level 1, supplemented with a sensitivity study to meet the requirements for a design-specific PRA. This proposal would be acceptable if changes associated with initiating event frequencies and system configurations, failure mechanisms, failure data, and success criteria do not have a significant impact on PRA results and insights. Westinghouse expects to be able to confirm, through additional analyses, that the initiating event frequencies and the success criteria for both systems and operator actions used in the AP600 PRA event trees are also valid for the AP1000. If this exercise is successful, the AP600 PRA quantification will be maintained. In case some success criteria, which affect the results and insights of the PRA and its use in the certification process, change, the PRA will need to be requantified with the new success criteria.

The NRC staff will determine whether the results of the AP1000 Level 1 PRA LOCA Success Sequences Analysis Report are sufficient to conclude that the AP1000 Level 1 success criteria for LOCA are the same as those for the AP600 design. Westinghouse used the MAAP4 code to screen PRA success criteria for the AP600. MAAP4 was benchmarked against the NOTRUMP code with risk-significant accident sequences for the AP600. The AP600 PRA also used a “margin-based” approach for the resolution of the T/H uncertainties. The review of the AP1000 PRA success criteria will involve benchmarking of MAAP4 for its validity for AP1000 event sequence analysis, and sufficient margins to address T/H uncertainties. As previously discussed, a determination must be made as to whether NOTRUMP is adequate for the analysis of the small-break LOCA for the AP1000. Consequently, a determination must also be made as to whether the MAAP4 benchmark with NOTRUMP for the AP600 is adequate for the AP1000. To benchmark MAAP4 for the AP1000 PRA, Westinghouse must rerun the risk-significant sequences used for the AP600 benchmark with both MAAP4 and an acceptable NOTRUMP and evaluate any significant differences in the results. Conservative bounding inputs and assumptions must be employed to demonstrate adequate margins to core damage. The NRC staff needs to evaluate Westinghouse’s criteria and bases used in the comparisons between the AP1000 and the AP600 results to justify that these comparisons are sufficient for concluding that the same AP600 success criteria are being maintained. Otherwise, Westinghouse must use the benchmarked MAAP4 code to rerun a spectrum of event sequences, following a similar approach as the one used for AP600, to demonstrate that the success criteria are the same. Therefore, Westinghouse must provide the following Level 1 PRA information:

1. A detailed description of the approach that will be followed to confirm the validity of the success criteria for both systems and operator actions. In the AP600 PRA, the success criteria were determined by a risk-based margins approach that used conservative assumptions for key T/H parameters, such as decay heat. This process resulted in success criteria that are sequence dependent and take into account T/H uncertainties. Westinghouse should discuss how the proposed design changes will affect the implementation of the margins approach for the AP1000. If it is proposed that some portion of the AP600 margins approach implementation be retained, Westinghouse should provide documentation showing that this action will not compromise the robustness of the success criteria (for both systems and human actions) used in the AP1000 PRA models.

2. A list of changes in the AP600 design with an explanation of why such changes would not introduce additional hardware failure mechanisms or increases in hardware failure rates. Both power operation and shutdown operation need to be addressed.

The NRC's review of Item 4 will require three former AP600 reviewers for 3 to 4 months and will consume about 800 professional staff hours.

<u>Item 5 - Defer Selected Design Activities</u>

The purpose of this item is to determine if selected design activities can be deferred to the combined license review stage. Specifically, it must be determined if Westinghouse can use design acceptance criteria (DAC) in lieu of detailed design information for the AP1000 seismic analysis, structural design, and piping design. In order to perform this evaluation, the NRC staff expects Westinghouse to provide the following:

1. Revised DCD Sections 2, 3.6, 3.7, 3.8, and 3.9 for the AP1000.
2. Draft DACs for seismic analysis, structural design, and piping design.
3. Results of an AP1000 seismic analysis for a hard rock site.
4. Westinghouse's rationale for using DAC in lieu of detailed design information.

The NRC's review of Item 5 will require three staff members for 2 to 3 months and will consume 400 to 500 professional staff hours, depending on the availability of former AP600 reviewers. In addition to the submittals previously mentioned, Westinghouse should consider the following structural issues regarding the feasibility of converting the AP600 design to the AP1000 design:

1. Dynamic stability of the nuclear island (sliding and overturning) - the ability of safety significant plant structures to resist sliding and overturning as a result of an earthquake is very important. Because of the increase of (1) the height of the shield building and the containment vessel, (2) the size of the cooling water storage tank and the size of nuclear steam supply system (NSSS) components, the overall horizontal seismic force and overturning moment will increase in comparison to the AP600 design. Westinghouse should demonstrate that the factors of safety for both horizontal sliding and overturning motion as a result of seismic excitation meet the acceptance criteria.

2. Westinghouse should demonstrate the adequacy of its 6-foot-thick foundation mat (in the balance-of-plant area) under the increased design loads (dead loads and seismic loads) for the AP1000.

3. Because the design margin of some critical sections documented in the AP600 DCD (for example, modular walls for the reactor water storage tank) is minimal, Westinghouse should demonstrate the adequacy of these critical sections under the increased design loads (thermal load, pressure load, and seismic loads).

4. If Westinghouse plans to use a newer edition of the design codes (e.g., American Society of Mechanical Engineers [ASME] 1999 Addenda) for the design of safety-related structures, it will be required to (1) compare the new codes with those already endorsed by the NRC, (2) identify differences between the two sets of design codes, (3) evaluate the significance of these differences, and (4) demonstrate an acceptable level of quality and safety in the use of the new codes pursuant to 10 CFR 50.55a(a)(3)(i).

5. Because of the increased size of NSSS components (diameter and height), the thermal and pressure loads in the subcompartments are expected to increase. Assuming these loads are found acceptable, Westinghouse needs to demonstrate the design adequacy of the subcompartment walls with these higher subcompartment pressures.

6. Westinghouse will need to demonstrate that the AP1000 steel containment will continue to meet the containment performance requirement for severe accidents (withstand the internal pressure at 24 hours after the start of an accident at ASME Service Level C limits).

7. The staff's preliminary review of the "Tier 2 Master Table of Contents of AP1000 DCD" found that changes to additional sections, tables, and figures of the AP600 DCD will be necessary for the AP1000 design. For example, because of the design changes of structural elements (i.e., the height of the shield building, the size of the cooling water storage tank), the dead weight of the nuclear island will be increased significantly, especially in the containment area (i.e., the containment shell, internal structures, and the shield building). Therefore, Section 3.8.5.4.3, "Analysis for Loads During Construction," should either be deleted because it is plant specific or revised. Additional sections that need to be changed are as follows:

    a. Seismic Design: Section 3.7.2.4, Table 3.7.1-2, Figures 3.7.1-17 through -19, and Figure 3.7.2-1.

    b. Steel Containment Design: Sections 3.8.2.1.1, 3.8.2.1.3, 3.8.2.4.1.2, 3.8.2.4.2.2, and 3.8.2.4.2.3 and Tables 3.8.2-2 and 3.8.2-3.

    c. Foundation Mat: Sections 3.8.5.1, 3.8.5.4.1, 3.8.5.4.2, 3.8.5.4.3, and 3.8.5.5.3.

<u>Exemptions</u>

The purpose of this item is to determine if any of the exemptions that were granted for the AP600 design certification can be used in the AP1000 application. In order to perform this evaluation, the NRC staff expects Westinghouse to provide the following:

1. Identification of all exemptions that Westinghouse plans to request for the AP1000.
2. Justification for the exemptions in accordance with the requirements of 10 CFR 50.12.

The NRC's review of Item 6 will be performed by the AP1000 project manager, in consultation with selected staff members, and will be completed within 1 month and consume about 80 professional staff hours, depending on the availability of former AP600 reviewers.

Project Management for Phase Two

If Westinghouse decides to proceed with phase two of the AP1000 pre-application review, a senior project manager and a backup project manager will be assigned to manage the NRC staff's review. If phase two lasts 6 to 8 months, the project management effort will consume about 600 professional staff hours. This effort includes preparation of a paper on the phase two results for the Commission's review, a phase two letter report, and participation in internal briefings.

Advisory Committee on Reactor Safeguards

The NRC staff recommends that the Advisory Committee on Reactor Safeguards (ACRS) participate in the phase two portion of the AP1000 pre-application review. Therefore, an estimate was made of the hours the ACRS and the NRC staff would consume during two full Committee meetings and one Subcommittee meeting, namely, about 60 hours per meeting session for a full Committee meeting and 100 to 180 hours per meeting day for a Subcommittee meeting, based on billable hours in the past.

If the ACRS holds a full Committee meeting on the AP1000 phase one results, it is estimated that 10 NRC staff members would attend the meeting for 2 hours and consume 20 professional staff hours. These hours are in addition to the 60 hours needed by the ACRS. A memorandum from John T Larkins (ACRS) to William D. Travers (EDO), dated June 21, 2000, on the AP1000 pre-application review is provided in the attachment.

If the ACRS holds a full Committee meeting on the AP1000 phase two results, it is estimated that 15 NRC staff members would attend the meeting for 2 hours and consume 30 professional staff hours. These hours are in addition to the 60 hours needed by the ACRS. It may also be necessary to hold a 2-day subcommittee meeting on the test program and analytical codes, before the full Committee meeting on the phase two results. The Subcommittee meeting will consume about 170 professional staff hours to prepare and participate in the 2-day Subcommittee meeting and about 280 hours of ACRS time.

RESOURCE SUMMARY

NRC Review Items	Professional Staff Hours
1 - Scope of NRC review	1000
2 - Separate effect and integral system tests	1200
2 - Critical heat flux	40
3 - WCOBRA-TRAC	320
3 - LOFTRAN and NOTRUMP	300 - 600
3 - WGOTHIC	120
4 - AP1000 PRA, Level 1	800
5 - Design acceptance criteria for seismic, structural, and piping	400 - 500
AP600 exemptions	80
Project management	600
Advisory Committee on Reactor Safeguards	620
TOTAL	5480 - 5880

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