April 26, 2005

Mr. Gordon Bischoff, Manager
Owners Group Program Management Office
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: DRAFT SAFETY EVALUATION FOR WESTINGHOUSE OWNERS GROUP TOPICAL REPORT WCAP-15831-P, REVISION 1, "WOG RISK-INFORMED ATWS ASSESSMENT AND LICENSING IMPLEMENTATION PROCESS" (TAC NO. MB5741)

Dear Mr. Bischoff:

By letter dated July 23, 2002, the Westinghouse Owners Group (WOG) submitted Topical Report (TR) WCAP-15831-P, Revision 0, "WOG Risk-informed [Anticipated Transient Without Scram] ATWS Assessment and Licensing Implementation Process" to the staff for review. On March 5, 2004, the NRC issued a request for further clarifications concerning WCAP-15831. On May 17, 2004, the WOG provided a response to the NRC's request for clarifications. During several NRC/WOG conference calls in June 2004, additional clarification requests were identified by the NRC. On September 14, 2004, the WOG submitted the revised WCAP-15831-P, Revision 1, consistent with the responses to the clarification requests. WCAP-15831-P, Revision 1, contains the WOG's risk-informed methodology for reviewing plant- and cycle-specific core designs to ensure sufficient safety margins are maintained during an ATWS. The WOG anticipates that this approach and model for a risk-informed ATWS analysis can be implemented by all WOG plants to evaluate design changes, licensing issues, and plant operability concerns.

The staff has completed the review and enclosed, for the WOG's review and comment, a copy of the staff's draft safety evaluation (SE) for WCAP-15831-P, Revision 1. The staff has determined that the WCAP-15831-P, Revision 1, methodology is acceptable and can be used in license applications requesting to implement the methodology on a plant- and cycle-specific basis for Westinghouse plants as long as the limitations and conditions listed in the attached safety evaluation, in addition to those identified in WCAP-15831-P, Revision 1, are satisfied.

Pursuant to 10 CFR 2.390, we have determined that the enclosed draft SE does not contain proprietary information. However, we will delay placing the draft SE in the public document room for a period of ten working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects. If you believe that any information in the enclosure is proprietary, please identify such information line-by-line and define the basis pursuant to the criteria of 10 CFR 2.390. After ten working days, the draft SE will be made publicly available, and an additional ten working days are provided to you to comment on any factual errors or clarity concerns contained in the SE. The final SE will be issued after making any necessary changes and will be made publicly available. The staff's disposition of your comments on the draft SE will be discussed in the final SE.

To facilitate the staff's review of your comments, please provide a marked-up copy of the draft SE showing proposed changes and provide a summary table of the proposed changes.

If you have any questions, please contact Girija Shukla at (301) 415-8439.

Sincerely,

/RA/

Robert A. Gramm, Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 694

Enclosure: Draft Safety Evaluation

cc w/encl:
Mr. James A. Gresham, Manager
Regulatory Compliance and Plant Licensing
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

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DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT WCAP-15831-P, REVISION 1, "WOG RISK-INFORMED ATWS

ASSESSMENT AND LICENSING IMPLEMENTATION PROCESS"

WESTINGHOUSE OWNERS GROUP

PROJECT NO. 694

1.0 INTRODUCTION

By letter dated September 14, 2004, the Westinghouse Owners Group (WOG) submitted topical report WCAP-15831-P, Revision 1, "WOG Risk-Informed [Anticipated Transient Without Scram] ATWS Assessment and Licensing Implementation Process," to the U.S. Nuclear Regulatory Commission (NRC) for review and approval. This topical report contains the WOG's risk-informed methodology for reviewing plant- and cycle-specific core designs to ensure sufficient safety margins are maintained during an ATWS. The WOG anticipates that this approach and model for a risk-informed ATWS analysis can be implemented by all WOG plants to evaluate design changes, licensing issues, and plant operability concerns.

For more than 30 years, the NRC and nuclear industry have placed considerable emphasis on ATWS events because these events pose a unique challenge for ensuring the safety of nuclear power plants and the public. An ATWS is defined in Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.62 as "an anticipated operational occurrence [AOO] as defined in appendix A of this part followed by the failure of the reactor trip portion of the protection system specified in General Design Criterion 20 of appendix A of this part." As stated, Appendix A of Part 50 defines AOOs as "those conditions of normal operation which are expected to occur one or more times during the life of the nuclear power unit..." The two limiting ATWS AOOs are the Loss of Normal Feedwater (LONF) event and the Loss of Load (LOL) event. ATWS events result from a precursor anticipated transient (e.g., LONF or LOL) that requires the automatic shutdown of the plant via a reactor trip and control rod insertion. However, during a postulated ATWS event, the reactor trip system is assumed to fail such that no control rod insertion occurs. This results in an unmitigated increase in reactor coolant pressure which eventually leads to failure of the reactor coolant system (RCS) pressure boundary and subsequent core damage.

An ATWS event is not a design basis accident due the very low likelihood of the AOO followed by failure of the reactor protection system. However, due to its unique challenge potential, the regulations require that ATWS be considered for plant design and operation. Section 50.62 of 10 CFR, "Requirements for reduction of risk from anticipated transients without scram (ATWS) events for light-water-cooled nuclear power plants," lists the NRC regulatory requirements to minimize the risk of an ATWS event for pressurized and boiling water reactors. In NUREG-1780, "Regulatory Effectiveness of Anticipated Transient Without Scram Rule," it is concluded that the ATWS rule was effective in reducing ATWS risk and that the cost of implementing the

rule was reasonable. However, it also concluded that uncertainties in reactor protection system (RPS) reliability and mitigative capability warranted further attention to ensure the expected levels of safety are maintained.

The topical report contains three distinct aspects that required staff review. First, the calculation of a plant- and cycle-specific Unfavorable Exposure Time (UET) is essential in determining the percentage of the operating cycle that a plant is susceptible to ATWS-induced RCS pressure boundary failure and subsequent core damage. The UET is defined as the duration of the fuel cycle, for a specific plant configuration, for which the core reactivity feedback is insufficient to preclude exceeding a RCS pressure of 3200 psig following an ATWS event. This is essentially equivalent to the term unfavorable moderator temperature coefficient (MTC) used in the bases documentation of 10 CFR 50.62. Based on information presented in WCAP-15831-P, Revision 1, WOG plants that follow the proposed methodology would be designed such that they could achieve a zero percent UET every cycle. Secondly, the staff reviewed the Probabilistic Risk Assessment (PRA) analysis performed by the WOG. The WOG stated that its PRA analysis followed previously issued staff guidance from Regulatory Guide (RG) 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis", and RG 1.177, "An Approach for Plant-Specific, Risk-Informed Decisionmaking: Technical Specifications." The staff reviewed the topical report sections describing the PRA analysis to ensure that the analysis methodology and results complied with the previously-issued staff guidance. Finally, the staff reviewed the ATWS defense-in-depth mechanisms. The WOG's topical report requires that each licensee develop a plant-specific ATWS Configuration Management Program (CMP). The ATWS CMP will be updated every fuel cycle to ensure that ATWS mitigative equipment is not removed from service during periods where its inoperability would cause the plant to enter a UET.

Section 2.0 of this report describes the Regulatory Evaluation the staff performed including all applicable regulations, guidance documents, and reports. Section 3.0 of this report contains a detailed description of the Technical Evaluation the staff performed covering the areas of UET calculational methodology, PRA analysis, and defense-in-depth. Finally, Section 5.0 of this safety evaluation (SE) contains a detailed list of limitations and conditions that each licensee must satisfy, in addition to those identified in the topical report, prior to implementation of the WCAP-15831-P, Revision 1, methodology.

2.0 REGULATORY REQUIREMENTS

Section 50.62 of 10 CFR lists the NRC regulatory requirements to minimize the risk of an ATWS event for pressurized and boiling water reactors. For the Westinghouse plant design, 10 CFR 50.62 requires that each reactor "... have equipment from sensor output to final actuation device, that is diverse from the reactor trip system to automatically initiate the auxiliary (or emergency) feedwater system and initiate a turbine trip under conditions indicative of an ATWS." All Westinghouse plants installed ATWS Mitigation System Actuation Circuitry (AMSAC) systems to accomplish the regulatory requirements of 10 CFR 50.62. These systems reduced the risk from an ATWS to levels assumed during the development of the rule and ensured that key safety systems would respond automatically during an ATWS event. Topical report WCAP-15831-P, Revision 1, does not propose to change any of the requirements listed in 10 CFR 50.62. Instead, it provides a standard risk-informed methodology that all WOG plants can implement. This methodology can be used to ensure that future core and plant

design changes, licensing issues, and plant operability concerns are properly evaluated to minimize risk and maintain defense-in-depth.

Since the WOG's topical report does not propose any changes to the AMSAC systems, licensees who implement the topical report methodologies will continue to comply with 10 CFR 50.62. Therefore, the staff did not review the topical report against the requirements of the rule except to ensure that the methodology proposed would not alter the operation or availability of equipment that is part of the AMSAC system.

Regulatory Guide (RG) 1.174 provides decisionmaking guidance for proposed risk-informed license changes and RG 1.177 provides more specific guidance related to risk-informed technical specification (TS) changes. Although specific licensees that implement the WCAP-15831-P, Revision 1, methodology may or may not need to request specific TS changes, depending on their plant-specific licensing basis and TS, the three-tiered approach described in RG 1.177 is an acceptable approach for evaluating the implementation of the WCAP-15831-P, Revision 1, methodology.

RG 1.174 specifically states that a risk-informed license application should be evaluated to ensure that the proposed changes meet the following key principles:

- The proposed change(s) meets the current regulations, unless it explicitly relates to a requested exemption or rule change.
- The proposed change(s) is consistent with the defense-in-depth philosophy.
- The proposed change(s) maintains sufficient safety margins.
- When the proposed change(s) increases core damage frequency (CDF) or risk, the increase should be small and consistent with the Commission’s Safety Goal Policy Statement.
- The impact of the proposed change(s) should be monitored using performance measurement strategies.

RGs 1.174 and 1.177 provide more specific guidance and acceptance guidelines for assessing the nature and impact of licensing basis changes by considering engineering issues and applying risk insights. Specifically, for this application, the three-tiered approach described in RG 1.177 includes:

- Tier 1 evaluates the plant-specific risk associated with the proposed TS change, as shown by the change in CDF, change in large early release frequency (LERF), incremental conditional core damage probability (ICCDP), and incremental conditional large early release probability (ICLERP).
- Tier 2 identifies and evaluates, with respect to defense-in-depth, any potential risk-significant plant equipment outage configurations associated with the proposed change. The licensee should provide reasonable assurance that the risk-significant plant equipment outage configurations will not occur when equipment associated with this application is out of service.

- Tier 3 provides for the establishment of an overall ATWS configuration management program (CMP) and confirmation that its insights are incorporated into the decisionmaking process before taking equipment out of service before or during a UET period. Compared with Tier 2, Tier 3 provides additional coverage based on any other risk-significant configurations that may be encountered during maintenance and equipment outage scheduling over extended periods of plant operation.

RG 1.177 also describes acceptable implementation strategies and performance monitoring plans to help ensure that the assumptions and analysis used to support the implementation of the WCAP-15831-P, Revision 1, methodology will remain valid.

3.0 EVALUATION

In determining the acceptability of WCAP-15831-P, Revision 1, the staff reviewed the following three aspects of the topical report: 1) the calculation methodology used to determine cycle- and plant-specific UETs, 2) the PRA analysis employed to determine the overall change in risk of the proposed methodology, and 3) the defense-in-depth characteristics contained in the proposed ATWS CMP. For each part of the review, the staff evaluated whether the topical report's analyses and methodologies provided reasonable assurance that adequate protection, including safety margins, in accordance with NRC regulations and guidance documents, could be maintained upon implementation of the proposed methodology at the WOG plants.

3.1 Unfavorable Exposure Time Calculational Methodology

As previously stated, the UET is defined as the duration of the fuel cycle, for a specific plant configuration, for which the core reactivity feedback is insufficient to preclude exceeding a RCS pressure of 3200 psig following an ATWS event. The 3200 psig limit corresponds to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (BPV) Code Service Level C limit above which RCS piping failure is anticipated to occur. Since the UET represents plant conditions that result in susceptibility to ATWS-induced core damage, minimizing the existing UET at a plant can reduce risk. In 1983, the staff prepared SECY-83-293, "Amendments to 10 CFR 50 Related to Anticipated Transients Without Scram (ATWS) Events." In SECY-83-293, based on the operating conditions of that time, the staff concluded that an unfavorable MTC could exist for 10 percent of every cycle for non-turbine trip events and 1 percent of the cycle for turbine trip events. An unfavorable MTC is essentially identical to a UET in that it reflects portions of the operating cycle where the MTC is insufficiently negative to preclude the RCS from exceeding 3200 psig during an ATWS event. Westinghouse quantified the unfavorable MTC in its generic analysis documented in letter NS-TMA-2182, "ATWS Submittal." In its analysis, that was based on the 1979 plant operating and design data, Westinghouse determined that its plants would be more negative than -8 pcm/EF and -7 pcm/EF for 95 and 99 percent of the operating cycle, respectively.

In order to minimize the UET at operating nuclear facilities, it is necessary to have an approved methodology capable of evaluating core, operational, and design changes and their affects on the plant's UET. In WCAP-15831-P, Revision 1, the WOG presented a detailed methodology to perform deterministic analyses of plant UETs. The WOG's methodology focuses on the determination of the Critical Power Trajectories (CPTs) for specific plant configurations. The WOG used the LOFTRAN computer code to determine the ATWS plant conditions that would

result in a peak RCS pressure of 3200 psig. The variable conditions of significance to the resulting peak RCS pressure following the LONF and LOL ATWS events are total reactivity feedback (primarily MTC), primary-side pressure relief capacity, and auxiliary feedwater (AFW) capacity. For a given primary-side pressure relief configuration and AFW capacity, the reactivity feedback can be adjusted in the ATWS analysis until the peak RCS pressure during the specific ATWS event equals 3200 psig. At these specific reactivity feedback conditions, the change in power with increasing temperature represents the CPT. The heatup/shutdown characteristics of a given core at various times in the cycle can then be compared to the CPT to establish the UET for the given core at the specific plant configuration conditions.

The WOG's determination of the ATWS CPTs and resulting UETs was based primarily on plant design and operating conditions used in the 1979 generic ATWS analysis. For example, the ATWS CPTs presented in WCAP-15831-P, Revision 1, were generated based on the generic 4-Loop Westinghouse plant configuration with Model 51 steam generators. This is consistent with the generic case presented in NS-TMA-2182. However, the WOG did update some of the initial conditions and assumptions it used in WCAP-15831-P, Revision 1, to reflect current plant operating and design conditions. For example, to reflect uprated power conditions, the WOG used a Nuclear Steam Supply System power level of 3579 megawatts-thermal. Additionally, the WOG considered plant conditions such as three primary-side relief configurations (0 power-operated relief valves (PORVs), 1 PORV, 2 PORVs), two AFW capacities (full AFW, half AFW), and elevated inlet temperatures (i.e., > 600 EF). WCAP-15831-P, Revision 1, Tables 4-1 and 4-2 present the results of the WOG's generic analysis and determination of ATWS CPTs for the LONF and LOL events, respectively. Additionally, Tables 4-1 and 4-2 show the expected decreasing trend in ATWS CPTs as ATWS mitigation equipment is made unavailable (e.g., fewer PORVs, less AFW) or inlet temperature increases.

Once the CPTs are calculated for all the plant conditions previously described, the WOG's methodology employs the advanced nodal [computer] code (ANC) to determine the critical power as a function of inlet temperature at various cycle burnups. The WOG defines the "critical power" as the power that results in reactor criticality for a given set of conditions (e.g., inlet temperature, pressure, etc.). The methodology then compares these ANC critical power results to the ATWS CPTs. The time that the ANC calculated critical power is greater than the ATWS CPT represents the UET. Therefore, the WOG's methodology determines the times where specific plant conditions, such as operating with 1 PORV available and half AFW, would result in UET conditions. Tables 4-3 through 4-14 presented the WOG's calculated UETs for a myriad of plant operating and design conditions such as low, high, and bounding reactivity cores (i.e., increasing hot full power (HFP) MTCs), xenon concentration, and control rod insertion credit. Specifically, Table 4-8 presents the UET results of a high reactivity core model (i.e., HFP MTC < -5 pcm/EF) with equilibrium xenon and 1 minute of control rod insertion credit (i.e., 72 steps). The WOG considers these realistic design and operating conditions. Table 4-8 shows that for these initial conditions a Westinghouse plant can be designed to maintain a zero percent UET. Table 4-8 also shows that the unavailability of PORVs or less than full AFW capacity can result in considerable UETs. This demonstrates that UET conditions are highly sensitive to the initial conditions assumed in the analysis as well as the availability of ATWS mitigation equipment.

As previously stated, the WOG's methodology for determining the ATWS CPTs is based on plant design and operating data from its 1979 generic analyses, with limited updates to reflect current operating conditions and practices as well as plant design changes. Additionally, the

methodology presented in WCAP-15831-P, Revision 1, neither provides the specific details for some of the assumptions and initial conditions used in the determination of the ATWS CPTs nor does it provide sufficient detail to determine that these assumptions and conditions represent bounding conditions for Westinghouse plants that might adopt this methodology. As such, each licensee that adopts the methodology and begins using it for the determination of ATWS CPTs and plant UETs must input its own plant operating and design conditions. Since numerous advancements have occurred over the past 35 years (since the 1979 publication of NS-TMA-2182), it is possible that many of the assumptions used in WCAP-15831-P, Revision 1, may no longer represent bounding or limiting plant conditions for many licensees. Therefore, each licensee that adopts the methodology presented in WCAP-15831-P, Revision 1, must perform plant- and cycle-specific analyses based on current design and operating conditions. The staff expects that any licensee who adopts the WCAP-15831-P, Revision 1, methodology will submit, on a first-time-only basis, a plant-specific license application requesting to implement the methodology, including discussions of plant-specific procedures, compensatory measures, performance monitoring activities, and presenting the results of its analysis. This limitation is further explained in Section 5.0 of this SE.

3.2 Probabilistic Risk Assessment Analysis

While Section 3.1 addresses the deterministic calculational aspects of the methodology presented in WCAP-15831-P, Revision 1, this section addresses the probabilistic risk calculational aspects of the methodology. The WOG topical report provides in Chapters 5 and 8 of WCAP-15831-P, Revision 1, the general approach to the probabilistic risk analysis of the ATWS assessment and demonstrates the methodology for three types of core design:

- The WOG low reactivity core has a 5 percent UET for the ATWS Rule reference configuration of no control rod insertion (CRI), 100 percent AFW, and PORVs available. This core has the largest burnable absorber inventory and a maximum hot zero power (HZP) MTC of +3.5 pcm/EF.

- The WOG high reactivity core has excess reactivity between the low and bounding core designs. This core represents an aggressive, but realistic use of positive MTC TS with a most positive HZP MTC of +5 pcm/EF.

- The WOG bounding reactivity core was developed such that its most positive HZP MTC is +7 pcm/EF, which is consistent with the MTC TS for some plants. This core model was specifically developed to address ATWS performance of cores with minimum moderator temperature feedback.

The staff recognizes that the risk associated with ATWS events is driven by the probability that insufficient control rod insertion will occur. Given the multiple means of causing rod insertion, the failure probability is very low. However, if an ATWS event does occur and it occurs when the plant is operating in a UET condition, core damage is likely and there is also the potential for the event to directly result in a large release by failing steam generator (SG) tubes. Thus, the staff is concerned with associated defense-in-depth and safety margins, which are addressed in Section 3.3 of this SE.

The staff review of the probabilistic risk aspects of the WCAP-15831-P, Revision 1, methodology, determined that the methodology is appropriate for this application with the

conditions and limitations identified within Section 5.0 of this SE. The probabilistic considerations are described further below.

To implement the WCAP-15831-P, Revision 1, methodology, a licensee will need to submit a plant-specific license amendment to the NRC for its review and approval. In addition, as part of its implementation, licensees will need to re-perform these analyses for subsequent reloads to ensure that the results are acceptable. The probabilistic risk analyses will need to address all five operating states identified in the topical report for both CDF and LERF and will need to reflect the latest operational information (i.e., updated failure rates and operating conditions/positions of ATWS mitigating equipment) or provide a justification for why these analyses are not required for the specific core design.

The event tree end states presented in the topical report are appropriate for typical core design conditions, but may not accurately reflect all core design cases, especially the high reactivity or bounding reactivity core conditions. The event tree logic assumes 72 steps of control rod insertion occur even with rod drop failures (i.e., top events CRI and CR failures). This assumption provides some mitigation of the transient, though it may not completely shut down the plant, which is then addressed by the long-term shutdown (LTS) top event. The sequences that result in an end state designation of core damage due to long-term shutdown failure (CD-LTS) are assumed to have low RCS pressure. The licensee implementing this methodology will need to show for sequences that have an end state designated as CD-LTS, that 72 steps of insertion actually mitigate the transient for the specific plant and core design such that the pressure does not exceed 3200 psi. Otherwise, the licensee will need to assume these sequences create a high RCS pressure end state. In addition, sequences assumed to be successful mitigation may not actually avoid core damage, if the sequence of events still creates a UET condition. This is particularly true for the bounding reactivity core conditions. Thus, each licensee will need to evaluate and ensure the validity of the end state conditions for the specific core design utilized, including revising the event tree logic, end states, and results to reflect these logic modifications.

In calculating the impact on LERF, the topical report uses a pressure of 3584 psi, which is stated as the pressure at which SG tubes will fail. This pressure is greater than the ASME BPV Code Service Level C stress limit of 3200 psig that was used in the ATWS Rule and that is used in the topical report in assessing the impact on CDF. Since SG tube failure is one of the dominant contributors to LERF for pressurized water reactors, the staff accepts the use of the cited SG tube failure pressure in determining the impact on LERF. However, if there are indications that the SG tubes are susceptible to failure at a lower pressure, the licensee must use the lower pressure in determining these impacts and their acceptability. Further, in the analyses it was stated that although the increase in CDF met the acceptance guidelines of RG 1.174, the increase in LERF exceeded the acceptance guidelines if the UET was greater than 50 percent of the cycle. As such, when a licensee implements the WCAP-15831-P, Revision 1, methodology, the core design evaluation during the reload analyses must include the evaluation of the impacts on CDF and LERF and be shown to meet the RG 1.174 acceptance guidelines.

The staff agrees with the conclusion that although PORV availability may not be important for total CDF, as shown in the topical report, PORV availability can have a significant impact on ATWS CDF, especially during the worst time in the cycle. Since ICCDP and ICLERP are not expected to impact plant-specific decisionmaking (i.e., are expected to always meet the RG

1.177 acceptance guidelines due to the small contribution of ATWS to overall CDF and LERF, respectively), the calculations of ICCDP and ICLERP could be further simplified by setting the baseline CDF and baseline LERF, respectively, to zero.

The methodology is further demonstrated in Chapter 9 of WCAP-15831-P, Revision 1, using Braidwood as the demonstration plant. Although the information provided in Chapter 9 for Braidwood demonstrates the use of the methodology, the information is not sufficient to allow approval in this SE, especially given the conditions identified in Section 5.0 of this SE. Therefore, the Braidwood licensee will need to submit a plant-specific license amendment, consistent with this SE, to request to implement this methodology and remove the current restrictions in their TS.

Upon review of the probabilistic risk aspects of the WCAP-15831-P, Revision 1, methodology, the staff finds that the methodology is appropriate for this application with the conditions and limitations identified within this SE.

3.3 ATWS CMP

Regulatory Guide 1.174 lists five principles of risk-informed decisionmaking for the review of licensing basis changes. Two of those principles are that licensing basis changes must be consistent with the defense-in-depth philosophy and must maintain sufficient safety margins. In Section 7.0, "Configuration Management Program," of WCAP-15831-P, Revision 1, the WOG presented its methodology for ensuring adequate safety margins and defense-in-depth are maintained at Westinghouse plants for ATWS events.

The WOG stated in WCAP-15831-P, Revision 1, that the ATWS CMP will have the following five capabilities:

- Identify plant configurations (i.e., unfavorable configurations) that do not maintain defense-in-depth to an ATWS event.
- Track the time for individual occurrences when the plant is in an unfavorable plant configuration.
- Track the cumulative time per cycle when the plant is in an unfavorable plant configuration.
- Provide information on the length of time remaining in the UET for plant configurations.
- Provide compensatory actions to take if the unfavorable condition cannot be exited prior to expiration of the time allowed in the unfavorable configuration.

The staff reviewed the WCAP-15831-P, Revision 1, methodology for the development and implementation of an ATWS CMP to determine if it could maintain adequate safety margins, maintain defense-in-depth, and accomplish the five capabilities described.

3.3.1 Applicability of the ATWS CMP

In determining which plants would be required to implement the ATWS CMP, the WOG sorted the existing Westinghouse plants into the following three groups:

- Group 1: Plants with a Diverse Scram System (DSS)
- Group 2: Plants without a DSS, but are consistent with the ATWS rule (installed ATWS mitigating system actuation circuitry (AMSAC)) and the basis for the ATWS rule
- Group 3: Plants without a DSS, but are consistent with the ATWS rule (installed AMSAC) though not consistent with the basis for the ATWS rule

The WOG defined a plant as being consistent with the basis for the ATWS rule (Group 2) if it has either of the following:

- A core design limit on UET of less than 5 percent for the ATWS rule reference configuration of no control rod insertion, all AFW available, and no PORVs blocked, or
- A MTC of less than -8 pcm/EF for 95 percent of the cycle.

The WOG stated that plants in Groups 1 or 2 will not be required to implement the ATWS CMP. Plants in Group 3 would be required to implement the ATWS CMP. The staff agrees with the WOG's classification of the three groups; however, the staff does not agree with the designation of which plants are consistent with the basis of the ATWS rule (i.e., Group 2). The staff accepts that plants that meet a UET core design limit of less than 5 percent for the ATWS rule reference configuration of no control rod insertion, all AFW available, and no PORVs blocked should be considered consistent with the basis for the ATWS rule and should not be required to implement the ATWS CMP. However, the staff does not accept that a plant with an MTC of less than -8 pcm/EF for 95 percent of the cycle is consistent with the basis for the ATWS rule and should instead be considered part of Group 3. The staff has made this interpretation for the following two reasons. First, in SECY-83-293, the staff presented the NRC Commission with its analysis of the susceptibility of Westinghouse plants to an ATWS event. For non-turbine trip events, the staff assumed that the MTC was at an unfavorable value 10 percent of the time. For turbine trip events, the staff assumed that the MTC value was at an unfavorable value only 1 percent of the time. The WOG's value of -8 pcm/EF for 95 percent of the cycle resulted from its 1979 generic analyses presented in NS-TMA-2182. The staff, in its presentation of ATWS rule alternatives, SECY-83-293, did not provide this value to the NRC as part of the basis for the development and issuance of the ATWS rule. Secondly, the WOG's determination of the -8 pcm/EF MTC value is based on generic 1979 plant operating and design data. Changes in the design and operation of nuclear power plants over the last 25 years may result in this value being non-conservative when applied to currently operating plants. Additionally, future core design and operating conditions may make this rigid value incapable of ensuring acceptable UET limits are met. Since the WOG did not provide any supporting information in its topical report to demonstrate that this value remains bounding and conservative, the staff cannot accept that a plant that currently meets this limit is consistent with the basis for the ATWS rule. The staff has determined that UET limits are more appropriate than MTC limits for ensuring adequate safety margin and sufficient defense-in-depth. UET limits restrict the overall design and operation of the plant and reactor core to configurations that satisfy defense-in-depth requirements. A limit on MTC does not provide sufficient controls on ATWS mitigation equipment availability to ensure that current and future core designs

minimize UETs and maintain sufficient defense-in-depth. Therefore, the staff limits its approval of the classification of plants as being consistent with the basis for the ATWS rule (Group 2) to those who meet the former requirement only. This limitation is listed in Section 5.0 of this SE.

3.3.2 Development of the ATWS CMP

In Section 7.2.3, "Core Design Considerations," the WOG states that the primary approach of WCAP-15831-P, Revision 1, to maintain defense-in-depth, or ATWS pressure transient mitigation capability, is to operate each plant in a configuration with a zero percent UET. A plant designed and operated with a zero percent UET will maintain sufficient defense-in-depth during an ATWS event to prevent the peak RCS pressure from reaching the 3200 psig limit. The determination of a reference-case UET that has a zero percent UET condition is highly dependent on the initial core design conditions and assumptions. A licensee that adopts this ATWS risk-informed methodology must demonstrate in its reload analysis that it will have a zero percent UET at the most limiting point in the cycle based on the following reference-case conditions:

1) Hot full power moderator temperature coefficient,
2) Equilibrium xenon,
3) Nominal hot full power inlet temperature,
4) 72 steps of control rod insertion of the lead bank,
5) All PORVs operable,
6) 100 percent (all) AFW flow available.

Since the determination of a zero percent UET for each cycle is a crucial aspect of the topical report's defense-in-depth methodology, the staff considers this an important limitation and condition of its approval of WCAP-15831-P, Revision 1. Therefore, the determination of a plant- and cycle-specific zero percent UET based on the reference conditions listed above is included as a limitation in Section 5.0 of this SE.

Seventy-two steps of control rod insertion (CRI) credit is a pivotal assumption in the design and operation of every cycle with a zero percent UET. The 72 steps of CRI credit provides considerable negative reactivity feedback during the initial minute of an ATWS event. This negative reactivity feedback limits the peak RCS pressure attained during the event. Typically, the staff does not credit the operation of the rod control system during accident conditions because it is a "control" system. However, since ATWS is a beyond design basis accident that has an extremely low probability of occurrence, credit for CRI is potentially acceptable for mitigation and defense-in-depth purposes. In order for CRI credit to be acceptable, the system reliability must be demonstrated to be sufficiently high such that it can be reasonably expected to operate as credited under conditions indicative of an ATWS. The WOG presented information to support the conclusion that the rod control system is highly reliable. The WOG's information represented a general data collection spanning all Westinghouse plants. The staff expects that the reliability of the rod control system can vary from one plant to another. Therefore, the staff requires that a licensee that adopts the methodology provided in WCAP-15831-P, Revision 1, must provide sufficient plant-specific data to demonstrate that the rod control system at its facility is highly reliable and should be expected to operate as required under conditions indicative of an ATWS. This limitation is listed in Section 5.0 of this SE.

The remaining conditions defined in the reference-case UET reflect optimal plant conditions for ATWS mitigation. However, numerous operating conditions such as required preventive maintenance and surveillance testing can result in the necessary removal of vital ATWS mitigation equipment from service to ensure continued reliability. The removal of this equipment from service can adversely affect the UET of the plant. Since ATWS is a low risk event and much of this mitigative equipment is credited for the defense-in-depth of design basis accidents that have a higher risk, it is appropriate to perform all essential maintenance and surveillance requirements on ATWS mitigation equipment to ensure it remains operable and capable of performing its safety function.

Controlling when the preventive maintenance and surveillance testing is performed can limit the effects on the UET and reduce the overall risk to the plant while maintaining adequate defense-in-depth capabilities. To accomplish this, WCAP-15831-P, Revision 1, provides a methodology for the development and implementation of a plant- and cycle-specific ATWS CMP. Based on the methodology described in WCAP-15831-P, Revision 1, for calculating CPTs and UETs, a licensee can determine specific time intervals, based on effective full power days of operation, during each cycle where the removal of ATWS mitigation equipment from service would cause the plant to enter a UET period. Following the methodology outlined in the topical report, licensees can chart these specific time periods and ensure that during these periods they limit the unavailability of the systems important to ATWS event mitigation. Specific precautionary actions during such times may include the following: 1) operate with the rod control system in the automatic mode; 2) limit blocking pressurizer PORVs; and 3) limit activities on the AFW system, AMSAC, and RPS that result in the unavailability of components within these systems. Since the CPT and UET determinations presented in WCAP-15831-P, Revision 1, reflect moderately updated 1979 generic analyses and therefore are not necessarily bounding, each licensee will be required to develop its own plant- and cycle-specific ATWS CMP.

The staff agrees that the completion of surveillance requirements is essential for ensuring the reliability of mitigative equipment for design basis accidents. However, surveillance completion that results in entry into a UET cannot be ignored because of its adverse effects on defense-in-depth. The WOG proposed that time intervals for completing surveillance requirements, irrespective of the length, should not count against the allowed cumulative UET permitted for each cycle. The staff instead believes that a cap on the amount of time permitted, for tracking and monitoring purposes only, for individual surveillances is necessary and appropriate to maintain adequate defense-in-depth. A cap limits the potential that licensees will spend excessive periods of time in a UET completing an individual surveillance requirement and places emphasis on proper planning and timely completion for surveillance activities. Based on information presented by the WOG, the majority of surveillance requirements that could result in a plant entering a UET condition can be completed in significantly less than 24 hours. Therefore, the staff has determined that a 24-hour limit on the completion of surveillance requirements that result in UET conditions is reasonable. This provides licensees adequate time to complete required surveillance activities, yet provides reasonable controls and limits on remaining in a UET due to a surveillance requirement. Therefore, any entry into a surveillance that requires greater than 24 hours to complete must be tracked and counted, in its entirety, against the licensee's allowed 30-day cumulative UET. This limitation does not authorize a licensee to forego a surveillance requirement because its performance would count against the allowed 30-day cumulative UET. Instead, this limitation places appropriate

emphasis on proper planning and timely completion of surveillance requirements that result in entries into a UET condition. This limitation is listed in Section 5.0 of this SE.

In its probabilistic assessment presented in WCAP-15831-P, Revision 1, the WOG states that part-power conditions (i.e.,< 100 percent rated thermal power) have a low contribution to the overall risk for ATWS events. Because of the low calculated risk from part-power conditions, the WOG's ATWS CMP focuses solely on ATWS events initiated from HFP conditions when all of the reference-case mitigative equipment is available. Tables 4-24 through 4-28 of the topical report present the results of limited UET analyses performed at part-power conditions. The results demonstrate that the UET at part-power conditions is highly dependent on the xenon concentration in the core. Additionally, at lower power levels, the MTC will be more positive, resulting in less inherent reactivity feedback and potentially higher peak RCS pressures during an ATWS event. Because of the calculated low risk from part-power conditions, the WOG did not address the need for mitigative capabilities at part-power conditions in its topical report. Therefore, since WCAP-15831-P, Revision 1, does not present sufficient information to demonstrate that defense-in-depth will be maintained at part-power conditions, the staff has determined that a licensee that adopts the WCAP-15831-P, Revision 1, methodology must treat all part-power operating conditions as counting against the allowed cumulative UET for that cycle. Additionally, since the risk associated with operating in a part-power UET condition is independent of the plant-power level (i.e., a 50 percent power UET condition poses the same risk as a 75 percent power UET condition), the licensee must track time spent in a part-power UET condition based on the actual time and not the effective full power days (EFPDs) of operation. Finally, the licensee must cumulatively count this actual time spent operating at part-power conditions against its allowed 30-day cumulative UET. This limitation is listed in Section 5.0 of this SE.

3.3.3 Compensatory Actions for the ATWS CMP

As part of its CMP, the WOG recognized and the staff concurs that, despite designing each cycle for a reference-case zero percent UET, the potential exists for a plant to enter a UET due to unforeseen operating conditions or maintenance activities. A licensee is able to identify whether it will enter a UET by comparing its current plant operating conditions and equipment availability to its CMP. The WOG proposed multiple compensatory actions that licensees can implement to restore defense-in-depth capabilities during the UET period. Three actions include the following: 1) implementing a back-up reactor trip capability; 2) performing a UET re-calculation; and 3) initiating a power reduction. Implementing any one or more of these actions may further reduce the potential for an ATWS event and could potentially extricate the plant from the UET condition and restore adequate ATWS mitigative capability and defense-in-depth. Additionally, since ATWS is a low-probability event, the WOG proposed a cumulative time allowed in an unfavorable configuration prior to implementing the aforementioned compensatory actions.

The first compensatory action involves an alternate reactor trip method based on removing power to the control rod drive mechanisms (CRDMs). Two potential methods exist for an operator to initiate a backup reactor trip: 1) the operator interrupts power to the motor generator (MG) sets of the CRDMs or 2) the operator interrupts power from the MG sets to the CRDMs.

When power is interrupted to the MG sets a long coastdown may occur. This coastdown occurs as the MG slows to a speed at which the voltage degrades to a level such that the

CRDMs release the control rods. According to the WOG's initial analysis, a coastdown to the required "reactor trip speed" could exceed 30 seconds. The WOG's analyses showed that it would take the limiting ATWS event only approximately 90 seconds to reach the 3200 psig limit. Therefore, a licensee that intends to implement a backup reactor trip that relies on de-energizing power to the MG sets must demonstrate that sufficient time exists for the operators to diagnose the event, interrupt power to the MG sets, and allow the MG sets to coastdown such that the 3200 psig limit is not reached.

Another alternate reactor trip method is to remove power from the MG sets to the CRDMs. Removing power directly from the MG sets to the CRDMs would provide a nearly instantaneous de-energization of the CRDMs and, therefore, preclude the coastdown concerns described for the previous method. This method would involve installing equipment that would provide an undervoltage trip of the MG set breakers, located on the output of the MG sets, based on an undervoltage signal from the buses that power the MG sets. This setup is similar, but not identical, to the diverse scram system (DSS) installed at some Westinghouse plants and all other pressurized water reactors (as required by 10 CFR 50.62). The major difference between this approach and an installed DSS is the dependence on operator action to initiate the backup trip. As proposed by the WOG in WCAP-15831-P, Revision 1, this action could be taken by operators located either in the control room, with the appropriate equipment installed, or by a dedicated operator at the MG sets if an unfavorable configuration exists.

The reliance on operator action to initiate a backup trip raises human factor and defense-in-depth concerns, not addressed in WCAP-15831-P, Revision 1, due to the short duration available to the operators to diagnose the event and initiate the action. In particular, the staff is concerned with relying on operator actions outside the control room and believes such reliance is not consistent with the defense-in-depth philosophy presented in RG 1.174, one element of which states “Over-reliance on programmatic activities to compensate for weaknesses in plant design is avoided.” A licensee that implements the WCAP-15831-P, Revision 1, methodology must address the human factor and defense-in-depth concerns related to reliance on operator actions to implement either of the proposed backup reactor trip compensatory actions. The licensee must demonstrate that the relied upon actions are consistent with the defense-in-depth philosophy and that the operators will have sufficient time and training to diagnose an ATWS event and take appropriate actions to implement the backup reactor trip such that the 3200 psig limit is not reached. This limitation is listed in Section 5.0 of this SE.

Additional compensatory actions include UET re-calculation and power reduction. As stated by the WOG, a re-calculation of UETs can be done based on plant-specific information using analysis enhancements that may provide a shorter estimate of UETs. For example, a licensee may have conservatively used in its original analysis the generic rated thermal power from WCAP-15831-P, Revision 1, which is greater than its current operating conditions. That licensee could perform new UET analyses at its licensed rated thermal power level and likely identify shorter UET intervals. Likewise, a licensee may take compensatory actions to reduce power to levels where the RCS pressures following an ATWS event can be mitigated with reduced pressure relief capacity. However, detailed CPT and UET analyses, performed in accordance with the WCAP-15831-P, Revision 1, methodology, would be required for lower power levels to determine the power reduction necessary to eliminate the UET under all potential operating configurations at the reduced power level. Assuming an acceptable power level could be determined, the licensee could then operate at the reduced power level until the configuration becomes favorable as the time into the cycle increases.

As part of the development and implementation of the ATWS CMP, the WOG proposed a 30-day cumulative time limit in an unfavorable condition. The WOG stated that this 30-day limit would provide sufficient time for the licensee to exit the unfavorable configuration or implement the appropriate compensatory actions. The staff considers a 30-day cumulative limit acceptable because it correlates well to a 5 percent UET, which was reviewed and approved for the Byron and Braidwood stations. Additionally, in the development of the ATWS rule (10 CFR 50.62) the staff accepted that there would be limited periods of time where unfavorable plant conditions existed and that this was acceptable due to the low probability of an ATWS event. This acceptance was accounted for in the development of the ATWS rule, as well as the classification of an ATWS as a beyond-design-basis event.

As described above, the topical report identifies three types of compensatory actions licensees may implement if the 30-day cumulative limit on UET is reached. These actions range from analytical approaches (i.e., re-analysis UET conditions for the specific cycle to show the 30-day cumulative limit is not reached), to reliance on operator actions (i.e., interrupt power to the MG sets or interrupt power directly to the CRDMs), to power level reductions (i.e., lower power to a level such that a UET is reduced or eliminated). The staff recognizes that these actions are not equally effective in mitigating an ATWS. Therefore, licensees must describe the compensatory actions they will implement through plant-specific procedures and under what plant conditions these compensatory actions will be implemented.

4.0 CONCLUSIONS

The NRC staff reviewed the analyses and methodologies presented in WCAP-15831-P, Revision 1, and determined that they were developed in accordance with published NRC guidance documents. The staff found that the ATWS risk-informed methodology would minimize the risk from an ATWS event while maintaining adequate safety margins and ensuring defense-in-depth is maintained. Therefore, the staff finds the WCAP-15831-P, Revision 1, methodology acceptable for use in license applications requesting to implement the methodology for performing a risk-informed analysis of ATWS events and developing an effective ATWS CMP at WOG plants. The staff's approval is subject to the limitations and conditions set forth in Section 5.0 of this SE.

5.0 LIMITATIONS AND CONDITIONS

WCAP-15831-P, Revision 1, is based on generic analyses. In many cases, the topical report identifies the need for conditions to be addressed on a plant-specific basis. In addition to these recognized conditions in WCAP-15831-P, Revision 1, the staff's approval is subject to the following limitations and conditions:

1. A licensee that implements WCAP-15831-P, Revision 1, is required, as part of each cycle's reload analysis, to verify that its core is designed for a zero percent UET at the most limiting point in the cycle based on the following reference-case conditions:

   a. Hot full-power moderator temperature coefficient,
   b. Equilibrium xenon,
   c. Nominal hot full-power inlet temperature,

d. 72 steps of control rod insertion of the lead bank,
e. All PORVs operable,
f. All AFW flow available.

2. A plant may only be considered consistent with the basis for the ATWS rule (i.e., Group 2) if its cycle-specific reload analysis demonstrates that its UET is less than 5 percent for the ATWS rule reference configuration of no control rod insertion, no PORVs blocked, and all AFW available.

3. A plant that implements the WCAP-15831-P, Revision 1, methodology must submit a plant-specific implementation license amendment to the NRC for its review and approval prior to first implementing this approach. The license amendment must include discussions of plant-specific procedures, compensatory measures, plant- and cycle-specific calculations, and performance monitoring activities that will be utilized in implementing the WCAP-15831-P, Revision 1, methodology. The amendment must also contain the following plant- and cycle-specific information for the current plant design and operating conditions:

   a. The results of its CPT and UET calculations for the reference-case conditions showing that the plant is designed and can be operated with a zero percent UET for the upcoming cycle.

   b. The plant- and cycle-specific ATWS CMP demonstrating that ATWS mitigation equipment will be available and capable of performing its defense-in-depth function during intervals when its unavailability would result in a UET condition.

   c. An analysis of the minimum time to the 3200 psig limit under the most limiting operating conditions. The licensee must define its most limiting ATWS mitigation conditions (i.e., manual rod control, no PORVs, half AFW, etc.) and provide a basis for why these represent the most limiting conditions for its plant.

   d. A plant-specific list of proceduralized compensatory actions the licensee will take to further reduce the risk associated with a UET condition should it reach the 30-day cumulative limit on UET including a description of the specific conditions under which each of the various compensatory actions will be implemented.

   e. If the compensatory actions proposed include installation of a backup reactor trip, or any other action that requires a rapid response by operations personnel, the licensee must sufficiently address human factor concerns regarding the ability of the operators to diagnose the event and take appropriate actions such that the 3200 psig limit is not reached. This evaluation must include a determination that any credited operator action is highly reliable considering operational/environmental factors and is consistent with the defense-in-depth philosophy presented in RG 1.174, especially when crediting local (non-control room) operator actions and the extremely limited time available to perform these actions.

f. A plant-specific analysis of the rod control system that demonstrates that it has a high degree of reliability and would be expected to operate as required under conditions indicative of an ATWS.

g. A plant-specific risk analysis, similar to the generic analyses presented in WCAP-15831-P, Revision 1, addressing the risks for all five operating states.

h. A description of the analyses and controls (procedures) that will be implemented during each cycle's reload analysis to ensure the licensee's results are consistent with the methodology approved by the staff.

4. The time a plant spends in an unfavorable configuration due to the completion of a surveillance requirement does not need to be tracked as part of the plant's 30-day cumulative UET unless the time required to complete any individual surveillance exceeds 24 hours. Should the time necessary to complete any individual surveillance, which results in a UET condition, exceed 24 hours the licensee must count that time, in its entirety, against its allowed 30-day cumulative UET limit.

5. The UET at part-power conditions is highly dependent on the xenon concentration in the core. Additionally, at lower power levels, the MTC can be more positive, resulting in less inherent reactivity feedback and potentially higher peak RCS pressures during an ATWS event. Therefore, licensees must track and count all part-power operating conditions that create a UET against the allowed 30-day cumulative UET for that cycle. Additionally, since the risk associated with operating in a part-power UET condition is independent of the plant-power level (i.e., a 50 percent power UET condition poses the same risk as a 75 percent power UET condition), the licensee must track time spent in a part-power UET condition based on the actual time and not the EFPDs of operation.

6. The event tree end states presented in the topical report are appropriate for typical core design conditions, but may not accurately reflect all core design cases, especially the high reactivity or bounding reactivity core conditions. The event tree logic assumes 72 steps of control rod insertion occurs even with rod drop failures (i.e., top events CRI and CR failures). This assumption provides some mitigation of the transient, though it may not completely shutdown the plant, which is then addressed by the LTS top event. The sequences that result in an end state designation of core damage due to long-term shut down failure (CD-LTS) are assumed to have low RCS pressure. The licensee implementing this methodology will need to show, for sequences that have an end state designated as CD-LTS, that 72 steps of insertion actually mitigate the transient for the specific plant and core design such that the pressure does not exceed 3200 psi. Otherwise, the licensee will need to assume these sequences create a high RCS pressure end state. In addition, sequences assumed to be successful mitigated may not actually avoid core damage, if the sequence of events still creates a UET condition. This is particularly true for the bounding reactivity core conditions. Thus, each licensee will need to evaluate and ensure the validity of the end state conditions for the specific core design utilized, including revising the event tree logic, end states, and results to reflect these logic modifications.

7. In calculating the impact on LERF, the topical report uses a pressure of 3584 psi, which is stated as the pressure at which SG tubes will fail. This pressure is greater than the

ASME BPV Code Service Level C stress limit of 3200 psig that was used in the ATWS Rule and that is used in the topical report in assessing the impact on CDF. Since SG tube failure is one of the dominant contributors to LERF for pressurized water reactors, if there are indications that the SG tubes are susceptible to failure at a lower pressure, the licensee must use the lower pressure in determining the impact on LERF.

8. In the topical report analyses, it was stated that although the increase in CDF met the acceptance guidelines of RG 1.174, the increase in LERF exceeded the acceptance guidelines if the UET was greater than 50 percent of the cycle. As such, when a licensee implements the WCAP-15831-P, Revision 1, methodology, the core design evaluation during the reload analyses must include the evaluation of the impacts on CDF and LERF and be shown to meet the RG 1.174 acceptance guidelines.

9. The WOG's analyses showed that it would take the limiting ATWS event only approximately 90 seconds to reach the 3200 psig limit. Therefore, a licensee that intends to implement a backup reactor trip that relies on de-energizing power to the MG sets must demonstrate that sufficient time exists for the operators to diagnose the event, interrupt power to the MG sets, and allow the MG sets to coastdown such that the 3200 psig limit is not reached.

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