BAW-2295, Revision 1
Topical Report
October 1997

THE B&W *OWNERS GROUP*

Regulatory Reduction Working Group

Justification for Extension of Allowed Outage Time for Low Pressure Injection and Reactor Building Spray Systems

FRAMATOME
TECHNOLOGIES

BAW-2295, Rev. 1
Topical Report
October 1997

Justification for Extension of Allowed Outage Time for Low Pressure Injection and Reactor Building Spray Systems

Prepared for the B&W Owners Group
Regulatory Reduction Working Group

by:

the B&W Owners Group
Risk-Based Applications Working Group

R. E. Harris (Entergy)
H. D. Brewer (Duke Power)
M. W. Averett (Florida Power)
K. W. Byrd (Toledo Edison)
C. D. Adams/H. A. Elrada (GPUN)
D. J. Firth (Framatome Technologies)

and
Framatome Technologies
R. S. Enzinna
S. H. Levinson

3315 Old Forest Road
Lynchburg, VA 24501

Executive Summary

This report presents the technical justification for increasing the "ECCS Operating" Technical Specification allowable outage time (AOT) for one inoperable train of Low Pressure Injection (LPI) and the AOT for one inoperable train of Reactor Building Spray (RBS). LPI is an emergency operating mode of the Decay Heat Removal (DHR) system. The proposed AOT extension to 168 hours (seven days) will allow meaningful maintenance of the DHR system to be performed at power. The RBS is included because LPI and RBS share common suction piping from the borated water storage tank (BWST) and the reactor building emergency sump, and some LPI train maintenance impacts the operability of the corresponding train of RBS.

This report provides technical support for the proposed AOT extension, which the B&WOG believes is sufficient to allow the NRC to approve the proposed request. The report contains a generic methodology framework that includes: discussion of the need for an AOT extension, establishing the applicability of the plant-specific probabilistic risk assessments (PRAs) to the evaluation, choice and use of PRA figures of merit, and common reporting format to ensure consistency of form and content. The individual B&WOG utilities, under the guidance of the respective B&WOG Risk-Based Applications Working Group (RBAWG) members, have performed the plant-specific analyses using their PRAs. They have assessed the risk impact, as measured by change in core damage frequency (CDF) and large early release frequency (LERF), of increased maintenance unavailability at power for DHR (which includes LPI mode) and RBS systems, which is estimated to occur due to the proposed AOT.

A summary of the plant-specific results in terms of the expected increase in CDF as a result of the extended AOT is provided in the following table. Additional results, which are provided later in the report, include a sensitivity analysis performed using the full AOT that demonstrates robustness of the conclusions in light of variability in the actual maintenance duration. The results show that the proposed increase in the AOTs is not risk-significant. Supporting qualitative arguments are presented as well, including the benefits of the proposed AOT extension, such as increased flexibility to repair equipment and improved DHR system availability during shutdown operating modes.

Considering the potential benefits, the B&WOG feels that extending the AOT for LPI and RBS to 168 hours (seven days) enhances safety, and is therefore an appropriate change to the Technical Specifications.

Incremental Core Damage Frequency (CDF) for the LPI and RBS AOT Extensions (per reactor-year)				
ANO-1	**CR-3**	**DB-1**	**Oconee**	**TMI-1**
3.7×10^{-7}	4.4×10^{-7}	2.0×10^{-6}	2×10^{-7}	5.2×10^{-6}

Table of Contents

Tables

1.0 Introduction

The B&W Owners Group (B&WOG) has successfully used risk-based arguments in the past to justify changes to the Technical Specifications. Specific examples include test interval and allowed outage time (AOT) relaxation in the Reactor Trip System [1], and test interval relaxation in the Engineered Safeguards Actuation Systems [2]. Individual B&WOG utilities have also used their probabilistic risk assessments (PRAs) to justify Technical Specification changes on a plant-specific basis (see Section 3.2.1).

Other industry groups have also used PRAs to justify Technical Specification changes; some of these efforts, and guidance derived from them, are discussed in NUREG/CR-6141 [3]. More recently, the members of the Combustion Engineering Owners Group (CEOG) have collectively used their plant-specific PRAs to evaluate Technical Specifications changes. One of these CEOG efforts was for the Low Pressure Safety Injection (LPSI) system [4]. Recently-published EPRI guidance [5] is based on this CEOG experience. The B&WOG has followed the precedent set by these industry efforts and has developed this report, which documents a joint effort by the B&WOG members to justify Technical Specification changes based on application of their plant-specific PRAs.

The objective of this report is to present technical justification for increasing the "ECCS Operating" Technical Specification AOT for one inoperable train of Low Pressure Injection (LPI) and one inoperable train of Reactor Building Spray (RBS). In the B&W plant design, the Decay Heat Removal (DHR) and LPI systems are combined and share many components. The proposed AOT extension will allow meaningful DHR/LPI system maintenance to be performed at power. The maintenance to be performed at power includes both corrective maintenance (CM), and voluntary entry into a limiting condition of operation (LCO) for preventive maintenance (PM) and testing.

The AOT extension for RBS is included because the LPI and RBS share common suction piping from the borated water storage tank (BWST) and the reactor building emergency sump, and some LPI train maintenance impacts the operability of the corresponding train of RBS.

The approach of this report uses plant-specific PRAs to assess the risk-impact of increased DHR/LPI and RBS maintenance unavailability at power. This document provides a generic framework for the analysis and provides the results of each utility's analysis in a consistent format. The B&WOG utilities, under the guidance of the respective Risk-Based Applications Working Group (RBAWG) members, have performed the plant-specific analyses using their PRAs.

The technical elements that comprise the case for technical justification of the extended AOTs are summarized below. These include the compilation and documentation of specific items of information that the B&WOG believes is necessary to allow the NRC to approve the proposed request.

The scope and format of the information provided in this report were determined by consensus of the B&WOG Risk-Based Applications Working Group (RBAWG) to ensure that the results of the plant-specific analyses are consistent in format and content. Section 2 provides a brief system description, review of the applicable Technical Specifications, a discussion of the need for an extension of the AOT. and an assessment of the impact upon deteministic factors. In Section 3, common ground rules, assumptions, and the framework of the risk analysis methodology are developed: applicability of the utility-specific PRAs, the scope of the analysis, risk management controls for on-line maintenance, and the choice and use of PRA figures of merit. Section 4 contains a compilation of the quantitative results, including plant-specific PRA figures-of-merit, and offers some supporting qualitative arguments. Also included is a discussion of some real but unquantifiable benefits of the proposed AOT extension. Section 5 provides the B&WOG's conclusions and a summary of the technical support for the proposed AOT extension.

2.0 Traditional Engineering Evaluation

2.1 System Description

Low Pressure Injection (LPI) is an emergency operating mode of the Decay Heat Removal (DHR) system. In the B&W plant design, the DHR system and LPI are combined and share most components, including pumps, valves and piping. LPI is a portion of the Emergency Core Cooling System (ECCS) function and provides cooling water directly to the reactor after large- and intermediate-size loss of coolant accidents (LOCAs). The DHR system is a high-capacity, low-head system with appropriate separation and a sufficient number of components to provide two-train redundancy for the safeguards mode of operation. It includes two low-pressure centrifugal pumps that are normally available and aligned for operation[1]. The function of LPI is to flood the core with borated water immediately following a LOCA to prevent a significant amount of cladding failure along with subsequent release of fission products into the containment. It also provides for the removal of heat from the core for extended periods of time following a LOCA. Each train of LPI is automatically actuated via engineered safeguards signals upon low Reactor Coolant System (RCS) pressure or high reactor building pressure.

The Reactor Building Spray (RBS) system directs borated water spray into the containment following a LOCA. The RBS system has the functions of removing heat and fission products from the post-accident containment atmosphere. The system consists of two pumps, two spray headers, and necessary piping, valves, instrumentation, and controls. Each train of the RBS system is automatically actuated via engineered safeguards signals, such as high-high reactor building pressure.

The borated water storage tank (BWST) contains boron in solution and provides suction for LPI and RBS, as well as borated water for the other engineered safeguards systems (e.g., High

---

[1]The Oconee plants have a third non safety-related LPI pump that is not credited in accident analyses.

Pressure Injection). The BWST also provides water for filling the fuel transfer canal during refueling.

LPI and RBS can also draw suction from the reactor building sump for coolant recirculation. When the water in the BWST reaches a low level during the injection mode, the recirculation mode is initiated by realigning the LPI/RBS pump suctions from the BWST to the reactor building emergency sump. Each LPI train shares common suction piping with its corresponding RBS train.

In recirculation mode, the LPI pumps also provide suction for the High Pressure Injection (HPI) pumps, if they are needed; this is called "piggy back" mode, and is used for certain small LOCAs where the recirculation mode occurs at higher RCS pressures.

The DHR system also has non-emergency functions. In the DHR mode, it is used to remove decay heat during shutdown and refueling operations. The DHR system takes suction from the RCS hot leg and returns it back to the RCS after passing it through a DHR cooler in each train. The DHR system can also be used as a backup system for spent fuel pool cooling.

Each plant's DHR/LPI and RBS systems are checked periodically for leakage and/or obstruction, and equipment performance is tested on a regular basis. Tests include pump performance, and valve operability and performance.

2.2 Technical Specification Summary

The relevant portion of the Technical Specifications for this request is the portion of the "ECCS Operating" Technical Specifications pertaining to the AOT for one inoperable train of LPI. The Technical Specifications require that two trains of LPI be operable. They allow one train of LPI to be inoperable if it is restored to operable status within the specified AOT. For the B&WOG plants, this AOT varies from 24 hours (ANO-1) to 72 hours (Crystal River-3, Davis-Besse, Oconee-1,2,3, TMI-1). The B&W plant Improved Standard Technical Specifications [6] also have an AOT of 72 hours. After expiration of the AOT, the Technical Specifications require that the reactor be shutdown in a timely manner. **It is proposed that the AOT for one inoperable train of LPI be extended to seven days (168 hours).**

The operability of one train of RBS is sometimes impacted by LPI train maintenance due to the common suction piping. The current AOT for one inoperable RBS train allows a maintenance outage of a duration at least as long as the corresponding LPI train. This relationship should be maintained so that LPI maintenance will not be limited by the RBS AOT, and so there will continue to be flexibility for scheduling concurrent train outages of LPI and RBS. **It is proposed that the AOT for one inoperable train of RBS be extended to seven days (168 hours).**

An extension of the AOT for HPI is not requested at this time. While some plants' Technical Specifications have the AOT for the inoperable LPI train specified separately, other plants' Technical Specifications specify a single AOT for one inoperable "ECCS" train (i.e., combining LPI with HPI). Therefore, in the latter case, the LPI AOT will be split out from the ECCS AOT, that is, using the proposed seven-day AOT for LPI and retaining the current (e.g., 72-hour) AOT for an inoperable HPI train. The seven-day AOT will apply when a DHR/LPI train is the sole reason for the inoperability of the HPI train (i.e., high-pressure recirculation "piggy back" mode affected).

The requested AOT extension does not impact any other Technical Specification limits except as noted[2].

---

[2]For Crystal River-3, maintenance is performed on a "train outage" basis, which combines the outage of an LPI (ECCS) train with outage of the corresponding train of RBS, and the corresponding trains of their plant-specific support systems. This includes Decay Heat Closed Cycle Cooling and Decay Heat Seawater. These systems provide cooling for DHR and RBS pumps, and redundant cooling for two of the makeup pumps. Concurrent maintenance of the LPI (ECCS) and RBS trains with their support system trains is a method by which the operators at Crystal River-3 minimize the risk exposure for maintenance outages. Hence for Crystal River-3, it is also be proposed that the AOT for one inoperable train of Decay Heat Closed Cycle Cooling and Decay Heat Seawater Systems be extended from 72 hours to seven days (168 hours). The incremental risk calculations contained herein for Crystal River-3 include the effect of extension of the AOT for these systems to seven days.

2.3 The Need for an Increased AOT

The proposed changes to the Technical Specifications are needed by the utilities to improve plant operation. While the proposed AOT extension represents a minimal impact on safety at power, it allows utilities considerably more latitude in maintenance scheduling. The relaxed AOT limits will allow more significant maintenance to be performed on-line, and free up resources during refueling outages when the DHR system is the primary source of cooling. This section presents a general discussion of the types of maintenance activities that can be performed at power on the DHR/LPI system with an increased AOT.

The utilities performed a survey of the on-line maintenance that may be involved if the LPI AOT was extended to seven days, and what systems/functions are impacted by the AOT entry. Some maintenance outages of LPI have an effect upon RBS operability, because of isolation of common piping.

The AOT extension for RBS is needed because LPI and RBS share common suction piping from the borated water storage tank (BWST) and the reactor building emergency sump, and some LPI train maintenance impacts the operability of the corresponding train of RBS. The current AOT for one inoperable RBS train allows a maintenance outage of a duration at least as long as the corresponding LPI train. This relationship should be maintained so that LPI maintenance will not be limited by the RBS AOT, and so there will continue to be flexibility for scheduling concurrent train outages of LPI and RBS.

Concurrent maintenance of the LPI train with the dependent RBS train is also a method by which the operators can minimize the overall risk exposure for maintenance outages. Risk management controls (discussed further in Sections 3.3 and 3.4), provide assurance that simultaneous maintenance outages in same-train equipment will not lead to unforeseen risk.

To quantify the likely maintenance unavailability that would result from the proposed AOT, the following approach was taken: The plant-specific tagout configurations/system lineups required for on-line maintenance were reviewed. This review included impacts of the maintenance tagout, if any, on other "safety" functions (whether or not in Technical Specifications). This information was used to establish the relationship of the proposed maintenance changes to the probabilistic risk assessment (PRA) models (see Section 3).

In performing this analysis, each utility has reviewed the tagout configurations of maintenance that affects operability of one "train" of the LPI and/or RBS "subsystems" of ECCS. Maintenance that causes redundant trains to be inoperable (e.g., BWST), or does not cause train inoperability, was not a candidate. Each utility then made an estimate of the maintenance activities that would potentially be performed on-line if the AOT was extended to seven days. This information was used to reassess the at-power unavailability of the trains due to maintenance (estimates are presented in Section 4), which was subsequently used to assess the risk impact.

This review also helped the B&WOG utilities confirm that the AOT being requested (seven days) will support their on-line maintenance needs. Table 2-1 provides a summary of typical types of maintenance involved, including:

- Typical maintenance activities (preventive and corrective) that under the current AOT are or can be performed at power, and are included in the baseline risk.

- Typical additional maintenance activities that the utility (with a longer AOT) may schedule at power, if needed, rather than at shutdown. This includes both preventive maintenance (PM) and corrective maintenance (CM), and considers both past history and potential future needs.

It is desirable for utilities to schedule maintenance when the unit is at power due to decay heat removal demands during outages. Except for the simplest tasks, pump maintenance is difficult to schedule within the current AOT. There are some medium-duration (i.e., several days) valve maintenance tasks, such as refurbishment of the DHR cooler bypass valve (which involves train drain-down and refilling), that also are difficult to schedule within a 72-hour window. The proposed AOT would allow scheduling of longer-duration activities, as necessary, when the unit is at power.

In addition, there are short-duration maintenance tasks, such as MOV testing, that the utility could schedule in series given a longer AOT. The number of activities that can be performed on a train at the same time is sometimes limited by the physical arrangement. For example, due to physical limitations of the pump room, some activities for the pump and associated valves may normally be performed in series rather than in parallel. Therefore, the longest scheduled activity in a planned train outage does not always dictate the outage time period. The proposed AOT extension will help by allowing more short-duration activities to be scheduled within a planned train outage, decreasing the need for subsequent train outages.

The proposed AOT extension allows an increased level of on-line maintenance, which is beneficial for increasing system reliability, since maintenance (PM and CM) can be performed in a more timely manner. For the DHR system in particular, there is the special advantage of being able to take a train out-of-service at power when it is not the primary source of cooling, as it is during shutdown.

For example, one utility estimated that with the seven-day AOT they could schedule PM of each train once during each operating cycle. With the present 72-hour AOT, DHR system PM is performed during the refueling outages, and each DHR train is taken out-of-service only once every-other-operating-cycle (due to shutdown cooling concerns). Thus, the PM could be completed more often, which is the utility's preference for ensuring optimum equipment performance.

The plant-specific reviews were used by each utility to estimate the frequency and duration of maintenance that would be made possible by the longer AOT, and the resulting train unavailability (e.g., out-of-service hours per year). The estimates made by each utility are included in Section 4 (Table 4-1). Relevant plant-specific scheduling policies, which guide decisions for scheduling a particular maintenance activity, have been considered. For example, utilities typically schedule an amount of maintenance activity that will fit comfortably within the AOT, such that the probability of inadvertently exceeding the AOT is small. The PRA calculations, described in Section 4, use "mean" or "expected" maintenance unavailability, but a calculations were also performed that uses the full AOT[3]. The latter calculations serve as a sensitivity analysis to evaluate the impact of estimating actual maintenance tasks and their durations, versus using the full AOT length.

2.4 Assessment of Deterministic Factors

Each utility reviewed the systems and safety functions that are impacted by entry into the LPI/RBS train AOT. This review, as described in Section 3.1, provided assurance that all affected DHR, LPI and RBS safety functions (and any associated dependent equipment) were identified, and that the quantitative and qualitative assessments considered the specific equipment and the specific functions affected.

The changes that are proposed to the Technical Specifications meet all of the existing rules and regulations, as stated in 10 CFR 50.36 "Technical Specifications" (1997 revision), including the criteria for items to be included. No SSC will change its status with respect to these criteria due to the proposed change. In particular, there are no SSCs that were previously not significant to health and safety that will become so because of the proposed change. Nor will the proposed Technical Specification change result in non-compliance with any other portion of the current licensing basis.

---

[3]Analysts for Davis-Besse chose to be conservative and only calculated the incremental risk based upon the full AOT.

The impact of the proposed changes on defense-in-depth aspects of the plant design was considered. The balance between prevention of core damage and prevention of containment failure will not be changed. The results presented in Section 4 show that the margin between core damage frequency and large early release frequency is maintained when the AOT is extended. No new accidents or transients will be introduced as a result of the proposed changes to the AOT. Nor is the likelihood of any initiating event (e.g., large LOCA or steam generator tube rupture) affected in any way by the proposed change.

Protections are in place to ensure that there are no unanticipated compromises of system redundancy, independence, and diversity during maintenance activities. Utility maintenance policies include restrictions that preclude simultaneous equipment outages that would erode redundancy and diversity. These will continue after the proposed AOT is in use. Maintenance policies also include precautions and compensatory measures that are taken to offset any potential negative impact of the equipment outage. Typical plant-specific measures that are currently taken when a train of equipment is removed from service are discussed at the end of Section 3.3. For example, there is verification that certain other equipment, such as emergency feedwater, will not be out of service, and the outage tagging boundary will be set up to minimize equipment affected. Regardless of the AOT, the actual time duration and the amount of equipment taken out of service is never more than what the utility feels is necessary to complete the task.

Defense against common cause failure and human error will improve with the proposed Technical Specification change. The changes do not introduce any potential new common cause failures or human errors due to operational changes or changed operator response. Operational changes associated with the proposed Technical Specification change will be minimal because utility scheduling policy for maintenance activities allows an adequate margin to perform the task, and existing policies will remain in effect after the AOT is granted. However, the increased AOT gives the operators improved flexibility to repair degraded equipment, that might otherwise have waited for a scheduled shutdown. This will increase system reliability by reducing real deficiencies that could impact operations. Also the increased flexibility, and off-loading of maintenance from refueling outages, will reduce time stress for completion of maintenance tasks, and hence lower human error rates.

The impact of the proposed changes on safety margins was also considered. Changing the AOT from three to seven days for one inoperable train does not adversely impact any assumptions or inputs to the FSAR safety analysis. Assuming the plant is in the AOT and there are no additional failures, an assessment indicates that the FSAR acceptance criteria are not affected. There are no safety functions that will be not be satisfied as a result of entry into the proposed AOT.

The functions of LPI include flooding the core and providing long term cooling following LOCAs. The functions of RBS include removing fission products from the post-accident containment atmosphere. LOCA success criteria are based on traditional ECCS calculations that are performed in accordance with 10 CFR 50 Appendix K and the acceptance criteria of 10 CFR 50.46, and they are conservative. Also, the acceptance criteria for radiological releases following a LOCA (10 CFR 100) are based upon very conservative source terms. More realistic LOCA analyses, such as for leak-before-break, suggest that the traditional acceptance criteria for LOCA design basis accidents have very conservative safety margins. These safety margins will not be eroded by relaxing the three-day AOT for one train of LPI and RBS to seven days.

The DHR cooling mode is the safe end state for a steam generator tube rupture (SGTR) event. However for STGR, entry into DHR cooling can be delayed indefinitely as long as core cooling can be provided by steaming the intact steam generator. Therefore, the increased AOT will have no impact on this function.

The DHR system also has non-emergency functions. It is used to remove decay heat during shutdown and refueling operations. While LOCAs are infrequent events, the DHR function is always needed in the shutdown modes of operation. By allowing maintenance to be performed at power, there is an overall enhancement of safety because reliability and availability are improved for the shutdown modes where DHR is most needed.

TABLE 2-1 **Summary of Typical On-Line Maintenance for LPI/DHR Train**	
Preventive Maintenance (PM) **within Current AOT (Baseline)**	Typical activities included: • clean inspect and calibrate instrument loops • sample/analyze pump bearing oil and inspect/lubricate pump & motor • inspect pump motor breaker • MOV testing • repack valves
Corrective Maintenance (CM) **within Current AOT (Baseline)**	Typical activities included: • clean/inspect pump seals • minor pump and motor repairs • troubleshooting instrument loop problems • valve operator inspection/cleaning/calibration • minor valve repairs
Preventive Maintenance (PM) **within 7-Day AOT**	Typical activities included: • DHR cooler bypass valve maintenance • MOV testing • pump/motor inspection • check valve inspection • minor hardware modifications
Corrective Maintenance (CM) **within 7-Day AOT**	Typical activities included: • DHR cooler outlet valve internals inspection/repair/replacement (refurbishment) • DHR cooler bypass valve refurbishment • pump seal repair/replacement • replace leaky pump fitting • other major or minor pump and motor repairs • modify DHR cooler bypass valve control loop

3.0 Risk Analysis Approach

3.1 The Applicability of the Plant-Specific PRA

This portion of the report establishes that the safety functions that are impacted by taking a DHR/LPI/RBS train (and associated dependent equipment) out of service at power are modeled in the PRA, or are otherwise addressed. A systematic identification of the at-power functions of the DHR/LPI system and the RBS system was performed. This includes identification of applicable events that could challenge these systems, and whether the functions are impacted by the proposed equipment tagout. This provides assurance that there is a complete accounting of the at-power risk associated with the proposed on-line maintenance. This was especially important given the shared components of the LPI and DHR systems in the B&W design.

To model the effects of the AOT change in the plant-specific PRA, each utility made a careful accounting of the safety functions impacted by the train outages, and verified that the PRA addresses these functions. In doing so, the utility analyst identified the relationship between the proposed plant Technical Specification changes and their representation in the PRA model, and determined what specific parts of the PRA model to manipulate to account for the DHR/LPI/RBS train unavailability.

Table 3-1 provides a summary of the DHR/LPI and RBS system functions, and defines the scope of the plant-specific risk analyses that were performed. The table contains the following fields:

A. "Safety" functions of the DHR/LPI and RBS systems for non-shutdown operating modes.

B. Events that would challenge these functions.

C. Indication of functions that are impacted by the on-line maintenance tagout configurations used by each utility. System isolation boundaries for maintenance activities were reviewed to ensure that the effects are considered on all system safety functions, such as the ability of LPI to operate in the "piggy back" mode with High Pressure Injection (HPI).

D. Indication that the PRAs cover the function and events identified (or that the item was addressed deterministically). For impacted functions not covered in the PRA, it was verified that the deterministic treatment is not impacted by the proposed AOT extension, and that the function in question is not a significant risk contributor for the applicable event(s). The only function identified that was not explicitly modeled in the PRA is Reactor Coolant System (RCS) circulation to prevent boron precipitation following a LOCA. It was determined that this function is not significantly affected by unavailability of one LPI train (because of multiple mixing paths), and that unavailability/failure of both LPI trains would result in more severe consequences with respect to loss of core cooling, prior to the need for long-term boron precipitation control.

Table 3-1 is a summary table of typical DHR, LPI, and RBS functions applicable to power operation (compiled from plant-specific input), and a verification that the functions impacted by the proposed AOT extension are addressed in the PRAs.

Each utility has verified that the on-line maintenance would not affect operability of systems or functions other than the LPI subsystem of ECCS, and RBS, and/or has ensured that all of the impacts are identified for quantification in the incremental risk assessment. For example, isolation of an LPI train disables the ability of that train to provide "piggy back" suction to the HPI system for recirculation mode in high pressure events, such as some small break LOCAs. For those events, the incremental risk calculations reported in Section 4 include the effects upon HPI "piggy back" mode when a train of LPI is inoperable for maintenance.

3.2 PRA Pedigree and Scope

3.2.1 Pedigree

All of the plant-specific PRAs used by the B&WOG utilities to quantify the incremental risk associated with the proposed AOT extension have received extensive internal peer review. In addition, the PRAs and/or IPEs are in various stages of NRC review, and the participating utilities have been responsive to NRC reviewer questions.

In addition, several of the B&WOG PRAs have a long-standing and evolving history of development and application in plant operations and licensing. For example,

- The Oconee NSAC-60 PRA, a predecessor to the Oconee PRA currently in use, was reviewed in detail by Idaho National Engineering Laboratory and received an SER.

- The ANO-1 PRA was used to support justification of an AOT extension for the emergency feedwater system from 36 hours to 72 hours (SER issued March 1, 1995).

- The Davis-Besse PRA has been used in support of justification for extension of the AOT for emergency diesel generators (SER issued in 1996).

Furthermore, with respect to the application of these PRAs to the proposed relaxation of Technical Specifications, the guidance provided by the NEI/EPRI *PSA Applications Guide* [7] has been used to verify the general pedigree of the B&WOG PRAs. Specifically, Appendix B "Checklist for Technical Consistency in a PSA Model" of the *PSA Applications Guide* has been carefully reviewed by each B&WOG utility. In addition, the B&WOG RBAWG maintains communications between utility PRA experts to facilitate comparison and continuous improvement of the utilities' PRA methods.

3.2.2 Scope

The *PSA Applications Guide* also provides guidance for determining the applicability of the plant-specific PRA to specific issues. The *PSA Applications Guide* includes some questions related to the scope of the PRA and its appropriateness for the proposed PRA application. For example, does the proposed change (i.e., AOT) involve systems, structures or components involved in external events scenarios (external events PSA), or shutdown/low power operation (shutdown PSA). Table 3-2, "Questions to Assist in Establishing the Cause-Effect Relationship," of the *PSA Applications Guide* has received detailed review by each utility's PRA expert for insights to help determine which portions of the plant-specific PRA model need to be manipulated and to ensure that there are no other scope issues that have not been considered. This material was used to determine the appropriate scope for the quantitative analysis that is reported herein. Justification of the use of the Level 1 PRAs (internal events) as a basis for the risk analysis is provided below.

3.2.2.1 External Events PRA

External events were treated qualitatively. It was determined that the proposed AOT extension does not significantly impact the frequency of core damage due to an external event. In part, this is because the probability of large- or medium-LOCA concurrent with a seismic event is small, and because a safe plant condition can be maintained for long periods of time prior to entering the DHR cooling mode.

Nonetheless, a sensitivity analysis was performed by Duke Power Company, who has completed an external events PRA for Oconee. Section 4 reports the incremental change in core damage frequency associated with the proposed AOT extension. These results were calculated using internal events PRA models. The incremental change in core damage frequency was also calculated for Oconee using the external events PRA. The impact of the proposed AOT extension on the external events PRA was negligible, and the entire incremental contribution can be attributed to internal events. Hence, it was determined that judgments about the risk impact of the proposed AOT extension could be made based upon the internal events PRAs.

3.2.2.2 Core Damage Frequency and LERF

Core damage frequency (CDF) is an appropriate risk measure for this analysis. In addition, since a change to the RBS AOT is being requested, large early release frequency (LERF) is also an appropriate risk measure, because the impact of the proposed AOT extension, and the associated increase in on-line maintenance, potentially affects performance of the containment safeguards systems. Therefore, the risk measures include incremental contribution to LERF as well as CDF.

3.3 Risk Management Controls for On-Line Maintenance

Risk management controls provide assurance that the increased on-line maintenance resulting from the AOT relaxation will not lead to an unforseen risk vulnerability. Since the plant-specific PRA-based calculations estimate time-averaged risk, they do not provide inherent assurance that instantaneous risk peaks will not occur, for example, due to simultaneous maintenance outages in diverse equipment. These potential time-dependent vulnerabilities are masked when the risk is averaged out over the fuel cycle. Assurance that time-dependent vulnerabilities will not occur, and that the average risk calculations (discussed in Section 4) are representative, are provided by management controls for equipment-out-of-service, such as those required by the Maintenance Rule [8].

There are two factors associated with taking equipment out of service for maintenance that determine the impact on core damage risk and public health risk. These are:

- the duration that the equipment is out of service, and
- the potential combined effect with other equipment that is out of service at the same time.

Technical Specifications limit the time that equipment can be out of service and they restrict the plant configuration by identifying equipment that can not be out of service at the same time (usually trains within the same system). For example, the current Standard Technical Specifications [6] for LPI limit the time that one train can be out of service to no more than 72 hours, and they prevent both LPI trains from being out at the same time. However, there are no explicit restrictions on the number of times this limiting condition of operation (LCO) can be entered. Also, there are few Technical Specification restrictions preventing other equipment associated with the same or opposite train as the inoperable LPI train from being out at the same time. The Maintenance Rule requires that both of these concerns be addressed.

Paragraph a(1) of the Maintenance Rule requires that licensees establish goals for and monitor the performance of applicable Systems, Structures and Components (SSCs). NUMARC 93-01, "Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," [9] recommends establishing performance criteria for the availability of risk-significant systems. *Availability* is the time that an SSC is capable of performing its intended function as a fraction of the total time that the intended function may be required. To meet this requirement, B&WOG utilities have established controls on the hours that a train can be out of service over a period of a refueling cycle, thus ensuring that the availability goals are met. Criteria are established for the total time that a system can be out of service rather than specifying an AOT without a limit on the number of entries.

Paragraph a(3) of the Maintenance Rule states "an assessment of the total plant equipment that is out of service should be taken into account to determine the overall effect on performance of safety functions." To meet this requirement, licensees have developed plant-specific methods and procedures to control the process for removing equipment from service. The methods used by utilities vary. Some B&WOG utilities have developed simple matrices that identify that specific combinations of two risk-significant systems or components should not be removed from service at the same time. Others have developed complex computer models that can quickly recalculate the core damage frequency (CDF) or large early release frequency (LERF) for the given plant configuration. Regardless of the actual method being used, all B&WOG utilities use probabilistic risk assessment insights to place additional restrictions beyond those required by Technical Specifications.

Typical precautions and compensatory actions that are used by B&WOG utilities when a train of LPI/RBS is taken out of service include:

- Ascertaining the risk ranking (Risk Achievement Worth) of the component/train,

- Identifying risk-related impacts/concerns caused by the train outage such as reductions in safety system redundancy, function, or defense-in-depth. The evaluation may include other systems, structures, and components (SSCs) affected, PRA initiating events affected, and containment capability impacts.

- Verification that certain other SSCs will not be out of service during the outage, possibilities include the opposite train of LPI/RBS, either train of emergency feedwater (EFW), HPI, or Reactor Building Cooling Units, and related power supplies.

- Setting up the outage tagging boundary of the LPI train to maintain RBS train operability, if maintenance needs allow.

- If forced to cold shutdown during the outage, maintaining steam generator cooling until the DHR train is returned to service or decay heat levels allow an alternate cooling method.

The additional requirements imposed by the Maintenance Rule help ensure that maintenance activities performed under the present or any future Technical Specifications will not create a safety concern. The methods used by licensees to comply with this rule take advantage of probabilistic risk assessment insights and should result in enhanced safe plant operation.

3.4 Risk for Concurrent LPI and RBS Train Outage

The RBS and LPI are physically dependent because of shared suction piping from the BWST and from the reactor building sump. In addition, for long-term containment cooling following a LOCA, the RBS system, in conjunction with LPI (DHR) coolers, is a backup to the reactor building emergency coolers. Consequently at most plants, tagout of an LPI train for maintenance causes the LCO for RBS to be invoked as well. The Technical Specifications allow simultaneous outage of one train of LPI and the corresponding train of RBS.

Per the discussion presented above in Section 3.3, B&WOG utilities have developed measures to manage on-line maintenance risk. This has included using insights from their PRAs to identify undesirable plant configurations. These efforts provide assurance that the simultaneous outage of one train of LPI and the corresponding train of RBS does not create a safety concern. Furthermore, since a maintenance outage of an LPI train may affect operability of the corresponding train of RBS, some utilities prefer performing the RBS maintenance in parallel with LPI maintenance to minimize overall risk exposure.

3.5 PRA-Derived Figures-of-Merit

The justification for increasing the AOT is based on demonstrating that the additional risk incurred during power operation from the increased maintenance is not significant. With a longer AOT, tasks will be performed at power that were previously deferred to shutdown because they could not be scheduled within the current AOT. This effectively increases the total system unavailability, at power. The overall incremental contribution to risk, considering all modes, comes from three areas:

1. on-line risk increment (risk associated with performing more maintenance on-line),

2. shutdown risk increment (risk averted by not performing maintenance during shutdown), and
3. forced outage/transition risk (risk of not completing corrective maintenance within the AOT).

As presented in Section 4, the amount of increase in on-line risk is minimal, and it is therefore not necessary to show the tradeoff with the corresponding improvements in risk incurred during shutdown and the transition to shutdown. The second two items in the risk equation are, however, included qualitatively, as discussed in Section 4.2.

The analysis quantifies the first element of the incremental risk equation, the on-line risk increment. Section 4 includes this information, developed from plant-specific PRAs, to support the claim that the risk significance of the proposed AOT extension is small. Figures-of-merit, expressing the incremental **at-power** risk (in terms of CDF and LERF) associated with the increased AOT (and corresponding increase of on-line maintenance tasks), are presented for each utility.

Two separate calculations of incremental CDF and LERF have been performed, one that uses a realistic estimate of the mean maintenance task duration, and the other that assumes the full AOT duration is used for each train[4]. The latter calculation serves to determine the sensitivity of the results to the maintenance outage estimates.

The approach used to calculate these increments in CDF and LERF is shown in Table 4-1. The development is consistent with the intent of the guidance provided in NUREG/CR-6141 (*Handbook of Methods for Risk-Based Analyses of Technical Specifications*) [3]. One figure-of-merit is the conditional core damage frequency with one train of DHR/LPI/RBS unavailable (i.e., configuration-specific core damage frequency), which is intended to show the short-term risk

---

[4]Analysts for Davis-Besse chose to be conservative and only calculated the incremental risk based upon the full AOT duration.

increase that results from an entry into the AOT. However, instead of using the conditional CDF to derive the other figures-of-merit, all figures-of-merit are calculated directly from the plant-specific PRAs. The utility has calculated results (core damage frequency and LERF) based on a "roll up" of the total unavailability from all estimated maintenance activities with the proposed seven-day AOT. Modeling of PM and CM uses the utility-specific analysis methods that were adopted for the base-case PRAs. The results include the effect of common cause failure, consistent with plant-specific PRA treatment, for the tagout configurations modeled (i.e., for CM resulting from functional failure). The figures-of-merit include incremental changes in core damage frequency and LERF, derived from the difference between the newly-calculated results (with extended AOT) and the base PRA results (with current AOT) so that the aggregate effect of the proposed extended AOT is shown.

Specific methods for PRA requantification are utility-specific, however general guidance was taken from the NEI/EPRI *PSA Applications Guide* [7] and from NUREG/CR-6141 [3]. The B&WOG utilities have calculated or extracted from their PRAs:

- the conditional CDF, with one train of DHR/LPI/RBS unavailable (i.e , configuration-specific average CDF); if there is more than one tagout configuration, then the worst case is provided

- the base average CDF and LERF (with current AOT)

- the "new" average CDF and LERF using the total estimated "roll up" of all of the maintenance tasks that will be undertaken with the extended AOTs

- the "new" average CDF and LERF if the full AOT is used.

All of the computations were made using the plant-specific PRA models. The figures-of-merit are based on internal initiating events. The utilities are maintaining the backup documentation that supports the conclusions presented in this report based on requantification of the PRAs.

Specific criteria for judging the acceptability of the proposed AOT increase are based on Appendix C "Selection of Decision Criteria"of the NEI/EPRI *PSA Applications Guide* [7]. The B&WOG is aware that the NRC, working with industry, is in the process of developing screening criteria similar to Figures 4-1 and 4-2 of the *PSA Applications Guide,* and that, as of the date of this report's publication, these efforts are not yet final. The proposed NRC criteria, as of the date of this writing, are presented in Draft Regulatory Guides DG-1061[10] and DG-1065 [11]. Nonetheless, without implying endorsement of the Draft Regulatory Guides, the B&WOG believes that they will also show the reasonableness of the B&WOG results.

TABLE 3-1 Applicability of PRAs for LPI and RBS AOT Analysis							
DHR/LPI and RBS System Functions[1] (for non-shutdown operating modes)	Applicable Event(s)	Is Function Impacted (reliability, redundancy, etc.) by LPI and/or RBS Train Tagout?					Do the PRAs cover the function and events in question (if impacted)?
		ANO-1	Crystal River-3	Davis-Besse	Oconee-1,2,3	TMI-1	
DHR/LPI Functions:							
Provide high volume injection of borated water from BWST to RCS to assure core cooling and adequate shutdown margin	LOCAs	Yes	Yes	Yes	Yes	Yes	Yes
Provide long term heat removal by recirculating coolant from RB sump	LOCAs	Yes	Yes	Yes	Yes	Yes	Yes
Provide coolant from RB sump/NPSH for HPI pumps (piggyback mode)	LOCAs	Yes	Yes	Yes	Yes[2]	Yes	Yes
Provide borated water supply from BWST to HPI	LOCAs[3]	No, isolation valve is down-stream of branch point for HPI suction	No	Yes	No, isolation valve is down-stream of branch point for HPI suction.	No	Yes

TABLE 3-1 **Applicability of PRAs for LPI and RBS AOT Analysis**							
DHR/LPI and RBS System Functions[1] (for non-shutdown operating modes)	Applicable Event(s)	Is Function Impacted (reliability, redundancy, etc.) by LPI and/or RBS Train Tagout?					Do the PRAs cover the function and events in question (if impacted)?
		ANO-1	Crystal River-3	Davis-Besse	Oconee-1,2,3	TMI-1	
Provide borated water supply from BWST and RB sump (recirculation mode) to RBS	LOCAs	No, isolation valve is down-stream of branch point for RBS suction	Yes	Yes	No	Yes	Yes
Provide long term RCS normal DH removal	SGTR	Yes	Yes	Yes	Yes	Yes	Yes
Provide RCS pressure boundary integrity	LOCAs	No	No	No	No	No	Yes
Provide critical parameter information to operators	LOCAs	No	No	No	No	No	Yes
Provide containment isolation	LOCAs	No	No	No	No	No	Yes
Provide RCS circulation to prevent boron precipitation after a LOCA	LOCAs	Yes	Yes	Yes	Yes	Yes	No[4]

TABLE 3-1 Applicability of PRAs for LPI and RBS AOT Analysis							
DHR/LPI and RBS System Functions[1] (for non-shutdown operating modes)	Applicable Event(s)	Is Function Impacted (reliability, redundancy, etc.) by LPI and/or RBS Train Tagout?					Do the PRAs cover the function and events in question (if impacted)?
		ANO-1	Crystal River-3	Davis-Besse	Oconee-1,2,3	TMI-1	
RBS Functions:							
RB emergency cooling and long term pressure reduction	LOCAs	Yes	Yes	Yes	Yes	Yes	Yes[5]
Removal of fission product iodine from containment atmosphere (includes caustic addition if applic.)	LOCAs	Yes	Yes	Yes	Yes	Yes	Yes[5]
Provide critical parameter information to operators	LOCAs	No	No	No	No	No	Yes
Provide containment isolation	LOCAs	No	No	No	No	No	Yes
Beyond design basis "functions" for severe accident management, e.g. combustion control, reactor cavity flooding, fission product control	Severe Accidents (Level 2 PRA)	Yes	Yes	Yes	Yes	Yes	Yes

TABLE 3-1 Applicability of PRAs for LPI and RBS AOT Analysis							
DHR/LPI and RBS System Functions[1] (for non-shutdown operating modes)	Applicable Event(s)	Is Function Impacted (reliability, redundancy, etc.) by LPI and/or RBS Train Tagout?					Do the PRAs cover the function and events in question (if impacted)?
		ANO-1	Crystal River-3	Davis-Besse	Oconee-1,2,3	TMI-1	
Support System Functions[6]:							
Cooling systems: cooling for DHR and RBS pumps and redundant cooling for makeup pumps	LOCAs	No	Yes	No	No	No	Yes

Notes for Table 3-1:

1. Or other systems potentially affected by the tagout.

2. Oconee also has an RBS "piggy back" mode, however, it is not required for success. In addition to the usual RBS suction (see below), Oconee has a "piggy back" mode that allows RBS to take its suction from downstream of the LPI pumps and DHR coolers.

3. Also applicable to transient events for "feed and bleed" method of decay heat removal. Davis-Besse has a makeup system separate from HPI that is used for feed and bleed; other plants have combined HPI/makeup system.

4. RCS circulation to prevent boron precipitation following a LOCA is not explicitly modeled in most of the B&WOG PRAs. (The PRA for TMI-1 considers this function explicitly in its success criteria for LPI/DHR.) It was determined that this function is not significantly affected by unavailability of one LPI train (because of multiple mixing paths), and that unavailability/failure of both LPI trains would result in more severe consequences with respect to loss of core cooling, prior to the need for long-term boron precipitation control. In addition, there is another boron mixing path that does not involve the LPI trains.

5. Function affects design-basis accident dose consequences, becomes pertinent in the PRAs when the accident progresses beyond the design basis into a severe accident.

6. Applies only to Crystal River-3 because they use a "train outage" concept that combines outage of DHR/LPI train with same train outage of support systems.

4.0 Results

The incremental contribution to risk associated with the extended AOT is related to the changes in maintenance that will occur as a result of the longer AOT. There is a tradeoff between the risk associated with performing PM and CM at power, and the risk associated with performing the maintenance at a lower operating mode. The overall incremental risk, considering all modes, comes from three areas: the on-line risk increment (risk associated with performing more maintenance on-line), the shutdown risk increment (risk averted by not performing maintenance during shutdown), and the incremental forced outage/transition risk (risk from additional shutdown/startup cycles, possibly with impaired DHR). These three contributions to incremental risk are discussed below. Incremental at-power risk is quantified based on plant-specific PRAs; the shutdown and transition risks are treated qualitatively.

4.1 <u>Incremental At-Power Risk Associated with Increased AOT</u>

Two separate calculations of incremental core damage frequency (CDF) and large early release frequency (LERF) have been performed by each B&WOG utility, one using realistic estimates of mean maintenance duration, and the other assuming that the full AOT duration is used[5]. Both of these calculations are presented in Table 4-1, which contains the results calculated by each B&WOG utility, compiled to ensure consistency of form and content.

Table 4-1 is divided into three sections containing: the parameters used by the utilities in their plant-specific PRA calculations to characterize the maintenance unavailability with the current and the proposed AOT (items 1 through 8), the incremental CDF associated with the proposed AOT extension (items 9 through 14), and the incremental LERF associated with the AOT extension

---

[5]Analysts for Davis-Besse chose to be conservative and only calculated the incremental risk based upon the full AOT.

(items 15 through 20). To ensure a common understanding of each of the parameters, the definition for each parameter is provided in Table 4-2.

Items 1 through 8, the maintenance unavailability parameters, are inputs provided by the utilities; these values represent a roll-up of unavailability across all maintenance activities (corrective and preventive) for specific tagout configurations, and across all tagout configurations, if more than one was considered. The calculational results from each utility include the aggregate impact of all of the tagout configurations (including symmetric and asymmetric configurations) considered for on-line maintenance activities, and the combined impact of both corrective and preventive maintenance activities.

Items 13 and 14 (incremental CDF due to additional maintenance at power using mean duration and full AOT, respectively) represent mean and upper bound values for the incremental change in CDF resulting from the increased train unavailability for maintenance that is likely to occur with the longer AOT. Items 19 and 20 represent similar values for LERF. These results have not factored in the reliability benefits of the increased on-line maintenance, nor the risk improvements to be obtained in the off-line operating modes. However, it can be seen from the results that the effect of the increased AOT on the at-power safety of the plants (as measured by change in CDF and LERF) is minimal.

Table 4-1 also shows the conditional core damage frequency (parameter 10) and the conditional LERF (parameter 16) with one train of DHR/LPI/RBS unavailable. These can be characterized as the configuration-specific CDF and LERF during the maintenance outage. The configuration-specific risk increase is not excessive, for example the *PSA Applications Guide* [7] indicates that a short-term configuration-specific risk level of 1×10^{-3}/year is undesirable. All of the conditional CDFs are well below this value. In addition, the LERF levels are all a factor of at least 20 below the corresponding CDF levels, which is typical, indicating that there are no specific vulnerabilities in the containment safeguards systems with respect to the proposed AOT.

The incremental changes in CDF and LERF were compared against the quantitative screening criteria presented in the *PSA Applications Guide* [7]. The *PSA Applications Guide* provides risk significance criteria for permanent changes in plant risk on a sliding scale as a function of the plants' baseline risk values (in terms of CDF and LERF). The proposed Technical Specification changes are "non-risk-significant" using the *PSA Applications Guide*'s screening criteria.

In order to illustrate the robustness of the results, they were also compared against the NRC's proposed quantitative acceptance guidelines, which were presented in Draft Regulatory Guide DG-1061 [10]. As of the date of this writing, these guidelines are still being debated, and may therefore change. While not to be construed as a B&WOG endorsement of the Draft Regulatory Guide, Table 4-1 shows that the proposed Technical Specification changes meet the NRC's draft acceptance criteria. The NRC's guidelines allow an increase in calculated CDF of up to 1×10^{-5} per reactor year, and an increase in calculated LERF of up to 1×10^{-6} per reactor year. All of the mean values for incremental CDF and LERF, shown on Table 4-1, are within the acceptable region of the NRC's guidelines. All of the "full AOT" incremental CDF and LERF values, shown on Table 4-1, are also within the NRC's acceptance guidelines. The "full AOT" values should be characterized as demonstrating the robustness of results in light of sensitivity to maintenance duration assumptions. The B&WOG recognizes that different acceptance criteria may be applied by the NRC in the future. However, based on this analysis, the B&WOG is confident that the proposed AOT changes will not have an adverse impact the plant risk.

The B&WOG plants vary in their calculated baseline CDF and LERF values, due to both real plant differences and differences in analytical conservatism. Because the results fall within the acceptable region of both the NEI/EPRI and NRC criteria, using five different PRAs and five different plants, this demonstrates robustness of the analysis process and lends credibility to the conclusion that the proposed AOT extensions are not risk-significant.

4.2 Qualitative Support

The quantitative results discussed above provide one piece of the argument to justify the increase in AOT. There are also several qualitative arguments that can be made to further support the quantitative ones. Two of these supportive arguments are given in the following subsections. These are the other two elements of the contributions to risk: shutdown risk and transition risk. In addition, a discussion of some of the tangible and intangible benefits of an increased AOT are given in Section 4.3.

4.2.1 Shutdown Risk

This section discusses the qualitative arguments to support the contention that shutdown risk will decrease as a result of implementing the increased LPI and RBS AOT, and permitting more maintenance activities to be performed at power.

At power, main feedwater is the primary means of cooling the core, with emergency feedwater, makeup/HPI, and DHR systems (with depressurization) as backups. During shutdown conditions, DHR is the primary means of cooling the core. Performing a DHR train outage during shutdown removes the redundancy of the primary source of cooling. In addition, DHR serves as a backup to spent fuel pool cooling, and heat loads in the spent fuel pools are higher during outages.

With an extended AOT for an LPI/RBS train, more DHR maintenance activities can be scheduled at power; additional corrective maintenance for the DHR can also be performed at power. Accordingly, maintenance activity for DHR at shutdown should decrease, effectively increasing its availability during the time (shutdown) when unavailability of DHR may be a significant contributor to risk. In addition, with maintenance performed at power, the reliability of DHR during shutdown will be enhanced (i.e., higher probability of DHR operating as desired, if needed). Therefore, with increased availability of DHR during an outage (less maintenance during the outage) and increased reliability (enhanced operability during the outage), it is expected that there will be a decrease in the risk at shutdown.

In addition, when DHR maintenance activities are performed at power, there is less overall maintenance to be performed during shutdown, planning of maintenance activities is simplified, crews can work in a more focused manner, and maintenance-induced errors can likely be reduced.

4.2.2 Forced Outage due to AOT (Transition Risk)

"Transition risk" refers to the risk associated with transitioning to a shutdown mode, following equipment inoperability, to effect repairs. There is a tradeoff between the risk associated with staying at power with the inoperable LPI/DHR/RBS train (to make repairs within the AOT) and the risk associated with incurring an additional shutdown/startup cycle (to allow repairs to be made at a lower operating mode).

In requesting an extended AOT, an assumption is made that the resulting increase in on-line maintenance activity will not cause an increase in forced outages. With no change in the forced outage rate, there will be no increase in risk from reducing power and going to hot or cold shutdown, i.e., transition risk. For this analysis, the value of the transition risk is not the question, but rather would there be a change in transition risk with an increased AOT?

It can be reasonably assumed that, if the number of forced outages does not change, then there will be no change in the transition risk. In theory, the frequency of forced shutdowns should decrease with the proposed AOT because CM could be performed that otherwise would not have been attempted at power. Hypothetically, an increase in PM activity at power could result in more forced outages if the activities inadvertently exceed the time limit. However, this is not expected to be the case because utility policy with respect to scheduling of maintenance activities allows an adequate margin to perform the task. With the increased AOT, this margin is assumed to be the same or better compared to the existing AOT. Historical experience with the frequency of forced plant outages due to DHR/LPI/RBS train inoperability has not been significant[6] and supports this assumption. Since it is assumed that the scheduling policy with the longer AOT will be similar, the frequency of inadvertently exceeding the time limit should not increase.

The premise, supported by experience, is that forced outages due to DHR/LPI and RBS are infrequent, and that they would remain so with increased AOT and on-line maintenance.

There is, nonetheless, a finite risk that is incurred if the plant undergoes a shutdown/startup cycle, with an inoperable DHR train. Other industry groups (e.g., CEOG) have projects underway to quantify this risk. The transition risk can be avoided, however, by remaining at power and restoring the inoperable equipment within the limits of a sufficiently long AOT. In this case, the overall risk increment is bounded by the at-power incremental risk results presented in Table 4-1.

4.3 Benefits of Longer AOT

There are additional tangible and intangible benefits of the proposed AOT extension. These include improved operations as well as safety benefit. These benefits include:

- Increased DHR/LPI system reliability, from reduction of equipment and system deficiencies that could impact operations. The train outages are used for preventive maintenance as well as correction of real problems in the systems.

- More focused attention on the DHR/LPI maintenance tasks, because of scheduling during periods when fewer activities are competing for specialized resources. On-line maintenance can result in improved safety compared to maintenance during a refueling

---

[6]The forced outage rate caused by the DHR/LPI and RBS systems in B&W-designed nuclear power plants is 0.05 average number of occurrences per unit year based on North American Electric Reliability Council (NERC) Generating Availability Data System (GADS) for the period from 1988 through 1992 (run number 93-129).

outage, because a plant can use its best qualified personnel for the maintenance, and distractions to the maintenance crew and plant management are minimized.

- Reduced time stress for completion of maintenance tasks, and hence fewer human errors, because increased margins and flexibility for task scheduling are possible.

- Improved maintenance efficiency. For example, existing AOTs allow for some on-line maintenance for short-duration tasks, and a longer AOT will allow more of these short-duration tasks to be performed during the same tagout. Since each train outage event requires preparation and restoration work, the longer AOT requires that less train unavailability be allocated to preparation and restoration time for a given amount of maintenance. This will improve overall train unavailability (fewer changes of lineup) and/or allow more preventive maintenance tasks to be performed for a given train unavailability target.

- Reduction of work scope during plant outages.

The overall goal of these well-controlled train outages is to increase equipment reliability and train availability in the long term. The current PRA models do not include the long-term reliability growth that is expected from the improved maintenance made possible by the proposed AOT. The improvement in equipment failure rates will only be quantified with accumulation of reliability data after implementation, and reflected in future updates to the plant-specific PRAs.

TABLE 4-1
Incremental Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) Contributions for the LPI and RBS AOT Extensions

Item	Parameter		ANO-1	CR-3	DB-1	Oconee	TMI-1
1	Current AOT (hours)	LPI	24	72	72	72	72
		RBS	24	72	72	24 (168 if 3 RB coolers avail.)	72
2	Proposed AOT (hours)		168	168	168	168	168
3	Current Maintenance Unavailability (hrs/train/year) (note 1)		31.5	80	46	88	56.5
4	Current Frequency of Entry into AOT(s) for Maintenance (events/train/yr) (note 1)		2	2	(note 4)	4	1.625
5	Current Maintenance Mean Duration (hrs/event) (note 1)		15.75	40	(note 4)	22	34.75
6	Expected Maintenance Unavailability (hrs/train/year) (note 1)		125	68 to 93 (note 2, 3)	(note 4)	128	120
7	Expected Frequency of Entry into proposed AOT for Maintenance (events/train/yr) (note 1)		2	1	(note 4)	2	1.6
8	Expected Maintenance Mean Duration (hrs/event) (note 1)		62.5	68 to 93 (note 2, 3)	(note 4)	64	75
9	Base Core Damage Frequency (CDF) (from the PRA) (/yr)		1.40×10^{-5}	8.18×10^{-6}	6.6×10^{-5}	2.61×10^{-5} (note 5)	4.19×10^{-5}
10	Conditional CDF, with one LPI/RBS train unavailable (/yr)		8.84×10^{-5}	4.97×10^{-5}	2.53×10^{-4}	4.37×10^{-5}	2.3×10^{-4} (note 6)

TABLE 4-1
Incremental Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) Contributions for the LPI and RBS AOT Extensions

Item	Parameter	ANO-1	CR-3	DB-1	Oconee	TMI-1
11	Overall CDF with 7-day AOT (with maintenance using the expected mean durations) (/yr)	$1.44x10^{-5}$	$8.62x10^{-6}$	(note 4)	$2.63x10^{-5}$	$4.71x10^{-5}$ (note 6)
12	Overall CDF with 7-day AOT (with maintenance using the full AOT) (/yr)	$1.46x10^{-5}$	$1.04x10^{-5}$	$6.8x10^{-5}$	$2.64x10^{-5}$	$4.91x10^{-5}$ (note 6)
13	Incremental CDF due to additional maintenance at power (mean duration) (/yr)	$3.7x10^{-7}$	$4.4x10^{-7}$	(note 4)	$2x10^{-7}$	$5.2x10^{-6}$ (note 6)
14	Incremental CDF due to additional maintenance at power (full AOT) (/yr)	$5.4x10^{-7}$	$2.3x10^{-6}$	$2.0x10^{-6}$	$4x10^{-7}$	$7.2x10^{-6}$ (note 6)
15	Base Large Early Release Frequency (LERF) (from the PRA) (/yr)	$7.12x10^{-7}$	$1.84x10^{-7}$	$1.22x10^{-6}$	$1.070x10^{-7}$ (note 5)	$1.34x10^{-6}$
16	Conditional LERF,with one LPI/RBS train unavailable (/yr)	$1.01x10^{-6}$	$9.51x10^{-7}$	$1.06x10^{-5}$	$1.30x10^{-7}$	$7.17x10^{-6}$
17	LERF with 7-day AOT (with maintenance using the expected mean durations) (/yr)	$7.13x10^{-7}$	$1.93x10^{-7}$	(note 4)	$1.072x10^{-7}$	$1.50x10^{-6}$ (note 6)
18	LERF with 7-day AOT (with maintenance using the full AOT) (/yr)	$7.14x10^{-7}$	$2.29x10^{-7}$	$1.25x10^{-6}$	$1.074x10^{-7}$	$1.56x10^{-6}$ (note 6)
19	Incremental LERF due to additional maintenance at power (mean duration) (/yr)	$1.5x10^{-9}$	$9x10^{-9}$	(note 4)	$2x10^{-10}$	$1.6x10^{-7}$ (note 6)
20	Incremental LERF due to additional maintenance at power (full AOT) (/yr)	$2.2x10^{-9}$	$4.5x10^{-8}$	$3.0x10^{-8}$	$4x10^{-10}$	$2.2x10^{-7}$ (note 6)

Notes for Table 4-1:

1 Most RBS maintenance occurs concurrently with LPI maintenance, therefore maintenance unavailability parameters for LPI and RBS are shown combined.

2 [CR-3] Risk calculations use the higher value, which assumes outage duration will be in same proportion to AOT as currently. Actual maintenance duration may be closer to the lower value. This is because in order to accomplish the needed work under the shorter AOT two train outages per year are required, and preparation and restoration time is included in the estimate. The longer AOT allows the needed work to be accomplished in one outage per year, thus saving the duplication of preparation and restoration work.

3 [CR-3] Crystal River-3 uses "train outages" to manage maintenance risk, which combine the outage of the LPI and RBS trains with corresponding trains of support systems including Decay Heat Closed Cycle Cooling and Decay Heat Seawater. The calculations contained herein for CR-3 have applied the longer outage time to these systems as well.

4 [DB-1] In lieu of providing this information, analysts for Davis-Besse chose to be conservative and only calculated the incremental risk based upon the full AOT duration (one full AOT duration per train per year).

5 [Oconee] Does not include seismic and other external events. Base core damage frequency with external events is 8.92×10^{-5}/year. Base LERF with external events is 5.86×10^{-7}/year. In sensitivity analysis, incremental CDF and LERF results (parameters 13, 14, 19, 20) did not change when external events were included.

6 [TMI-1] This calculation assumes no other preventive maintenance can take place during the same time period on the opposite train ES diesel generator, DHR, makeup, or DHR cooling water systems. However simultaneous opposite-train corrective maintenance on these systems remains in the model, a conservative assumption.

TABLE 4-2 Parameter Definitions			
Item Number	Parameter	Definition	Comments
1	Current AOT for LPI; RBS (hours)	The current allowed outage time (AOT) for one train of LPI and RBS.	Taken from current Technical Specifications.
2	Proposed AOT for LPI and RBS (hours)	Seven days, the proposed AOT for one train of LPI and RBS.	Proposed Technical Specification change.
3	Current Maintenance Unavailability for LPI and RBS (hrs/train/year)	Total unavailability (per train) for maintenance performed within the current AOT(s) of LPI and RBS Tech. Specs.	Sum of all CM & PM maintenance unavailability for current Tech. Specs.
4	Current Frequency of Entry into LPI and RBS AOT(s) for Maintenance (events/train/yr)	The frequency of current maintenance activity requiring one train of LPI and/or RBS to be unavailable.	Sum of all CM & PM frequency of downtime (entry into AOT) for current Tech. Specs.
5	Current Maintenance Mean Duration (hrs/event)	The mean (train) downtime to perform maintenance activity with the current AOT(s).	Equals unavailability (item 3) / frequency (item 4).
6	Expected Maintenance Unavailability for LPI and RBS (hrs/train/year)	Total unavailability (per train) for maintenance expected to be performed within the proposed seven-day AOT for LPI and RBS.	Sum of all CM & PM maintenance unavailability for proposed Tech. Specs.
7	Expected Frequency of Entry into proposed LPI and RBS AOT for Maintenance (events/train/yr)	The frequency of expected maintenance activity requiring one train of LPI and/or RBS to be unavailable, with the proposed seven-day AOT.	Sum of all CM & PM frequency of downtime (entry into AOT) for proposed Tech. Specs.
8	Expected Maintenance Mean Duration (hrs/event)	The expected mean (train) downtime to perform maintenance activity with the proposed seven-day AOT.	Equals unavailability (item 6) / frequency (item 7).
9	Base Core Damage Frequency (CDF) (from the PRA) (/yr)	The average CDF (no conditions).	This value is taken directly from the PRA.
10	Conditional CDF, with one LPI/RBS train unavailable (/yr)	The conditional average CDF given that one "train" of LPI/RBS is inoperable (i.e., CDF while within AOT)	Calculated from the PRA for worst case tagout configuration.

TABLE 4-2
Parameter Definitions

Item Number	Parameter	Definition	Comments
11	Overall CDF with seven-day AOT (with maintenance using the expected mean durations) (/yr)	Overall (at-power) average CDF with an increase in on-line LPI/RBS train unavailability due to maintenance, using the mean values for expected maintenance estimated above (item 6).	From requantification of the PRA, accounting for the specific tagout configurations and maintenance unavailabilities. Specific approaches for PRA requantification are utility-specific.
12	Overall CDF with seven-day AOT (with maintenance using the full AOT) (/yr)	Overall (at-power) average CDF with an increase in on-line LPI/RBS train unavailability due to maintenance, using the upper bound values for expected maintenance.	From PRA requantification, as above, but using full AOT (seven days). Upper bound maintenance unavailabilities calculated using seven days per train per year.
13	Incremental CDF due to additional maintenance at power (mean duration) (/yr)	Additional CDF incurred at power by extending AOT to seven-days.	Difference between CDF with seven-day AOT, mean maintenance duration (item 11) and base CDF (item 9).
14	Incremental CDF due to additional maintenance at power (full AOT) (/yr)	Upper bound estimate of additional CDF incurred at power by extending AOT to seven-days (if always use full AOT).	Difference between CDF with seven-day AOT, upper bound maintenance duration (item 12) and base CDF (item 9).
15	Base Large Early Release Frequency (LERF) (from the PRA) (/yr)	The average LERF (no conditions).	This value is from the base PRA.
16	Conditional LERF,with one LPI/RBS train unavailable (/yr)	The conditional average LERF given that one "train" of LPI/RBS is inoperable (i.e., LERF while within AOT).	Calculated from the PRA for the worst case tagout configuration.
17	LERF with seven-day AOT (with maintenance using the expected mean durations) (/yr)	Overall (at-power) average LERF with an increase in on-line LPI/RBS train unavailability due to maintenance, using the mean values for expected maintenance estimated above (item 6).	From requantification of the PRA, accounting for the specific tagout configurations and maintenance unavailabilities. Specific approaches for PRA requantification are utility-specific.

TABLE 4-2 Parameter Definitions			
Item Number	Parameter	Definition	Comments
18	LERF with seven-day AOT (with maintenance using the full AOT) (/yr)	Overall (at-power) average LERF with an increase in on-line LPI/RBS train unavailability due to maintenance, using the upper bound values for expected maintenance.	From PRA requantification, as above, but using full AOT (seven days). Upper bound maintenance unavailabilities calculated using seven days per train per year.
19	Incremental LERF due to additional maintenance at power (mean duration) (/yr)	Additional LERF incurred at power by extending AOT to seven-days.	Difference between LERF with seven-day AOT, mean maintenance duration (item 17) and base LERF (item 15).
20	Incremental LERF due to additional maintenance at power (full AOT) (/yr)	Upper bound estimate of additional LERF incurred at power by extending AOT to seven-days (if always use full AOT).	Difference between LERF with seven-day AOT, upper bound maintenance duration (item 18) and base LERF (item 15).

5.0 Summary and Conclusions

This report presents the technical justification for increasing the "ECCS Operating" Technical Specification allowable outage time (AOT) for one inoperable train of Low Pressure Injection (LPI) and the AOT for one inoperable train of Reactor Building Spray (RBS). LPI is an operating mode of the Decay Heat Removal (DHR) system, and the proposed AOT extension to 168 hours (seven days) will allow meaningful maintenance of the DHR system to be performed at power. The RBS is included because LPI and RBS share common suction piping from the borated water storage tank (BWST) and the reactor building emergency sump, and some LPI train maintenance impacts the operability of the corresponding train of RBS.

This report has provided technical support for the proposed AOT extension, which the B&WOG believes is sufficient to allow the NRC to approve the proposed request. This report has included a brief system description, review of the applicable Technical Specifications, discussion of the need for an extension of the AOT, and an assessment of the impact upon deterministic factors. The generic framework of the risk analysis methodology has been discussed, including how the applicability of the plant-specific PRAs was established, and the choice and use of PRA figures of merit. The individual B&WOG utilities, under the guidance of the respective B&WOG Risk-Based Applications Working Group (RBAWG) members, have performed the plant-specific analyses using their PRAs. They have assessed the risk impact, as measured by change in core damage frequency (CDF) and large early release frequency (LERF), of increased maintenance unavailability at power for DHR (which includes LPI mode) and RBS systems. A compilation of the plant-specific quantitative results, supporting qualitative arguments, and benefits of the proposed AOT extension, has been provided.

The results show that increasing the AOTs as proposed is not risk-significant. These results reflect both the mean values of expected maintenance unavailability, and the full AOTs, which demonstrates the robustness of the conclusions in light of assumed variability in actual maintenance duration. In addition, the configuration-specific short-term risk levels (i.e., during train maintenance tagouts) are reasonable, indicating that there are no vulnerabilities in the plant or containment systems that would preclude the proposed AOT extension.

The benefits of the proposed AOT extension, which will be realized by permitting more DHR maintenance activities to be performed at power, include reduction of shutdown risk, increased system reliability, and improved maintenance efficiency. While at power, DHR/LPI is a backup cooling system. However, during shutdown the DHR system is the primary means of cooling the core. Performing DHR train outages during shutdown reduces the redundancy of the primary cooling source. DHR is also a backup cooling source for the spent fuel pool. Performing the DHR maintenance at power is a more efficient use of resources and improves the reliability of the equipment for subsequent periods of shutdown or emergency use.

The B&WOG feels it has demonstrated that extending the AOT for Low Pressure Injection and Reactor Building Spray systems to 168 hours (seven days) does not adversely impact risk. Considering the qualitative benefits, the B&WOG believes that the proposed AOT extension is a safety enhancement, and therefore an appropriate change to the Technical Specifications.

6.0 References

[1] BAW-10167A, *Justification for Increasing the Reactor Trip System On-Line Test Intervals*, B&WOG, August 1992. (Volumes 1 & 2 originally published May 1986, Supplement Number 1: *Questions & Answers*, originally published February 1988, Supplement Number 2: *Additional Information on Allowed Outage Time*, originally published September 1989, SERs issued December 1988 and July 1992.)

[2] BAW-10182A, *Justification for Increasing the Engineered Safety Features Actuation System (ESFAS) On-Line Test Intervals*, B&WOG, February 1994. (Originally published February 1992, SER issued January 1994.)

[3] NUREG/CR-6141, *Handbook of Methods for Risk-Based Analyses of Technical Specifications*, December 1994.

[4] CE NPSD-995, *Joint Applications Report for Low Pressure Safety Injection System AOT Extension,* CEOG, April 1995 (Advance Copy). SER issued as attachment to SECY-97-095, April 30, 1997.

[5] EPRI TR 105987, *Template for the Submission of Revised Risk Based Technical Specifications,* EPRI, December 1995.

[6] NUREG-1430, *Standard Technical Specifications, Babcock & Wilcox Plants.* September 1992.

[7] EPRI TR-105396, *PSA Applications Guide*, EPRI, August 1995.

[8] 10CFR50.65, *Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants*, July 10, 1991.

[9] NUMARC 93-01, *Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants*, May 1993.

[10] Draft Regulatory Guide DG-1061, *An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Current Licensing Basis*, (Draft for Comment), March 28, 1997.

[11] Draft Regulatory Guide DG-1065, *An Approach for Plant Specific, Risk-Informed Decision Making: Technical Specifications*, (Draft for Comment), March 13, 1997.