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POSITION ON USE OF THE ROD POSITION INFORMATION SYSTEM FOR POST-ACCIDENT MONITORING

Prepared for the BWR Owners' Group
by GE Nuclear Energy

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Prepared by: Jason Post
Jason Post, Project Manager

Approved by: S. J. Stark
Steven J Stark, BWROG Programs Manager

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ABSTRACT

Current BWR Rod Position Information Systems (RPIS) are designed consistent with Regulatory Guide 1.97, Revision 3, requirements that it be a Type B, Category 3, variable. An event at Nine Mile Point Unit 2 in August 1991 has caused the Staff to question if the current design is adequate. The information provided to the operator by RPIS, if available, is used in execution of plant specific EOPs. A spectrum of events is evaluated, within and somewhat beyond plant licensing bases, considering RPIS to both function properly and to fail, in order to determine the importance of the system for post-accident monitoring. The BWROG concludes that the existing design criteria is appropriate and consistent with the importance of the system for post-accident monitoring.

1.0 INTRODUCTION

1.1 Background

The Control Rod Position Information System (RPIS) has been classified by the NRC in Regulatory Guide 1.97, Revision 2, which was issued as an active guide in December 1980, as a Type B, Category 3 instrument. The current BWR RPIS designs fully comply with the Reg Guide 1.97, Revision 2, requirements.

The event on August 13, 1991 at Nine Mile Point Unit 2 (NMP-2), which is described in Reference 1, has led to several Staff concerns regarding reactivity monitoring. Specifically, the Staff requested an assessment of the impact of the NMP-2 event on the proposed NMS post-accident functional criteria documented in NEDO-31558, "Position on NRC Regulatory Guide 1.97, Revision 3, Requirements for Post-Accident Neutron Monitoring System", March 1988 (Reference 2). The BWROG evaluation was provided to the Staff in Reference 3, and was discussed with the Staff at a meeting held on March 11, 1992. At that meeting, the Staff concern over RPIS was discussed. Following the meeting, the Staff action plan to respond to the NMP-2 event, which includes an issue related to the RPIS, was provided to the BWROG (Reference 4).

As a result of the March 11 Committee meeting with the Staff and subsequent BWROG/NRC management discussions, the BWROG agreed to assess the adequacy of the existing RPIS for post-accident monitoring.

1.2 Purpose of Report

The purpose of this report is to provide BWROG input on Issue 2, Action c, of the NRR Staff Action Plan included with the memo from James Taylor, Executive Director for Operations, to Thomas Murley, Director, NRR, et.al., January 6, 1992 (Reference 4). The stated action is: "Evaluate the need to provide an alternate Rod Position Indication (RPI) or safety-grade power [to RPI] for BWRs."

This issue came about as a result of a scram event caused by an electrical power transient at Nine Mile Point Unit 2 (NMP-2) on August 13, 1991, which resulted in the loss of power to a significant number of instruments including the Rod Position

Information System (RPIS. The common mode Uninterruptable Power Supply (UPS) failure for undervoltage conditions was unique to NMP-2 and has been resolved with the licensee. However, the operator response to this scram event was made more difficult by the loss of RPIS (and other) instrumentation and has resulted in this assessment of the adequacy of RPIS for post-accident monitoring.

The BWROG has undertaken a task to evaluate the importance of the RPIS for post-accident monitoring to determine if the existing design basis for RPIS is acceptable. The BWROG approach is to use an event based analysis to evaluate the importance of RPIS, and thereby make a judgement as to the adequacy of the current RPIS design bases. This RPIS evaluation employs the same methodology as was used to determine appropriate post-accident monitoring functional criteria for the Neutron Monitoring System (NMS) (Reference 2). A range of plant events is considered up to and somewhat beyond the plant licensing basis. An impact assessment for each event, which considers the difference in plant and operator response between having RPIS available/unavailable, is used to determine the importance of the RPIS for post-accident monitoring. The BWROG Emergency Procedure Guideline, Revision 4 (Reference 5), is used as the basis for evaluating the operator actions both with and without RPIS available.

This report is generally applicable to all BWR/2-6s even though some plant design differences exist in RPIS system and component design.

1.3 Sponsoring Utilities

This report has been generated by the Regulator Guide 1.97/Neutron Monitoring System (RG1.97/NMS) Committee of the BWROG. The sponsoring utilities of this activity are identified below:

Boston Edison Company
Carolina Power & Light Company
Cleveland Electric Illuminating Company
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Nebraska Public Power District
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Niagara Mohawk Power Corporation
Northern States Power
Philadelphia Electric Company
Public Service Electric & Gas Company
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Tennessee Valley Authority

2.0 RPIS DESCRIPTION AND DESIGN BASES

2.1 General

Control rods are used to regulate neutron flux distribution and power level within the reactor core by moving the control rods according to a predetermined pattern and sequence. Improper control rod positioning could result in uneconomic fuel consumption or possible damage to the fuel and fuel assemblies. To prevent operator errors during control rod movements, reactor performance and control rod positions are constantly monitored by systems that either give an alarm demanding operator attention, or which completely block control rod withdrawals until the error has been corrected.

A necessary prerequisite of the operator actions to maneuver control rods and the associated automatic monitoring functions is to know the position of each control rod. This information is provided by the RPIS. RPIS is essential for normal reactor operating modes, and is one of the power generation systems, but it is not a part of the Reactor Protection System (i.e. RPIS does not cause a reactor scram).

The RPIS is best described by separating the BWR/6 design from the BWR/2-5 designs because there are substantial differences, though many similarities, between the two designs. The regulatory requirements and the design descriptions of the RPIS are provided in the following sections.

2.2 Design Description

2.2.1 BWR/2-5 RPIS Design Description

For BWR designs prior to BWR/6, the RPIS is part of the Reactor Manual Control System (RMCS). The RMCS consists of two major subsystems:

- o The Control Rod Drive Control System (RDCS) which includes the Rod Block Trip System.

- o The Rod Position Information System (RPIS) which electronically processes data from the Control Rod Drive (CRD) assembly position and indicator probe, and distributes the processed data to operator displays, annunciators, the plant computers, and the Rod Worth Minimizer (RWM).

The RMCS is a power generation system and is not classified as safety related. The design bases of the RMCS are:

- o To inhibit further control rod withdrawal after an erroneous control rod manipulation and thereby avoid local fuel damage or a reactor scram,

- o To provide the means for reactor operators to determine control rod position and achieve desired control rod patterns,

- o To provide an indication of control rod drift (failure to lock into position), and

- o To ensure that no system failure negates the effectiveness of a reactor scram (if required by the Reactor Protection System).

The RMCS is not required for any plant safety function, nor is it relied upon to operate during or following any design basis accident or transient event. The power generation design basis of the RPIS is to ensure that the operator is provided with the means to achieve prescribed control rod patterns. This is achieved by providing information pertinent to the position and motion of control rods on displays in the control room and to other systems which limit and regulate control rod position, such as the RWM and the Rod Sequence Control System (RSCS).

As a component of the RMCS, the RPIS is a non-Class 1E system. The RPIS is designed so that system failures will result in rod blocks to prevent further control rod withdrawals. It is designed to be highly reliable because of its importance to normal plant operations.

The RPIS consists of the position probes and the electronic hardware and software that process the probe signals. The system operates on a continuous scanning basis with a complete cycle typically every 45 msec. Control rod position information is provided by the system to various plant computers, operator displays, annunciators, and other subsystems within the RMCS.

The position probe is a long cylindrical assembly that fits inside the CRD. It includes 53 magnetically operated reed switches, located along the length of the probe. The control rod has 48 increments over its 12 foot length (one position every 3 inches), though it only locks at the even numbered notched positions (or every 6 inches). There is one reed switch at each increment, plus an extra switch at Notch 48 (full out), two additional switches at Notch 00 (full in), one switch at beyond full in, and one switch at beyond full out (48+1+2+1+1=53).

The reed switches in the position probes are operated by a permanent magnet fixed to the moving part of the hydraulic drive mechanism. As the drive and control blade move into and out of the core, the magnet causes reed switches to close as it passes over the switch locations. The closed reed switch indicates the position of the control rod drive and hence of the control blade.

The reed switches at the notch position indicate when the drive is in a locked position. The reed switches at the mid-notch positions are used to indicate if rod drift occurs. The overtravel position can be used to provide drive-to-rod coupling indication since the drive cannot be physically withdrawn to the overtravel position when they are connected.

The control rod information display in the control room on the reactor control panel is patterned after a top view of the reactor core. The display is designed to facilitate the operator's ability to rapidly determine rod position, but varies in actual design between plants. For some plants, the numerical position of each rod in the core is indicated across the face of the full core display. Some plants have lights for each control rod

which indicate the position of that control rod by color. For example, a green light means the rod is fully inserted, and a red light means the rod is fully withdrawn. Some plants have both a numerical position and an indicating light for each control rod on the full core display.

In addition to the full core display, many plants have a four-rod display (some plants which have the numerical position of each control rod shown on the full core display do not have an additional 4-rod display). The rod group which is shown on the 4-rod display is selectable by the operator. The numerical position of the four rods in the selected group are indicated on the display. They are shown on the display in the same geometric arrangement that exists in the core. When a control rod is selected for movement, it is shown on the 4-rod display along with the other three rods in the group. The 4-rod display is a scanned electronic system. The local LPRMs near the selected rod are also displayed in conjunction with the 4-rod display to facilitate the operators ability to monitor local neutron flux changes when the selected rod is moved.

Additional tools used by the operator to monitor control rod position are various plant computers. Plant computers are supplied the position of each control rod by the RPIS and can display or print the rod position information depending upon the function of the plant computer. For example, a plant computer will have all the RWM information on rod sequences for plant operation, administrative controls, and rod patterns to avoid high rod worth and limit the magnitude of potential control rod drop accidents (CRDA). There is also a plant computer which performs the core axial and radial power distribution calculation using control rod position as well as power, core flow, and other heat balance information.

2.2.2 BWR/6 RPIS Design Description

For BWR/6 designs, the RPIS is part of the Rod Control and Information System (RC&IS). The RC&IS consists of three major subsystems:

o The Rod Action Control System (RACS), which imposes restrictions on rod movements to minimize the effects of a postulated control rod drop accident.

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- The Rod Gang Drive System (RGDS), which provides signals to the control rod solenoid valves for all rod movements except scram.

- The Rod Interface System (RIS), which provides the man-machine interface on the control panel.

The RACS has two subsystems:

- The Rod Position Information System (RPIS), which provides the RC&IS with control rod vertical position information.

- The Rod Pattern Controller (RPC), which provides permission to move control rods based on built-in tables of permitted rod patterns.

The power generation design basis of the BWR/6 RC&IS is basically the same as the power generation design basis of the BWR/2-5 RMCS. The RC&IS is designed to the following bases:

- The circuitry provided for the manipulation of control rods shall be designed so that no single failure can negate the effectiveness of a reactor scram.

- Repair, replacement, or adjustment of any failed or malfunctioning component shall not require that any element needed for reactor scram be bypassed unless a bypass is normally allowed.

- Further control rod withdrawal after an erroneous control rod manipulation is inhibited.

- Reactor operators can determine control rod position and manipulate control rod position to achieve desired control rod patterns.

- Control rod drift (failure of a control rod to lock) will be indicated.

The BWR/6 design is different from earlier designs in that the RPIS is a two channel system, rather than a single channel system as in BWR/2-5. The BWR/6 design has a two channel RPC to provide redundant regulation of acceptable control rod patterns.

[illegible]

Therefore, the RPIS was also designed as a two channel system to maintain redundant input to the two channel RPC.

The RPIS consists of the position probes and the electronic hardware and software that process the probe signals. The system operates on a continuous scanning basis with a complete cycle typically every 60 msec. Control rod position information is provided by the system to various plant computers, operator display, annunciators, and other subsystems within the RC&IS.

The RPIS position indication is supplied by magnetically operated reed switches inside the rod position probes, just as in earlier designs. The position probe is a long cylindrical assembly that fits inside the CRD. However, for BWR/6, each position probe has two complete sets of reed switches for redundant indication of the control rod position. The two sets of reed switches are electrically and mechanically separate within a common enclosure.

Each set of reed switches includes 53 magnetically operated switches which are placed at the same locations along the control rod as described above for pre-BWR/6 designs. The reed switches in each probe are operated by a permanent magnet which is fixed to the moving part of the hydraulic drive mechanism. As the drive and the control blade move along its length, the magnet causes the reed switches to close as it passes over the switch locations. The particular switch that is closed indicates the position of the drive and hence of the control blade.

Reed switches in the probe are provided at each 3-inch increment of rod travel. The notch positions are every 6 inches, the half-notch positions are used to indicate if rod drift occurs. The overtravel position can be used to provide drive-to-rod coupling indication since the drive cannot be physically withdrawn to the overtravel position when they are connected.

The rod information display in the control room on the reactor control panel is patterned after a top view of a reactor core. The BWR/6 full core display has both position indication for each control rod and lights to indicate if the rod is fully inserted or fully withdrawn. The position indication for all rods is via a selector switch which must be depressed to show all rods simultaneously. For BWR/6 displays, the control rod position data is automatically alternated between the two RPIS channels. The alternation

[illegible]

rate is designed so that if there are discrepancies between the channels, they will be readily apparent to the operator.

The, rod or rod group which is selected by the operator is shown on the display. The rods are shown in the same geometric pattern that exists in the core. When a rod is selected for movement, it is displayed on the full core display. If gang mode is selected, then the selected group (consisting of one, three, or four rods) is displayed. The LPRM near the selected control rod is also shown on a separate display near the lower corner of the full core display. When control rods are moved in gangs, proper motion of ganged rods is directly indicated by observing position changes indicated on the full core display.

2.3 Use by Reactor Operators

The RPIS is used every time a control rod is moved during normal operation (i.e., whenever control rods are being moved to a new position). The RPIS is used in the performance of various Technical Specification surveillances as described in Section 3.2 of this report. The frequency of its use during normal operation provides a high assurance that any system problems will be promptly uncovered and remedied.

The RPIS provides inputs to other systems described above, which determine if errors in control rod withdrawal have occurred, and thus prevent further withdrawals until the error has been corrected. The RPIS also provides indication of abnormal operation including a drifting control rod, rod coupling integrity, and scram success in inserting all control rods. The post-accident use of RPIS and its relation to the emergency procedures is further discussed in Section 4.

2.4 RPIS Power Supplies

For pre BWR/6 designs, RPIS power is typically supplied by an uninterruptable power supply (UPS). Typically, the UPS which routes power to the RPIS is a vital AC supply. Therefore, even though the UPS is typically not safety related, consistent with the non-safety design basis of the overall system, it does have a backup power supply such as a diesel or station battery, or UPS battery. This provides high assurance that power will be available to the RPIS even when off-site power is lost.

For BWR/6, power to the RPIS is typically from a Class 1E bus. Each channel of the RPIS is connected to separate 1E busses. Each Class 1E bus is designed with emergency diesel generator (EDG) and/or station battery backup power supplies. Since a redundant display of control rod positions on the main operator control board is not necessary to support two channel RPIS input to the two channel RPC, the display is typically powered by an UPS which has backup power supplies, but it is not powered from a 1E bus like the rest of the RPIS.

2.5 Potential for Control Rods to Drift

An evaluation of the importance of RPIS for post-accident monitoring must also consider the potential for control rods to move during the course of an event. There are two types of events to consider: a) an event where the control rods inserted correctly on a scram signal, and b) an event where there was some failure of control rods to correctly fully insert (commonly referred to as an ATWS event). Both of these events must be considered in light of the robust BWR control rod latching mechanism.

Each control rod is attached to an individual Control Rod Drive (CRD) which moves the control rod in and out of the core along an index tube which has a notch machined into it every six inches. The control rod has a latching mechanism, much like the ratchet on a winch to engage the notches: When a rod is at rest (not moving) the weight of the rod rests on one of the machined notches, with the latch engaged; When the control rod is inserted, hydraulic pressure slides the control rod in and the latch clicks over the notches until the insert pressure is removed, and the control rod settles into the new notch; When the control rod is withdrawn, the control rod must be <u>inserted</u> sufficiently to remove the weight of the rod from the notch it is resting on, the latch is disengaged, and the control rod is hydraulically withdrawn; When the withdraw pressure is removed, the latch reengages the index tube and the control rod settles of its own weight into the new notch.

This locking mechanism has proven to be very reliable in plant operation. Rod drift has occurred on some occasions when a single control rod is being withdrawn and it fails to lock when the hydraulic drive-out pressure is removed. It, therefore, is withdrawn further than intended. However, this has only happened where an operator has taken deliberate action to unlatch a control rod and withdraw it to a new position (for example

during a plant startup). Rod drift has not happened to rods that are being inserted either individually or via a reactor scram.

Some plants have also experienced rod bounce following scram, where a number of control rods have locked at Notch 02 instead of fully inserted at Notch 00. The plants that have experienced this problem have determined that they are shutdown with margin even if all the control rods inserted and locked at Notch 02. Furthermore, once locked in a position, the rods have not withdrawn further until commanded by the operator.

Therefore, for scram events, the operator would like to determine control rod position immediately after the scram. Long-term determination of control rod position for events with a successful scram is not important since the rods lock into place and universal plant experience is that they do not withdraw until commanded to do so.

For ATWS events, the operator would like to determine control rod position immediately after the event, and for the time during which the operator takes actions to insert control rods. However, if rod position indication is lost sometime during the event while the operator is attempting to insert control rods, the operator knows that control rod position can only improve. The locking mechanism prevents the rods from being further withdrawn until the operator purposefully withdraws them.

3.0 REGULATORY REQUIREMENTS

3.1 Code of Federal Regulations

Appendix A of 10CFR50 provides General Design Criteria (GDC) which establish minimum requirements for nuclear power station systems. Most of the GDC are general and applicable to more than one system. Those which set general requirements encompassing the RPIS are as follows:

o GDC 13, Instrumentation and Control

Requirement: Instrumentation must be available to monitor variables over anticipated ranges, including variables and systems that can affect the fission process.

Applicability: Control Rods affect the fission process and the RPIS is the instrument provided in compliance with GDC 13 to monitor the system.

o GDC 24, Separation of Protection and Control Systems

Requirement: The protection and control systems must be separated to the degree that the control system will not prevent the safety system from performing the intended function.

Applicability: In compliance with GDC 24, the RPIS is designed to ensure that any single failure in the system does not degrade the scram safety function.

3.2 Technical Specifications

There are several reactivity control system technical specifications (TS) which cannot be performed unless RPIS is operable, and which assure that RPIS is frequently checked to confirm continued operation. The applicable requirements are extracted from the new updated technical specifications (Reference 6) and are described below.

It is appropriate to use the proposed updated TS since most plants will be implementing them in the future and the new requirements are reasonably consistent with the existing plant TS. Existing TS may require more actions or surveillances involving RPIS and implementation of the improved TS may relax some surveillance intervals or remove some surveillance requirements. Therefore, it is conservative to base this report on the updated TS.

The BWR/4 requirements from the update TS related to RPIS are as follows:

TS 3.1.2 Control Rod Operability

Contains a surveillance requirement (SR) to determine control rod position every 24 hours, each rod that is fully withdrawn must be tested by inserting it at least one notch every 7 days, and each rod that is partially withdrawn must be tested by inserting it at least one notch every 31 days.

TS 3.1.5 Control Rod Drive Coupling

Contains a SR to ensure, each time a rod is fully withdrawn, that the rod does not continue to the overtravel position.

TS 3.1.7 Rod Pattern Controller (or Rod Sequence Controller)

This TS ensures that the rod sequence conforms to the Banked Position Withdrawal Sequence (BPWS). It contains a SR to verify that all operable control rods comply with the BPWS.

TS 3.9 Refueling Operations

This section of the TS contains several requirements for rods to be fully inserted, for a maximum of one rod to be withdrawn, and for all Full-In indicators to be operable.

TS 3.10 Special Operations

This section of the TS contains requirements for single control rod withdrawals during Hot Shutdown, Cold Shutdown, and Refueling. They include SRs to verify the position of every control rod every 24 hours.

The BWR/6 requirements are essentially the same as for the BWR/4. Both provide frequent assurance that RPIS is functional by the weekly checks on control rod operability. If there is a problem with the system, it will be discovered during the periodic use of the system and the problem corrected. The RPIS has to be reliable or the routine day-to-day power generation requirements could not be met and the plant could not be operated.

3.3 Other Regulatory Requirements

Regulatory Guide 1.97, Revision 2 has set post-accident monitoring requirements for the RPIS. Existing RPIS designs comply with these requirements. In Reg Guide 1.97, RPIS is classified as a Type B, Category 3 instrument. Type B are those instruments

which indicate whether a plant safety function is being accomplished (RPIS provides an indication of reactivity control). In general, key Type B variables are classified as Category 1 (the most stringent requirement) and backup variables are classified as Category 3. Category 3 is intended to ensure that high quality off-the-shelf instrumentation is used. Category 3 applies to backup and diagnostic instrumentation which is consistent with the Reg Guide 1.97 stated purpose of "Verification" of control rod position.

Plant Safety Analysis Reports (SARs) clearly state that the RPIS is part of a power generation system. The SARs also confirm the requirement that no single failure in the system can result in the prevention of a reactor scram when it is required. The RPIS, together with the other rod control systems, function to limit the worth of any single control rod to limit the effects of a postulated Rod Drop Accident (RDA) or any rod withdrawal error.

All plants are also required to have a Safety Parameter Display System (SPDS). The SPDS is integrated with the plant emergency procedures and control room design review to ensure that information needed by the operator to execute emergency procedure actions is available. Therefore, the SPDS also displays rod position information to the operator based on the rod position information supplied to the SPDS by the RPIS.

4.0 EVENT ANALYSIS TO DETERMINE RPIS POST-ACCIDENT MONITORING FUNCTION

4.1 Introduction

The purpose of the event analysis is to assess the importance of RPIS by examining how it is used in post-accident conditions by reactor operators. This includes examining the consequences of RPIS failure on the event progression and operator actions.

RPIS provides reactivity indication along with the NMS. Therefore, the impact of RPIS failures may depend upon the availability of the NMS in addition to the type of event that is postulated to occur. The impact of RPIS failure both when NMS is available and unavailable has been considered in this event analysis.

The mechanistic means by which the RPIS (or NMS) might fail are not considered. The analysis assumes the system is functioning properly or is completely unavailable. This assumption is supported by the feature that RPIS is more like a "digital" system than an "analog" system. Since RPIS indicates discreet positions with reed switches, there is no potential for the instrument to drift or be out of calibration. The instrument also cannot fail "upscale" or "downscale". This minimizes the potential for the instrument to provide misleading information to the operator; plant experience is that lights may burn out or displays may go blank, but the system does not provide erroneous position indication while appearing to be functioning correctly.

The scope and selection of events is described in Section 4.3. The event analysis includes a range of postulated events where the operator may want to use RPIS for post-accident monitoring. The range of analyzed events extends to and somewhat beyond the licensing basis of BWRs.

4.2 Emergency Procedure Instructions

The top-level instructions for the operator's response to significant transient and accident events are contained in each plant's Emergency Operating Procedures (EOPs). Supplemental plant procedures provide more detailed system operating instructions, but these instructions must not conflict with the top-level EOP instructions. Each plant has based their plant unique EOPs on the generic BWROG EPGs. The EPGs contain the fundamental actions based on symptomatic conditions that plant operators must take in response to postulated events. This analysis is based on EPG Revision 4 (Reference 5).

The EPGs address conditions both less severe and more severe than design basis accident conditions. For example, the scope of EPG development included instructions to mitigate events when the reactor is not shutdown, when power is still high, and when the operator cannot determine shutdown status or power level. The EPGs do not specify which instruments are to be used to determine the values and trends of specific parameters. Detailed guidance to operators on use of instruments is covered in operator training. It is anticipated that the operator would use the RPIS, if available, to determine control rod position while executing the EOP actions.

Within the scope of EPG actions, the operator may use the RPIS to determine the following information:

1. Determine if control rods are inserted sufficiently to ensure that the reactor is shutdown now and will remain shutdown during a cooldown evolution. This can be an indication that all rods are fully inserted, all rods are fully inserted except one rod is stuck out, all control rods inserted to at least the Maximum Subcritical Banked Withdrawal Position (MSBWP), or control rods are inserted in a pattern that the operator recognizes as ensuring reactor shutdown. The MSBWP is a parameter designed specifically for the EPGs to aid the operator in determining when the reactor is shutdown and will remain shutdown during a reactor cooldown. The MSBWP is typically Notch 02.

2. Determine if the reactor is critical or if the reactor is shutdown. This determination is based on operator experience with rod patterns during startup and shutdown. The operator uses the indicated pattern to make a judgement regarding the severity of the event. If the rod pattern is not recognized by the operator as indicating whether the reactor is shutdown, an evaluation by the Reactor Engineer may be required in order to make this judgement.

3. Determine which rods need to be driven into the core following a scram failure and determine the success of actions being taken to drive control rods. This information would be very useful to the operator taking mitigating actions during a scram failure event.

In the event that control rods are not fully inserted, EOPs provide multiple actions which can be taken in attempts to drive control rods. These include methods which will drive individual control rods and methods which will universally drive all control rods. Individual rod methods include de-energizing the scram solenoids, opening individual scram test switches, individually driving control rods, and venting control rod drive overpiston volumes. Methods to drive multiple rods include venting the scram air header, resetting the scram, draining the scram discharge volume, initiating a manual scram, and increasing the control rod drive (CRD) cooling water differential pressure. Following a scram failure, the immediate indication on RPIS will be that all rods are not inserted. This will be sufficient to initiate EOP actions to mitigate the scram failure.

Long-term monitoring of control rod position would be useful to determine the success of control rod insertion actions, but is not necessary to ensure that ATWS mitigative actions are performed.

4.3 Selection of Events

A broad spectrum of events has been considered in establishing the events which are analyzed to determine the importance of RPIS. These include all FSAR transient and accident events as well as ATWS and other events beyond the plant design basis to be consistent with the methodology used on the NMS post-accident monitoring evaluation (Reference 2). The evaluated event categories include:

- Transients with scram
- Accidents with scram
- Transients without scram
- Other occurrences without scram

In general, these are events which occur with the reactor operating at full power. "Transients without scram" includes both events where no control rods are ever driven into the reactor core and those events with some or delayed control rod insertion. "Other occurrences without scram" assume that the operator is eventually able to insert control rods. Reactivity events such as rod withdrawal errors and control rod drop accidents have been considered in the "Accidents with scram" category. Other events such as a Loss of Coolant Accident (LOCA) with a scram failure have not been considered credible events for this analysis, since they are of very low probability and are outside the scope of ATWS requirements.

Events within each category have been selected for analysis. The events selected are bounding for the post-accident assessment of RPIS functionality in that together, they meet the following criteria:

1. The shutdown status information provided by RPIS would be most useful to the operator.

2. The spectrum of actions related to post-accident shutdown status are exercised.

3. The spectrum of conditions the operator must evaluate to determine appropriate actions if the RPIS were to fail are exercised.

4. The impact on plant parameters and operator actions if the RPIS were to fail are maximized.

For these events, the postulated post-accident failure of RPIS is defined to be loss of all system indication, including the electronic input to the SPDS, process computer, and other related systems.

4.4 Events Analyzed

The events analyzed are described below. The event discussion includes the operator actions, the impact of a RPIS failure on the plant response, and the impact of losing all reactivity control instrumentation for the event.

4.4.1 Transients With Scram

1. Feedwater Controller Failure - Maximum Demand

Description: A feedwater controller failure increases feedwater flow to the maximum the system can deliver. With excess feedwater flow, core inlet temperature decreases and water level rises to the high level main turbine and turbine-driven feedwater pump trip setpoint. The turbine trip causes a reactor scram signal. The high water level trip occurs before the temperature decrease causes an increase in neutron flux to reach the high flux scram setpoint.

Operator Actions: Following turbine trip, the operator enters the EOPs for RPV control (level, pressure, and power) following turbine trip on the high RPV pressure signal (above the high RPV pressure scram setpoint). The EOP actions are: confirm automatic actions, establish high pressure injection systems for long-term maintenance of RPV water level, control reactor pressure and begin a reactor cooldown with the turbine bypass valves, and monitor and control reactor power. The EOP actions related to power control are complete as soon as it is determined that the reactor is shut down.

Control rods "Full-In" indication would immediately confirm reactor shutdown. The APRMs would trip downscale and the operator could not use the NMS to confirm reactor shutdown until the SRMs or IRMs had been driven into the core. (Note: plants with an ex-core NMS that extends to the shutdown range, or plants with fixed in-core SRM and IRM detectors, can use NMS to determine shutdown status without waiting for detectors to be driven into the core.)

Impact of RPIS Failure: With a RPIS failure, the operator could not determine that all the control rods were fully inserted. Inability to determine that the reactor will remain shutdown under all conditions will transfer water level control from the Reactor Level control (RC/L) portion of the procedure to the Level/Power control (Contingency #5) for ATWS conditions. This transfer would have little impact on water level control since the operator could determine that reactor power was below the APRM downscale trip setpoint (e.g. 3% reactor power) and it would not be necessary to reduce reactor water level to control reactor power. The operator would also execute the Reactor Power control (RC/Q) portion of the procedure. Actions in RC/Q to place the mode switch in SHUTDOWN and runback recirculation pumps are normal actions taken by the operator following a scram. The operator is told to initiate the Alternate Rod Insertion system (ARI), but this is performed quickly and has no deleterious effect if the reactor has already scrammed. The RC/Q action to inject liquid boron would not be required for this event since the operator can determine that power is low and there is no suppression pool heatup. Additional RC/Q actions to insert control rods by various means would be required, but would not be a high priority since all indications are that power has been reduced to the decay heat range. The Reactor Pressure control (RC/P) portion of the procedure would not permit the operator to begin a controlled reactor cooldown until it was determined that the reactor was shutdown. Since it is not known that all control rods are inserted due to the RPIS failure, the operator would use SRMs and IRMs to determine that the reactor is shutdown prior to commencing a reactor cooldown. The net effect on the plant response to a loss of RPIS for this event is minor, and significant unnecessary operator actions to mitigate ATWS conditions would not be required.

Impact of Lost RPIS and NMS: If both RPIS and NMS indications are lost, the operator actions in C#5 would be slightly more complicated since the operator would be forced to rely on alternate indications (the number of turbine bypass valves open, reactor pressure trend, etc.) to determine that reactor power was below the APRM downscale

trip. Unnecessary actions to lower water level in C#5 would not be required. Suppression pool heatup will not occur with all steam directed to the main condenser via the turbine bypass valves, so boron injection will not be required by RC/Q. The operator would not be permitted to begin a reactor cooldown by RC/P until some means other than NMS can be used to determine that the reactor is shutdown. The net effect on the plant response to a loss of RPIS and NMS for this event is minor, and significant unnecessary operator actions to mitigate ATWS conditions would not be required.

2. Turbine Trip With Bypass Failure

Description: A variety of malfunctions will cause a turbine trip. This trip will cause the turbine stop valves to close and initiate a reactor scram. With a turbine bypass failure, the reactor will pressurize until the SRVs open to relieve pressure and discharge energy to the suppression pool.

Operator Actions: The operator enters the EOPs for RPV control on the high RPV pressure signal. The EOP specified actions are: Confirm automatic actions, manually open SRVs to terminate SRV cycling (or confirm low-low set SRV operation), establish reactor high pressure injection for long-term maintenance of RPV water level, and monitor and control reactor power. As discussed above, the operator completes EOP specified power control actions as soon as it is determined that the reactor is shutdown (control rods are sufficiently inserted or neutron flux indication).

Impact of RPIS Failure: With a RPIS failure, the operator could not determine that all control rods were fully inserted. Inability to determine that the reactor will remain shutdown for all conditions will transfer water level control from RC/L to C#5. This transfer would have little impact on water level control since the operator could determine that reactor power was below the APRM downscale trip setpoint and it would not be necessary to reduce reactor water level to control reactor power. The RC/Q portion of the procedure would require the operator to place the mode switch in SHUTDOWN and runback recirculation pumps, which are normal actions following a scram. The additional action to initiate ARI is performed quickly and has no deleterious effect if the reactor has already scrammed. The RC/Q action to inject liquid boron would not be required for this event even with suppression pool heat up because the operator can determine that power is low. Additional RC/Q actions to insert control

rods by various means would be required, but would not be a high priority since all indictions are that power has been reduced to the decay heat range. RC/P would not permit the operator to begin a controlled cooldown until it was determined that the reactor was shutdown. The net effect on the plant response to a loss of RPIS for this event is minor, and significant unnecessary operator actions to mitigate ATWS conditions would not be required.

Impact of Lost RPIS and NMS: If both RPIS and NMS indications are lost, the operator actions in C#5 would be slightly more complicated since the operator would be forced to rely on alternate indications (the number of SRVs open, pressure trend, etc.) to determine that reactor power was below the APRM downscale trip. Unnecessary actions to lower reactor water level in C#5 would not be required. The suppression pool heatup associated with this isolation event would be moderate since the reactor is isolated from the main condenser, but is not expected to require unnecessary boron injection. The operator would not be permitted to begin a reactor cooldown by RC/P until some means other than NMS can be used to determine that the reactor is shutdown. The reactor pressure, steam flow, and injection makeup requirements, along with the suppression pool heatup rate will all be indicative of a decay heat generation condition. The net effect on the plant response to a loss of RPIS and NMS for this event is minor, and significant unnecessary operator actions to mitigate ATWS conditions would not be required.

This is similar in nature to the event that occurred at NMP-2 on August 13, 1991. The NMP-2 event also resulted in a loss of RPIS and NMS with the reactor isolated, though the operator was able to determine from back panel NMS indications that power was below the APRM downscale trip setpoint. The actual operator actions for that event confirm the conclusion that though the operator has entered the C#5 procedure, unnecessary ATWS mitigative actions to lower water level and inject liquid boron are not required.

4.4.2 Accidents With Scram

1. Large Break LOCA With Failure of One Division of ECCS

Description: The break causes immediate high drywell pressure and low RPV water

level signals. The plant scrams and begins a rapid depressurization through the break. The low pressure injection restores RPV water level. However, the initial water level drop may cause a significant core uncovery. Core reflood will be with a highly voided mixture inside the core shroud which swells water level above the top-of-active fuel (TAF). As the core is subcooled by the large amount of water injected, water level will settle out at just above the top of the jet pumps with the injection rate equal to the rate at which water is pouring out the break (BWRs without jet pumps rely on core spray to maintain core cooling in lieu of recovering water level above TAF).

Operator Actions: The initial operator actions for this event are relatively limited. The event occurs rapidly and the automatic systems are designed such that the operator does not have to take manual actions until the reactor is depressurized and low pressure ECCS is injecting. The operator cannot restore water level above TAF for this event. Therefore, the actions in the primary containment flooding contingency are executed to flood containment until water level can be restored above the TAF.

Impact of RPIS Failure: The automatic plant response to a large break LOCA occurs rapidly and there is little opportunity for the operator to interfere with the initial response. With a loss of RPIS, level control would be transferred from RC/L to C#5, but that transfer would not substantially change the level control actions. The operator would be allowed to maintain a slightly lower water level without resorting to primary containment flooding (at the Minimum Steam Cooling RPV Water Level instead of the TAF) and the flooding action might be avoided. This would not adversely affect plant safety since adequate core cooling is assured at the MSCRWL even if the plant were in fact shutdown. The RC/Q action to place the mode switch in SHUTDOWN is a normal post-scram instruction. The recirculation pumps will have already tripped, so that RC/Q instructions do not affect the plant response. SRM and IRM indication would not be expected to survive the event, but the APRM downscale trip indication should occur. Therefore, the RC/Q action to inject liquid boron will not be required. Other RC/Q actions to manually insert control rods will have a low priority for this event and not alter the event outcome. The RC/P actions will not be changed by a loss of RPIS since the reactor is already depressurized as a result of the event. The net effect on the plant response to a loss of RPIS for this event is minor, unless primary containment flooding is avoided in which case the operator response is simplified without adversely affecting plant safety.

Impact of Lost RPIS and NMS: If both RPIS and NMS were lost for this event, it would be extremely difficult for the operator to determine reactor power relative to the APRM downscale trip setpoint. The RC/L transfer to C#5 and the RC/P actions would not be affected. There could be a change to the RC/Q actions if the operator determines that boron injection is required because of the inability to determine reactor power. However, the operator would probably recognize the event from extensive operator training and practice on the simulator, and determine that the containment response is as expected for a DBA with power in the decay heat range, and boron injection might be avoided. Other than the potential unnecessary operator action to inject boron for a DBA LOCA and the possibility to avoid primary containment flooding described above, there is little impact on this event response for a loss of both RPIS and NMS.

2. Small Break LOCA With Failure of High Pressure ECCS and Loss of Off-Site Power

Description: The small break causes a containment pressurization above the scram setpoint. The loss of offsite power is assumed to cause a loss of feedwater and MSIV closure. RPV water level decreases due to decay heat boiloff and steaming through the break and SRVs. With failure of the high pressure systems, the RPV is depressurized by the automatic depressurization system (ADS) and low pressure systems restore RPV water level.

Operator Actions: The operator enters the EOPs for RPV control and containment control on the high drywell pressure scram signal. The EOP specified actions for RPV control are: confirm scram and isolation, attempt to restore high pressure injection systems, and manually open SRVs to terminate SRV cycling (or confirm low-low set SRV operation). When the operator determines that high pressure systems cannot be restored and low pressure systems are available, the operator will follow actions in the EOP to open SRVs to depressurize the RPV and restore RPV water level with low pressure systems. The operator may manually initiate reactor blowdown when water level reaches TAF, or may decide to let the ADS initiate in accordance with its automatic logic. The operator completes EOP specified actions related to power control as soon as it is determined that the reactor is shut down or RPIS indicates that control rods are sufficiently inserted.

Impact of RPIS Failure: With a RPIS failure, the operator could not determine that all control rods were fully inserted. This would transfer reactor level control from RC/L to C#5. The first action in C#5 is to prevent automatic initiation of ADS. This is to avoid an automatic blowdown followed by substantial cold water injection when the reactor is not shutdown. The RC/P actions will also be affected by a loss of RPIS for this event, since a controlled cooldown may not be initiated until it is determined that the reactor is shutdown. The C#5 action to deliberately lower reactor water level would not be required since NMS would indicate that the APRM downscale trip had occurred. With the loss of high pressure makeup systems, water level will be decreasing. It is possible that level will be lowered below TAF before emergency RPV depressurization manually is initiated due to the lower allowable level (the MSCRWL) in C#5. When it is determined that a blowdown is required, low pressure systems would be secured prior to the blowdown to avoid a cold water power excursion. Injection is carefully restored and increased once the reactor is depressurized. This is an unnecessary action for an event which has scrammed, but does not threaten plant safety. The RC/Q actions would be as described above for other scram events with a loss of RPIS. Liquid boron injection would not be required since NMS would indicate that power is below the APRM downscale trip setpoint. The net effect on the plant response to a loss of RPIS for this event is to unnecessarily complicate the low pressure level restoration in order to avoid a cold water power excursion, but other ATWS mitigation actions such as injecting liquid boron are not required: plant safety is not threatened by the loss of RPIS for this event.

Impact of Lost RPIS and NMS: If both RPIS and NMS indications are lost, operator actions would be more complicated since the presence of the small break would make it difficult to determine if power were below the APRM downscale trip setpoint. The RC/L transfer to C#5, the C#5 actions, the decision on when emergency RPV depressurization is required, the RC/P actions, and the actions to avoid a cold water power excursion would be the same as described above for a RPIS failure. With a loss of NMS, boron injection might be required in RC/Q due to the containment heatup from the event and the difficulty in determining if power is below the APRM downscale trip with a small break LOCA. With a loss of NMS, level reduction might also be required, but the loss of high pressure injection results in the event itself causing water level to be lowered. The net effect on the plant response to a loss of RPIS and NMS for this event is to unnecessarily complicate the blowdown/low pressure level restoration actions and to possibly require unneeded liquid boron injection, but plant safety is not threatened by the loss of these instruments for this event.

3. Control Rod Drop Accident (CRDA)

Description: The most limiting response to this event is when the reactor is at low power. During the normal process of withdrawing control rods, a high worth control rod sticks in the fully inserted position and becomes decoupled from its drive mechanism. After the drive is withdrawn, the rod frees and drops to the drive location. The rapid rod withdrawal causes a reactor power increase which is teminated by the negative feedback provided by the nuclear doppler effect. A high power signal scrams the reactor, which limits the total enthalpy increase in the fuel and prevents return to criticality. This event is considered in the fuel design and rod withdrawal control rod pattern control design. It is not a challenge for post-accident operator actions. The control rod withdrawal pattern and supporting plant systems (e.g. RWM) have been designed to ensure that reactivity insertions from a CRDA are limited such that a coolable geometry is maintained.

Operator Actions: Prior to the event, it is assumed that the operator is monitoring rod position and neutron flux while pulling control rods. Following the rod drop and automatic scram, the operator enters the scram procedure and uses RPIS to confirm that control rods are sufficiently inserted to ensure the reactor is shut down. This event does not generate an entry condition to the EOPs since it does not significantly affect RPV water level, RPV pressure, or drywell pressure.

Impact of RPIS Failure: If there was a loss of RPIS concurrent with the scram, then the operator would not be able to determine control rod position. NMS would indicate that power is below the APRM downscale trip setpoint, and there would still be no entry into the EOPs. The operator would continue in the scram procedure and try to restore the RPIS so that rod position could be determined. A RPIS failure would cause little impact on the plant response to this event.

Impact of Lost RPIS and NMS: If RPIS and NMS were both lost concurrent with the reactor scram signal, then the operator would not know if rods had been inserted or not. The operator would then use other indications to determine if reactor power was below the APRM downscale trip setpoint in order to determine if an EOP entry was required. Even if an EOP entry was made, there would be little impact on the operator response to the event.

4.4.3 Transients Without Scram

1. MSIV Closure With Complete Scram Failure

Description: During full power operation, all MSIVs close. MSIV closure generates a reactor scram. The scram is not successful; the reactor pressurizes until several SRVs open and discharge steam to the suppression pool. Plants with safety valves that discharge directly to the drywell may have these valves open briefly, depending upon plant capacity and specific plant incorporated automatic ATWS mitigation features to runback feedwater and trip recirculation pumps.

Operator Actions: The scram failure with MSIVs closed will give an EOP entry. The operator will place the reactor mode switch in "SHUTDOWN". If automatic ATWS features have not activated, the operator will initiate ARI and trip recirculation pumps. Without control rods inserted sufficiently to assure shutdown, water level control will be transferred from RC/L to C#5. The rapid and continued pool heatup (along with the reactor not shut down) will quickly generate an instruction to inject liquid boron. With reactor power well above the APRM downscale trip (approximately 3% power), the operator will lower RPV water level to reduce reactor power. The operator will also try to drive control rods into the core, though this event assumes there is no successful rod insertion. After liquid boron sufficient to assure cold shutdown has been injected, a 100 F/hr cooldown is begun. The hot and cold shutdown boron amounts are predetermined based on conservative concentrations and volumes and do not rely on neutron flux measurements.

Level/Power Control (C#5) also establishes a priority on injection systems. Outside the shroud injection systems are used in preference to inside the shroud systems to promote thermal mixing and avoid a potential power excursion that could result from injecting subcooled water into a core that is not shutdown. In addition, if emergency RPV depressurization is required, the EOP specifies actions to assure that excessive amounts of subcooled water are not inserted into the reactor.

During this event, the RPIS would be used to determine that all rods are not inserted and in fact an ATWS has occurred. RPIS would also be used to monitor the effectiveness of actions taken to manually insert control rods. NMS would be used to monitor power level and trends during the water level reduction, boron injection, and water level

restoration. Note that once boron injection has begun, it is not terminated until control rods are sufficiently inserted to assure the reactor is shutdown for all conditions, or the cold shutdown boron weight has been inserted.

Impact of RPIS Failure: If RPIS is lost for this event, then level control is transferred from RC/L to C#5, which is exactly where the operator should be. In other words, the loss of RPIS reinforces the entry into the ATWS portion of the EOP. In C#5, the operator will be required to lower reactor water level to reduce reactor power since NMS indication will show a high power level, well above the APRM downscale trip. RC/Q actions will be as described above for this event if the RPIS were functioning; all necessary ATWS mitigation actions, including liquid boron injection, would occur even if the RPIS were to fail. There is essentially no effect on the plant response to this event if the RPIS were to fail.

Impact of Lost RPIS and NMS: The EPGs have been written to address this type of event even if all reactivity instrumentation is lost. The operator would be required to execute actions to lower water level and inject boron for this event regardless of the operation of RPIS and NMS. There is essentially no effect on the plant response to this event if both the RPIS and NMS were to fail.

2. Inadvertent SRV Opening With Partial Scram Failure

Description: During full power operation, a SRV opens and fails to close. When the suppression pool has heated up to the pool temperature at which reactor scram is required, the operator manually initiates scram. With a partial scram failure, some of the control rods are inserted on the initial scram signal and/or the operator has success with manual attempts to drive control rods. The operator still follows the action specified in the EOPs, but the plant consequences are less severe than for the previous case with no control rod insertion.

Operator Actions: Suppression pool temperature above the limiting condition for operation (LCO) causes the operator to enter the containment control portion of the EOP. Actions to initiate pool cooling will not be sufficient to terminate the temperature rise and the operator will enter the RPV control EOP where the first instruction is to initiate a reactor scram. With a scram failure as indicated by RPIS and NMS, the

operator will follow the EOP power control instructions to place the mode switch in SHUTDOWN, initiate ARI, runback and trip recirculation pumps, inject boron with the standby liquid control system (SLCS) when the Boron Injection Initiation Temperature (BIIT) is reached, and attempt to drive control rods. Without control rod insertion sufficient to assure shutdown, water level control will be transferred to the Level/Power control contingency. The operator will use the main turbine bypass valves to control RPV pressure.

With a SRV open, reactor power still above the APRM downscale trip, and elevated suppression pool temperature, the operator will lower RPV water level per the C#5 instructions to reduce natural circulation and reduce generated power. When a pre-determined amount of boron has been inserted, or when a sufficient number of control rods have been driven in, RPV water level will be restored to its normal range and the operator will proceed to take the plant to cold shutdown.

The actual plant response would depend upon the extent and timing of control rod insertion. If the initial insertion was sufficient to reduce power below the APRM downscale trip, then the recirculation pumps would be run back but not tripped, and the reactor water level would not be lowered to reduce reactor power. Furthermore, liquid boron injection could be delayed until the suppression pool reached a hotter temperature, or even avoided if the BIIT was not reached.

If the initial control rod insertion was not sufficient to prevent boron injection, then RPV water level reduction and additional rod insertion could reduce power below the APRM downscale trip. This would allow for a less extensive water level reduction than for a complete scram failure. The RPIS would be used by the operator to determine which rods needed to be driven into the core and to monitor control rod position as rods are inserted.

Impact of RPIS Failure: If RPIS were lost, water level control would be transferred from RC/L to C#5, exactly as it should be for ATWS events. NMS would provide immediate indication that a scram failure had occurred if power was above the APRM downscale trip. If rod insertion was sufficient to reduce power to below the APRM downscale trip, then the operator would not know the extent of the scram failure when RPIS is lost since the NMS response may be very similar to that expected for scram events. The loss of RPIS also prevents the operator from using that direct indication of

the effect of control rod insertion actions. NMS indication would show neutron flux reductions as rods are successfully inserted. There is a moderate impact on the plant response to this event if RPIS were to fail because the operator may be less effective in actions to insert control rods following a scram failure when the current rod position cannot be determined.

Impact of Lost RPIS and NMS: If RPIS and NMS were both to fail for this event, the operator would need to resort to other indications of reactor power level. The operator would have less precision in determining reactor power if NMS were lost which might lead to an earlier boron injection, but the stuck open SRV does not unduly restrict the operators ability to estimate reactor power level. The effect of actions to insert control rods would be indirectly indicated on steam flow, pressure trend, etc., but the operator ability to insert rods would not be jeopardized. As above, there is a moderate impact on the plant response to this event if RPIS and NMS were to both fail because the operator would be less effective in actions to insert control rods.

4.4.4 Other Occurrences Without Scram

1. Recirculation Pump Seal Leakage and Failure to Scram When Initiated by the Operator

Description: During normal full power operation, a recirculation pump seal begins to leak excessively. The operator runs back recirculation pumps to minimum speed and manually initiates reactor scram. The scram does not occur.

Operator Actions: The operator enters the EOPs for RPV control when the scram does not occur. The operator uses feedwater to control reactor water level, trips the turbine and uses turbine bypass to control reactor pressure, initiates the alternate rod insertion system (ARI), trips recirculation pumps, and if ARI has not inserted them, attempts to manually drive control rods. The containment heatup for this event would be small because the reactor is not isolated from the main condenser and the drywell coolers prevent the leak from causing a substantial drywell temperature increase. Therefore, other ATWS mitigation actions such as boron injection and water level reduction would not be required. The operator would use RPIS to monitor rod position and NMS to monitor power/neutron flux as control rods are inserted. As power is reduced, the

operator would insert IRMs and SRMs to continue monitoring neutron flux until the reactor is fully shutdown. The EOP actions related to power control are completed as soon as it is determined that the plant is shutdown or RPIS indicates that control rods are sufficiently inserted.

Impact of RPIS Failure: With a RPIS failure, the operator could not determine to what extent control rods had not been inserted. Being unable to confirm control rod insertion, the operator would be instructed to enter C#5. Thus, the correct action path would be executed even if RPIS were lost for this event. The loss of RPIS also prevents the operator from using that direct indication of the effect of control rod insertion actions. NMS indication would show neutron flux reductions as rods are successfully inserted. There is a moderate impact on the plant response to this event if RPIS were to fail because the operator may be less effective in actions to insert control rods following a scram failure when the current rod position cannot be determined.

Impact of Lost RPIS and NMS: This event does not have a significant pool heatup, so level reduction and boron injection would not be required. The effect of actions to insert control rods would be indirectly indicated on steam flow, pressure trend, etc., but the operator ability to insert rods would not be jeopardized. As above, there is a moderate impact on the plant response to this event if RPIS and NMS were to both fail because the operator would be less effective in actions to insert control rods.

2. Loss of Drywell Coolers, Failure to Scram

Description: During normal full power operation, all drywell coolers simultaneously fail. The operator would begin to reduce reactor power to reduce the heat load on the drywell. However, the drywell heats up and pressurizes until it reaches the scram setpoint, where a scram is initiated. The scram does not occur.

Operator Actions: The operator enters the EOPs for primary containment control on high drywell temperature and for RPV control when the high drywell pressure scram signal occurs. If drywell temperature approached the limiting temperature defined in the EOPs, drywell spray would be initiated and/or the RPV would be blown down. With all rods not inserted, the operator would be following the C#5 procedure for water level

control; the operator uses feedwater to control reactor water level. RC/P stabilizes reactor pressure using the turbine bypass valves. RC/Q actions initiate the ARI system, trips recirculation pumps, determines when boron injection is required, and attempts to manually drive control rods. The operator would use RPIS to monitor rod position and NMS to monitor power/neutron flux as control rods are inserted. As power was reduced, the operator would insert IRMs and SRMs to continue monitoring neutron flux until the reactor was fully shutdown. The EOP actions related to power control are completed as soon as it is determined that the plant is shutdown or RPIS indicates that control rods are sufficiently inserted. High drywell pressure is one of the conjunctive criteria for lowering RPV water level, but there is no suppression pool heatup for this event, so neither water level reduction nor boron injection would be required.

Impact of RPIS Failure: With a RPIS failure, the operator could not determine to what extent control rods failed to insert. Being unable to confirm control rod insertion, the operator would be instructed to enter C#5. Thus the correct action path would be executed even if RPIS were lost for this event. Except for determining the effectiveness of actions to insert control rods, there is no other need for the RPIS for this event. The net effect on the plant response to a loss of RPIS for this event is moderate since it can affect rod insertion efforts.

Impact of Lost RPIS and NMS: If both RPIS and NMS fail for this event, the operator must resort to other means to determine if reactor power is below the APRM downscale trip. This event does not have a significant pool heatup, so level reduction and boron injection would not be required. The net effect on the plant response to a loss of RPIS and NMS is moderate since it can affect rod insertion efforts.

4.5 Event Analysis Conclusions

A summary of the events analyzed and the impact on the event response of the RPIS failure is shown in Table 1. The table also summarizes the impact if both RPIS and NMS were to fail. The RPIS is most important to the operator for events which may appear to have a scram failure when in fact they do not (a small break LOCA for example). RPIS is also important for events that provide an opportunity to insert control rods during scram failure events. The RPIS is not as important for events in which automatic actions occur very rapidly (a DBA LOCA for example) or for which there has

been a substantial scram failure and there is little question that ATWS mitigative actions are required (a MSIV closure ATWS for example).

Table 1. Summary of Events and Impact of RPIS Failure

Event	Operator Use of RPIS	Impact of RPIS Failure	Impact of RPIS and NMS Failure
Feedwater control failure, max demand	Confirm all rods are in	Enter ATWS EOP, but few actions required	Delay RPV cooldown
Turbine Trip with bypass failure	Confirm all rods are in	Enter ATWS EOP, but few actions required	Delay RPV cooldown
Large break LOCA	Confirm all rods are in	Enter ATWS EOP, but few actions required	Possible boron injection
Small break LOCA	Confirm all rods are in	Enter ATWS EOP, terminate and prevent injection prior to ADS	Expect boron injection and water level reduction to be required
Control Rod Drop Accident	Confirm all rods are in	None	None
MSIV Closure ATWS	Determine rod pattern	None	None
SORV Partial ATWS	Determine rod pattern, prioritize rods to drive	Less effective in driving rods	Earlier boron injection
Recirc pump seal leakage ATWS	Determine rod pattern, prioritize rods to drive	Less effective in driving rods	None
Loss of drywell coolers ATWS	Determine rod pattern, prioritize rods to drive	Less effective in driving rods	None

5.0 BWROG CONCLUSIONS

RPIS has been evaluated to have the most importance to the operator for successful scram events less severe than a DBA LOCA in which unnecessary ATWS mitigation actions might not be avoided if RPIS were to fail. It is desirable to avoid the unnecessary actions to inject liquid boron, lower reactor water level, and complicate level control actions if a blowdown is required, but the actions do not threaten plant safety.

RPIS has also been evaluated to be of moderate importance to the operator for scram failure events where there is an opportunity for the operator to insert control rods to improve the event performance. Using RPIS to determine which rods to insert and to monitor the effectiveness of rod insertion actions would facilitate the operators ability to perform these actions. However, these actions can still be performed even if RPIS failed.

The analysis has shown that the RPIS is of low importance for a DBA LOCA, a MSIV closure ATWS, and events that do not result in heatup of the suppression pool or primary containment.

The RPIS has proven to be a very reliable system over many years of plant operation. Frequent use of the system during normal plant operation increases the probability that the system will provide indication during plant events. The BWROG participating utilities judge that the reliability is adequate and commensurate with the evaluated importance of the instrumentation. Therefore, there is no basis for requiring an upgrade to the RPIS design.

6.0 REFERENCES

(1) "Transformer Failure and Common-Mode Loss of Instrument Power at Nine Mile Point Unit 2 on August 13, 1991", NUREG-1455, published: October 1991.

(2) Position on NRC Regulatory Guide 1.97, Revision 3, Requirements for Post-Accident Neutron Monitoring System, NEDO-31558, March 1988.

(3) Letter from Robert D. Binz IV, BWROG Chairman, to Ashok C. Thadani, NRC, "BWROG Assessment on the Impact of the August 13, 1991 Event at NMP-2 on the BWROG Proposed Neutron Monitor System Functional Criteria", BWROG 92-019, March 13, 1992.

(4) Memorandum from James M. Taylor, Executive Director for Operations to Thomas E. Murley, Director, NRR, et. al., "Staff Actions Resulting From The Investigation Of The August 13, 1991, Incident at Nine Mile Point Unit 2 (NUREG-1455)", Jan 6, 1992.

(5) "Emergency Procedure Guidelines, Revision 4", NEDO-31331, March 1987.

(6) Updated Technical Specifications

7.0 LIST OF ACRONYMS AND ABBREVIATIONS

ADS	Automatic Depressurization System
APRM	Average Power Range Monitor
ARI	Alternate Rod Insertion system
ATWS	Anticipated Transient Without a Scram
BIIT	Boron Injection Initiation Temperature
BPWS	Banked Position Withdrawal Sequence
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners' Group
C#5	Contingency Number 5
CFR	Code of Federal Regulations
CRD	Control Rod Drive
CRDA	Control Rod Drop Accident
DBA	Design Basis Accident
ECCS	Emergency Core Cooling Systems
EDG	Emergency Diesel Generator
EOP	Emergency Operating Procedure
EPG	Emergency Procedure Guideline
FSAR	Final Safety Analysis Report

GDC	General Design Criteria
IRM	Intermediate Range Monitor
LCO	Limiting Condition for Operation
LOCA	Loss of Coolant Accident
MSBWP	Maximum Subcritical Banked Withdrawal Position
MSCRWL	Minimum Steam Cooling RPV Water Level
MSIV	Main Steam Isolation Valve
NMP-2	Nine Mile Point Unit 2
NMS	Neutron Monitor System
NRC	Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
RACS	Rod Action Control System
RC&IS	Rod Control and Information System
RC/L	Reactor Control/Water Level
RC/P	Reactor Control/Pressure
RC/Q	Reactor Control/Power
RDCS	Control Rod Drive Control System
RGDS	Rod Gang Drive System
RIS	Rod Interface System
RMCS	Reactor Manual Control System
RPIS	Rod Position Information System
RPC	Rod Pattern Controller
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RSCS	Rod Sequence Control System
RWM	Rod Worth Minimizer
SAR	Safety Analysis Report
SLCS	Standby Liquid Control System
SORV	Stuck Open Safety Relief Valve
SPDS	Safety Parameter Display System
SR	Surveillance Requirement
SRM	Source Range Monitor
SRV	Safety Relief Valve
TAF	Top of Active Fuel
TS	Technical Specification
UPS	Uninterruptable Power Supply