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Subject: **Submittal of ABWR Licensing Topical Report (LTR) NEDO-33328 "Advanced Boiling Water Reactor (ABWR) APRM Oscillation Monitoring Logic"**

Reference: Letter MFN 017-97, J. Quirk to NRC, *ABWR Design Control Document, Revision 4*, dated March 28, 1997, Docket No. 52-001

The enclosed Licensing Topical Report (LTR) is submitted for NRC generic review and approval as a Combined License (COL) license information item as required by the current ABWR certified design (referenced), Docket No. 52-001. The regulatory basis for this submittal is discussed below.

This is the fourth of a number of ABWR-related LTRs GE plans to submit and which have been discussed in South Texas Project 3&4 project meetings with the NRC. In support of the ABWR Design Centered Working Group (DCWG) plans, GE requests a generic review and approval of the subject LTR in advance of any future combined license application (COLA) submittals. Note that the submittal is the result of design detailing performed for ABWRs in the US and in Asia and provides for the generic resolution of a COL license information item, thereby contributing to standardization.

The enclosed LTR provides a response to a COL license information item in Tier 2 section 7.6.3.1 instructing applicants to implement the APRM oscillation monitoring logic function in accordance with the BWR Owner's Group as described in Subsection 7.6.1.1.2.2. General Electric believes that all applicants would benefit from following the COL license information item resolution provided in the enclosure and that the NRC can and should provide a generic review and approval of the plan in advance of

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any COLA submittal referencing the USABWR DCD. Future applicants such as STP 3 & 4 could then reference the LTR as a means of meeting their COL license information item submittal requirement.

The enclosure contains no information that GE considers proprietary although full copyright protection applies.

If you have any questions about the information provided here, please contact Joe Savage, project manager - ABWR licensing, at 910-602-1885, or contact me directly.

Sincerely,

S. J. Stark for

Joseph A. Savage
Project Manager, ABWR Licensing

Enclosure: NEDO-33305 "*Advanced Boiling Water Reactor (ABWR) Startup Administrative Manual*" February 2007 - Non-Proprietary

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LICENSING TOPICAL REPORT

Advanced Boiling Water Reactor (ABWR) APRM Oscillation Monitoring Logic

INFORMATION NOTICE

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

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1.0 Introduction

The purpose of this Licensing Topical Report (LTR) is to obtain US Nuclear Regulatory Commission acceptance of the implementation of the long-term stability solution designated as Option III by the BWR Owner's Group (BWROG) in NEDO-31960-A, "BWR Owner's Group Long-Term Stability Solutions Licensing Methodology" (Reference 10.1) and NEDO-32465-A, "Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," (Reference 10.2) as an amendment committed in Tier 2 DCD Section 7.6.3.1 to the certified design of the U.S. Advanced Boiling Water Reactor (ABWR). This LTR submittal complies with the COL Item 7.2 to implement the APRM oscillation monitoring logic function in accordance with the BWROG's stability solutions. This proposed Option III design replaces the hybrid stability design solution (combining parts of Option I-A and Option III) described in the Tier 2 of the ABWR DCD. The Option III design was one of the long-term solutions developed by the BWROG to meet the stability design requirements specified in the Advanced Light Water Reactor (ALWR) Utility Requirements Document. The Option III design uses the Oscillation Power Range Monitor (OPRM) to provide the automatic protection against the core instability while the Option I-A design uses the Average Power Range Monitor (APRM) to mitigate instability events in the low flow and high power operating conditions.

This document first briefly describes the Certified OPRM design, and then describes changes to this design based on field experience and BWR Owner's Group evaluations. The NRC has endorsed the new revised OPRM Option III design.

1.1 Acronyms

ABWR	Advanced Boiling Water Reactor
ABA	Amplitude Based Detection Algorithm
ALWR	Advanced Light Water Reactor
APRM	Average Power Range Monitor
BSP	Backup Stability Protection
BWROG	BWR Owner's Group
COLA	Combined Operating License Application
DCD	Design Certification Document
GE	General Electric Company
GRA	Growth Rate Detection Algorithm
GR3	The desired maximum allowable growth rate
ICA	Interim Corrective Actions
LTR	Licensing Topical Report
LPRM	Local Power Range Monitor
MCPR	Minimum Critical Power Ratio
NUMAC	Nuclear Measurement Analysis and Control
OPRM	Oscillation Power Range Monitor
P/A	Peak to Average
PBDA	Period Based Detection Algorithm

P/F	Power/Flow
PRNM	Power Range Neutron Monitoring
RIP	Reactor Internal Pump
RPS	Reactor Protection System
SCC	Successive Confirmation Counts
SLO	Single Loop Operation
SLMCPR	Safety Limit Minimum Critical Power Ratio
THI	Thermal-Hydraulic Instability

2.0 Description Of The Certified Design

2.1 Thermal-Hydraulic Stability Performance

The GE analytical methodology for demonstrating stability compliance for GE fuel designs on a generic basis is described in Tier 2 DCD Subsection 4.4.3.7, "Thermal-Hydraulic Stability Performance." Implementation of the BWROG long-term stability solution Option III for providing additional assurance that Thermal-Hydraulic Instability (THI) oscillations will be reliably detected and suppressed, is described in Reference 10.1.

The Option III long-term stability solution is implemented by adding the Oscillation Power Range Monitor (OPRM) trip logic function within the Average Power Range Monitor (APRM) system. The OPRM trip logic function provides protection from exceeding the fuel Minimum Critical Power Ratio (MCPR) Safety Limit in the event of thermal-hydraulic power oscillations. The OPRM receives input signals from the Local Power Range Monitors (LPRMs) within the reactor core. An OPRM Trip is issued if oscillatory changes in the neutron flux indicative of regional (or core-wide) THI, are detected in the "OPRM Armed Region" of the Power/Flow (P/F) maps for ABWRs shown in Figures 1 and 2 for ten internal pump operation and nine internal pump operation respectively.

A plant cycle specific Option III stability analysis will be performed to determine the appropriate OPRM setpoints, following the guidance contained in Reference 10.2 and the BWROG guideline on regional mode oscillation (Reference 10.3). The analysis will consider steady state startup operation, the limiting case of internal pump trip from rated power. The effect of bypass voids on the LPRM response will be accounted for in the setpoint. The resulting stability based Operating Limit MCPRs, as a function of OPRM setpoint will be reported in the applicant's initial core operating limit report (COLR). The actual OPRM setpoint is selected such that the MCPR Safety Limit is protected.

If the automatic OPRM trip function should become inoperable, a Backup Stability Protection (BSP) methodology will be implemented in accordance with the Technical Specifications. The BSP methodology is described in Reference 10.4.

2.2 Oscillation Power Range Monitor of Certified Design

2.2.1 General Description

The OPRM is a functional subsystem of the digital-based (NUMAC-based) APRM instrument design. This component design, which implements the BWROG Option III stability solution, was described and endorsed by NRC in Licensing Topical Report NEDC-32410P-A, "Nuclear Measurement Analysis and Control Power Range Neutron Monitoring (NUMAC PRNM) Retrofit Plus Option III Stability Trip Function" (Reference 10.5). There are four safety related OPRM channels. Each OPRM channel is associated with an APRM channel in the same reactor protection division. Each OPRM channel receives identical LPRM signals from the corresponding APRM channel as inputs, and forms a special OPRM cell configuration to monitor the neutron flux behavior of all regions of the core. Each OPRM cell signal represents a combination of four LPRM signals selected from the LPRM strings at the four corners of a four-by-four bundle square region and from different LPRM elevations. A trip signal from any cell causes a trip signal from the OPRM channel, and a trip signal from any two of the four OPRM channels causes a reactor trip. The OPRM trips together with the APRM trips from the same APRM channel are sent to the Reactor Protection System (RPS) as inputs for generating reactor trips to protect the safety thermal limits.

2.2.2 Power Sources

Each OPRM channel receives power from the same divisional 120 Vac UPS bus as its associated APRM channel and reactor protection division (e.g. Division I bus for OPRM A, etc.).

2.2.3 Signal Conditioning

The OPRM utilizes the same set of LPRM signals used by its associated APRM. Assignment of LPRMs to the four OPRM channels is identical to the assignment of LPRMs to APRM channels, as shown in Table 1.

Table 1. Assignment of LPRM Inputs to OPRM Channels

LPRM Detector Location	OPRM Channel A	OPRM Channel B	OPRM Channel C	OPRM Channel D	LPRM Detector Location	OPRM Channel A	OPRM Channel B	OPRM Channel C	OPRM Channel D
20-61	B	C	D	A	60-37	D	A	B	C
28-61	C	D	A	B	04-29	B	C	D	A
36-61	B	C	D	A	12-29	C	D	A	B
44-61	C	D	A	B	20-29	B	C	D	A
52-61	B	C	D	A	28-29	C	D	A	B
12-53	D	A	B	C	36-29	B	C	D	A
20-53	A	B	C	D	44-29	C	D	A	B
28-53	D	A	B	C	52-29	B	C	D	A
36-53	A	B	C	D	60-29	C	D	A	B
44-53	D	A	B	C	12-21	D	A	B	C
52-53	A	B	C	D	20-21	A	B	C	D
60-53	D	A	B	C	28-21	D	A	B	C
04-45	B	C	D	A	36-21	A	B	C	D
12-45	C	D	A	B	44-21	D	A	B	C
20-45	B	C	D	A	52-21	A	B	C	D
28-45	C	D	A	B	60-21	D	A	B	C
36-45	B	C	D	A	12-13	C	D	A	B
44-45	C	D	A	B	20-13	B	C	D	A
52-45	B	C	D	A	28-13	C	D	A	B
60-45	C	D	A	B	36-13	B	C	D	A
04-37	A	B	C	D	44-13	C	D	A	B
12-37	D	A	B	C	52-13	B	C	D	A
20-37	A	B	C	D	28-05	D	A	B	C
28-37	D	A	B	C	36-05	A	B	C	D
36-37	A	B	C	D	44-05	D	A	B	C
44-37	D	A	B	C					
52-37	A	B	C	D					

Figures 3 through 6 shows the detailed LPRM assignments to the four OPRM channels, including the assignment of LPRMs to the OPRM cells. The OPRM cell is the small circle with arrows pointing to the LPRMs, which provide input to the cell. With this channel configuration, each OPRM cell receives four LPRM inputs from four LPRM strings at the four corners of the 4×4 fuel bundle square. This is called the 4P design as defined in Reference 10.2. These four LPRM inputs are from all four different elevations in the core (Elevation A, B, C, or D). For locations near the periphery where one corner of the square does not include an LPRM string, the OPRM cells use the inputs from the remaining three LPRM strings. The LPRM signals may be input to more than one OPRM cell within an OPRM channel. The LPRM signals assigned to each cell are summed and averaged to provide an OPRM signal for this cell. There are a total of forty-four (44) cells for each OPRM channel. The overall axial and radial distributions of these LPRMs between the OPRM channels are uniform. A trip in any cell causes a trip of the OPRM channel and trip of any two of the four OPRM channels causes a reactor trip.

The OPRM trip protection algorithm consists of trip logic depending on signal oscillation magnitude and number of confirmed oscillations based on the signal oscillation period. For each cell, the oscillation amplitude is determined by measuring the peak to average (P/A) value of the OPRM signal and is evaluated in the setpoint algorithm. The OPRM signal sampling and computation frequency is well above the expected thermal-hydraulic oscillation frequency, allowing for essentially a continuous and simultaneous measurement of thermal hydraulic oscillations in all OPRM cells.

2.2.4 Trip Functions

The OPRM uses the Period Based Detection Algorithm (PBDA), the Amplitude Based Detection Algorithm (ABA), and the Growth Rate Detection Algorithm (GRA) for detection of power oscillation instability. Only the Period-based algorithm is credited with providing a trip before the fuel MCPR safety limit is violated. The Amplitude-based and Growth-based algorithms are categorized as defense-in-depth features.

The PBDA calculation starts counting the oscillation cycles when it detects an OPRM signal oscillation with a period ranging between T_{max} and T_{min}. If the oscillation persists such that the cycle count exceeds its preset limit, or the Successive Confirmation Count (SCC) exceeds the setpoint (N_p), which is normally set between 8 and 16 counts and the normalized OPRM cell (P/A) signal (S) reaches the amplitude setpoint (S_p), which is normally set within the range from 1.05 to 1.15, a PBDA trip is initiated.

The ABA calculation begins when the normalized cell signal exceeds an amplitude setpoint (S_1). An oscillation condition is confirmed to exist when the signal decreases below a second amplitude setpoint (S_2) within a time period (t_1). If the signal reaches the maximum amplitude setpoint (S_{max}) within a time period (t_2) after oscillation confirmation, an ABA trip is initiated.

The GRA is similar to the ABA. A GRA calculation is initiated when the normalized cell signal reaches S_3 within the time period (t_2) after oscillation confirmation. S_3 is a function of the previous oscillation cycle (P_1) and the desired maximum allowable growth rate (GR_3).

The OPRM trips are summarized in Table 2. For the OPRM trip function, the response signal of any one OPRM cell that satisfies the conditions and criteria of the trip algorithm will cause a trip of the associated OPRM channel. Figure 7 illustrates the trip algorithm logics.

Table 2. OPRM Trip Function Summary

Trip Function	Trip Setpoint (Nominal)*	Action
Period-Based Detection Trip (S_p)	$S = S_p = 1.05$ to 1.15 $SCC = Np = 10$	Scram***
Amplitude-Based Detection Trip (S_{max})	$S = S_{max} = 1.30$	Scram***
Growth Rate-Based Detection Trip (S_3)	$S = S_3 = (P_1{**} - 1.0) \times GR_3 + 1.0$ $GR_3 = 1.3$	Scram***

* Other Pre-Trip condition parameters of the algorithm are shown in Figure 7 in details

** P_1 is the last peak reading measured after the signal S exceeds S_1

*** Automatically bypassed if outside of the Armed Region (defined as core power ≤ 30% or core flow ≥ 60%).

Each OPRM channel provides a scram trip signal when one or more of the trip algorithms for an operable OPRM cell have detected an instability condition. Each OPRM channel also provides an oscillation pre-trip alarm when one of the trip algorithms has exceeded a predetermined value. The OPRM channel does not have its own inoperative trip for insufficient number of total LPRM inputs in the channel, but instead uses the APRM's inoperative trip for insufficient number of LPRMs.

2.2.5 Bypasses and Interlocks

The OPRM channel bypass is controlled by the bypass of the APRM channel associated with it. Bypass of the APRM channel will bypass the OPRM trip function in the same APRM channel. The OPRM also has its own separate automatic bypass functions: (1) any LPRM input to an OPRM cell is automatically bypassed if this LPRM reading is less than 5% of the full scale LPRM reading; (2) any OPRM cell in an OPRM channel is automatically bypassed if the cell has fewer than two operable LPRM inputs; and (3) all OPRM channel outputs are automatically bypassed when the APRM reading of the same channel is below 30% of rated power or the core flow reading is above 60% rated flow. For trip purposes, there is no requirement as to how many cells per OPRM channel have to be active since this is controlled by the total number of active LPRMs in the APRM channel.

2.2.6 Redundancy

There are four independent and redundant OPRM channels, each channel is associated with one APRM channel and hence, to one RPS division. Any OPRM channel trip will initiate a divisional trip to be combined with other APRM divisional trip outputs in the APRM two-out-of-four (2/4) voter. The voter compares the combined divisional trip with the same combined trips from the other three divisions and provides a final divisional trip output to the RPS of the same division when more than two combined trips are detected. The redundancy criteria are met so that in the event of a single failure under permissible bypass conditions, a scram signal can be generated in the RPS as required. In addition, each LPRM string with four LPRM detectors provides one LPRM input to each of the four independent and redundant OPRM channels. This provides core regional monitoring by redundant OPRM channels.

2.2.7 Testability

Each OPRM channel can be tested individually for the operability of its trip functions by introducing test signals. The APRM self-testing function also includes testing operability of the OPRM channel.

2.2.8 Environmental Considerations

The OPRM equipment is designed to operate in environments described in Tier 2 DCD Appendix 3I. The OPRM equipment is capable of functioning during and after the design basis events in which continued OPRM operation is required.

2.3 BWROG/GE Design Activities Since Time of Certification

This section shows the BWROG activities that resulted in the proposed changes to the certified design.

2.3.1 Butterworth Averaging Signal Filter Time Constant

The OPRM design uses two filters in the signal-processing algorithm - an Averaging Filter used to determine the average (A) of the P/A ratio, and a Conditioning Filter for obtaining the peak (P) value of the thermal-hydraulic oscillation signals. During the early stages of the OPRM design GE discovered that the time constant of 6 seconds (equivalent single pole filter) specified (Reference 10.2) for the Averaging Filter was too high by about a factor of 2π and the system response was too sluggish to monitor the oscillations. Subsequently, based on BWROG evaluations, a shorter time constant of approximately 0.95 seconds was specified. The actual OPRM design uses a second-order Butterworth filter with a cut-off frequency (3 dB) of 0.167 Hz for the Averaging Filter. This filter is a high performance filter with a sharper cut-off frequency characteristic than the single pole filter (like that used for the APRM simulated thermal power signal). The Butterworth second-order filter with a cut-off frequency of 0.167 Hz is a little more responsive than specified. However, it has demonstrated good performance, and is considered to be the appropriate value for the OPRM design.

2.3.2 Stability Interim Corrective Actions

The BWROG recommended new guidelines per BWROG-94079 (Reference 10.4) for reactor instability Interim Corrective Actions (ICA) to address the August 1992 power oscillation event at WNP-2. This guideline updated the GE/BWROG recommended actions included as Attachment 1 of the NRC Bulletin 88-07, "Power Oscillations in Boiling Water Reactors (BWR)," June 1988 (Reference 10.7) and provided guidance to reduce the potential for a significant instability occurrence prior to the implementation of the long term stability solutions described in Reference 10.7. New BSP stability regions developed by modifying the ICA regions were recommended per Reference 10.6, and operator actions in these regions were recommended for Technical Specifications as a backup solution for instability protection when the OPRM system is inoperable.

2.3.3 PBDA Allowable Settings

In July 2003, an instability event occurred at NMP-2 (Reference 10.8) and a scram was initiated by the OPRM. However, in this event only one out of 120 cells reached the Successive Confirmation Count (SCC) setpoint (N_p) and then the amplitude trip setpoint (S_p). The problem was traced to insufficient filtering of the high frequency, which led to noisy oscillations and too many SCC count resets. As a result of investigation, GE recommended changing the settings of the PBDA period tolerance (ε), cutoff frequency (f_c), maximum period (T_{max}), and minimum period (T_{min}) to 100 msec, 1.0 Hz, 3.5 second, and 1.0 seconds respectively. The setting changes were supported by analyses shown in GE-NE-0000-0020-9436-R0, "NMP-2 7/24/03 Instability Event OPRM Performance Evaluation," October 2003 (Reference 10.9) and put further restrictions on the setting ranges allowed in NEDO-32465-A (Reference 10.2). The analyses assured that the problem of having unexpected SCC resets during an instability event were corrected. In the analyses, the attenuation effect of the signal filter on the trip logic was also considered.

2.3.4 Nine Reactor Internal Pump Operation

Studies are proceeding to determine the generic impacts of the Single Loop Operation (SLO) stability event at Brunswick Unit 2 in December 2006. The reactor was tripped by the GRA and GE has confirmed that the OPRM logic performed as designed. The performance adequacy of the PBDA is being further analyzed for the SLO in the operating BWR fleet. However, no further analysis is required for the ABWR since the ABWRs do not operate with half of the flow loops being inactive. The design base faulted condition is 1 tripped pump and 9 out of the 10 pumps operating.

2.4 Description of Proposed OPRM Design Changes

This section shows the changes to the corresponding items in the certified design.

2.4.1 Trip Functions

The Averaging Filter time constant is changed from 6 to 0.95 seconds to increase the responsiveness of the system.

In response to the stability event at Nine Mile Point Unit 2 (NMP-2) in July 2003, the PBDA adjustable ranges were checked and modified to increase the responsiveness of this trip algorithm. The settings of the PBDA period tolerance (ε), cutoff frequency (f_c), maximum period (T_{max}), and minimum period (T_{min}) were changed to 100 msec, 1.0 Hz, 3.5 seconds, and 1.0 second respectively. These settings were validated in the Perry THI event on December 23, 2004 (Reference 10.12).

2.4.2 Bypasses and Interlocks

2.4.2.1 Backup Stability Protection Regions

New plant- and cycle-specific BSP regions are established by using the stability acceptance criterion from the ODYSY computer code. These BSP regions are reduced to two regions (Scram & Controlled Entry) from the three ICA stability regions described in BWROG-94078 (Reference 10.4) by combining the ICA Exit region and ICA Controlled Entry region to one BSP Controlled Entry region. The BSP operation regions for restricting core instability occurrences are applicable to the ABWR when the OPRM system is inoperable.

2.4.3 Redundancy

Each of the four OPRM channels is associated with one RPS division independent from the other three. The OPRM oscillation trips signals are separate from the APRM trip signals and are voted on separately by the two-out-of four channel voters. With this configuration, a trip in one APRM channel and in one OPRM channel will not cause a reactor scram. However, any two of the OPRM channels that sense an abnormal condition will initiate a reactor scram via the RPS. The redundancy criteria are set so that in the event of a single failure under permissible APRM bypass conditions, a scram signal can be generated in the RPS as required.

3.0 Justification for Changes

3.1 OPRM Algorithm Parameter Changes

The proposed changes to the DCD design are justified based on the following reasons:

3.1.1 Butterworth Signal Filter Time Constant

Changing the Averaging Filter time constant from 6 to 0.95 seconds by implementing a second-order Butterworth filter with a corner frequency of 0.167 Hz increases the responsiveness of the system. It allows an accurate measurement of average without reducing the peak of the thermal hydraulic oscillations. This design was incorporated in the NMP-2 OPRM design as described in Reference 10.9.

3.1.2 PBDA Parameter Changes

Reference 10.8 justified that the recommended changes to the PBDA period variables (f_c, ε, T_{max} & T_{min}) do not contribute to exceeding the SLMCPR for all anticipated instability events. Nor do the proposed changes produce a significant increase in the probability of a spurious scram. Since an OPRM cell signal trip requires both counts above the SCC setpoint and amplitude above the amplitude trip setpoint, it is highly unlikely that the SCC and amplitude trip setpoints would be exceeded simultaneously in multiple OPRM cells in multiple OPRM channels except during an actual instability event.

3.2 OPRM Backup Stability Protection

GE performed an evaluation under 10CFR21 on Option III use of the ICAs stated in BWROG-94079 (Reference 10.4) and found that continued use of the ICAs when the OPRM is inoperable does not create a significant hazard (Reference 10.6). In addition, using the plant cycle-specific BSP regions as part of the Option III solution implementation ensures long-term applicability. The BSP regions are generated based on the ICA stability regions. The BSP regions (using the generic shape function of fitting power/flow state points representing a constant decay ratio) and the ICA regions are equivalent since the minimal stability requirements are essentially the same.

3.3 Other OPRM Design Changes

Separating the OPRM trip logic from that of the APRM trip logic would reduce reactor scrams from failures of OPRM and APRM channels without impacting performance of their safety functions.

4.0 Qualification Information

The APRM instrumentation is environmentally qualified in accordance with IEEE Standard 323 (Reference 10.10) requirements for the environment conditions inside the reactor building for normal and accident conditions. The equipment is seismically qualified to the requirements of IEEE Standard 344 (Reference 10.11) and is also qualified to cope with electromagnetic interferences.

5.0 Operating Experience

The designs proposed in Sections 2.4 have been incorporated into the various GE OPRM instrumentation and its performance has been validated. Some of the settings have also been validated on OPRM equipment by non-GE vendors - such as successful mitigation of the Perry OPRM instability event in December 2004. The OPRM performance was evaluated in GE-NE-0000-0041-0403-R0, "Perry 12/23/04 Instability Event OPRM Performance Evaluation" (Reference 10.12). The Perry oscillation mode was core-wide and the reactor was tripped by the PBDA. The PBDA performed as expected since the OPRM P/A was at the amplitude trip setpoint when the reactor scram was initiated. Most of the OPRM cells performed as expected, exhibiting very few SCC resets. The Perry THI event did not produce any safety hazards and the Safety Limit Minimum Critical Power Ratio (SLMCPR) was protected by the Option III OPRM system.

The design proposed in Section 2.4 is the standard design of the APRM NUMAC instrumentation, which is in use at Brunswick and other U. S. power reactors, and is applied in the Lungmen design.

6.0 Nuclear Safety Review

The OPRM design changes in Section 2.4 will improve plant operation and availability but not impact plant safety. The Neutron Monitoring System has been shown to comply with General Design Criteria 2, 4, 10, 12, 13, 19, and 28 in Tier 2 DCD Section 7.6.2.1.1. The OPRM design changes proposed in this LTR have no effect on GE's evaluation of GDC compliance.

The OPRM design has incorporated the changes proposed by the BWROG Stability Solution Option III as stated in References 2, 4, 6, and 7 against the thermal-hydraulic stability performance requirements stated in Tier 2 DCD Section 4.4.3.7. The proposed changes or departures from Tier 2 design involved hardware modification of the 2/4-voter logic in NMS, which was reviewed and approved in Reference 10.5, and software fine-tuning of the OPRM parameters that was reviewed and approved in Reference 10.1, 10.2 and 10.6. Hence, the proposed changes are consistent with the current licensing methodology on the thermal-hydraulic stability.

The proposed changes do not involve a departure from Tier 1 information or Tier 2* information. ABWR generic Technical Specification 3.3.1.1, Safety System Logic and Control Sensor Instrumentation, and its associated Bases description will be revised regarding required actions to be taken when one or more channels of the OPRM monitoring function is inoperable. These Technical Specification changes will be submitted with an LTR entitled "ABWR Stability Evaluation" by June 15, 2007, which addresses the analysis used to support the changes proposed in this LTR. According to proposed changes to 10CFR52 (Reference 10.13) regarding the 10CFR50.59-like criteria contained in Appendix A.VIII.B.5.b for evaluating changes to Tier 2 information, GE has determined that NRC approval of this change is required.

The OPRM system conforms to all the regulatory guides stated in Tier 2 DCD Section 7.6.2.1.2(3) with the same interpretations and clarification identified in Sections 7.2.2.2.1(7), 7.3.2.1.2, and 7.1.2.10.

7.0 Consistency with ABWR DCD

There is no design departure from the Tier 1 DCD. The design changes described in this LTR are changes of the Tier 2 DCD Revision 4 for implementing the BWROG long-term Option III stability solution in the design certification for the ABWR design. The DCD markups are shown in Appendix A.

Details of proposed changes to the Tier 2 DCD are provided in the next section.

8.0 Descriptions of DCD Markups

The Tier 2 DCD markups provided in Appendix A reflect the intent of the proposed departures.

8.1 Tier 2 DCD Markups

The last sentence of Section 7.6.1.1.2.2(1)(b) is changed to read as "The OPRM trip logic is performed separately from the APRM trip logic."

The third sentence of Section 7.6.1.1.2.2(6)(b) is changed to read as "The OPRM trip outputs follow the two-out-of-four logic and are independent from the APRM trip outputs to the RPS."

The note "$\pm t_{error}$=0.15 s" of Table 7.6-2 is changed to "$\pm t_{error}$=0.1 s".

The note "Time Average Flux Filtered w/6 s time constant" of Figure 7.6-14 is changed to "Time Average Flux Filtered w/0.95 s time constant".

The note "t_e = 0.15 s" of Figure 7.6-14 is changed to "t_e = 0.1 s".

Since the two-out-of-four logic is performed in the APRM system, "C71-1030" on sheet 9 of Figure 7.6-2 is removed and the "RPS DIV X REF 3" is replaced with "DIV X 2/4", where X is the division number. The 2/4 voting logic is to be shown separately for each of the three APRM signals: APRM Upsc/Inop Trip; Core Flow Rapid Coastdown Trip and OPRM Trip.

Since the OPRM trip is not sent to RPS directly, "To RPS" is removed from sheet 27 of Figure 7.6-2.

9.0 Conclusions

The proposed design changes in accordance with the BWROG will improve plant safety and will fully meet the OPRM system design and performance requirements identified in the ABWR DCD.

There is no departure from the Tier 1 DCD. All Tier 2 DCD changes have been evaluated under the criteria in Section VIII.B.5 of the ABWR design certification rule and no un-reviewed safety question is created by the proposed departure.

10.0 References

10.1 NEDO-31960-A, "BWR Owner's Group Long Term Stability Solutions Licensing Methodology," Supplement 1, November 1995.

10.2 NEDO-32465-A, "Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," Licensing Topical Report, August 1996.

10.3 GE-NE-0000-0028-9714-R1, "Plant-Specific Regional Mode DIVOM Procedure Guideline," June 2005.

10.4 BWROG-94079, "BWR Owner's Group Guidelines for Stability Interim Corrective Actions," June 1994.

10.5 NEDC-32410P-A, "Nuclear Measurement Analysis and Control Power Range Neutron Monitoring (NUMAC PRNM) Retrofit Plus Option III Stability Trip Function."

10.6 OG-02-0119-260, "GE to BWR Owner's Group Detect and Suppress II Committee: Backup Stability Protection (BSP) for Inoperable Option III Solution," July 2002.

10.7 NRC Bulletin 88-07, "Power Oscillations in Boiling Water Reactors (BWR)," June 1988.

10.8 Letter from Jason Post to the Document Control Desk, US NRC, "Part 21 Notification: Stability Option III Period Based Detection Algorithm Allowable Settings," dated October 4, 2003.

10.9 GE-NE-0000-0020-9436-R0, "NMP-2 7/24/03 Instability Event OPRM Performance Evaluation," October 2003.

10.10 IEEE Std 323-1974, "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations".

10.11 IEEE Std 344-1987, "IEEE Recommended Practices for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations."

10.12 GE-NE-0000-0041-0403-R0, "Perry 12/23/04 Instability Event OPRM Performance Evaluation," June 2005.

10.13 SECY-06-0220, Final Rule to Update 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," October 31, 2006.

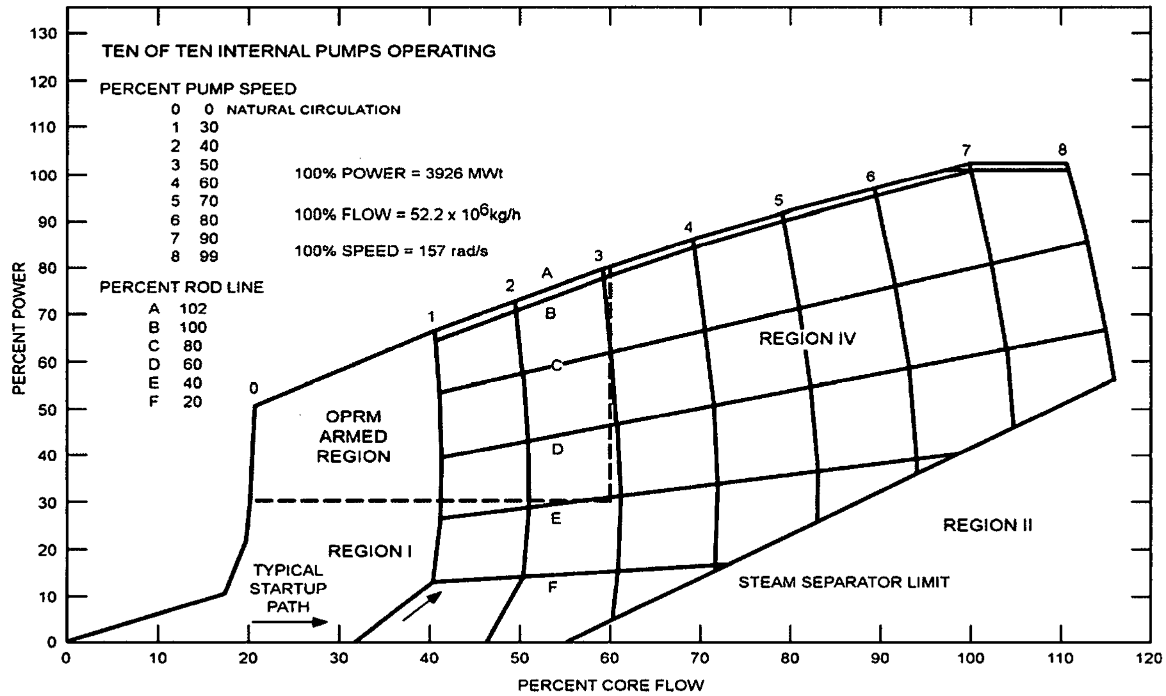


Figure 1 Power-Flow Operating Map Used for System Response Study

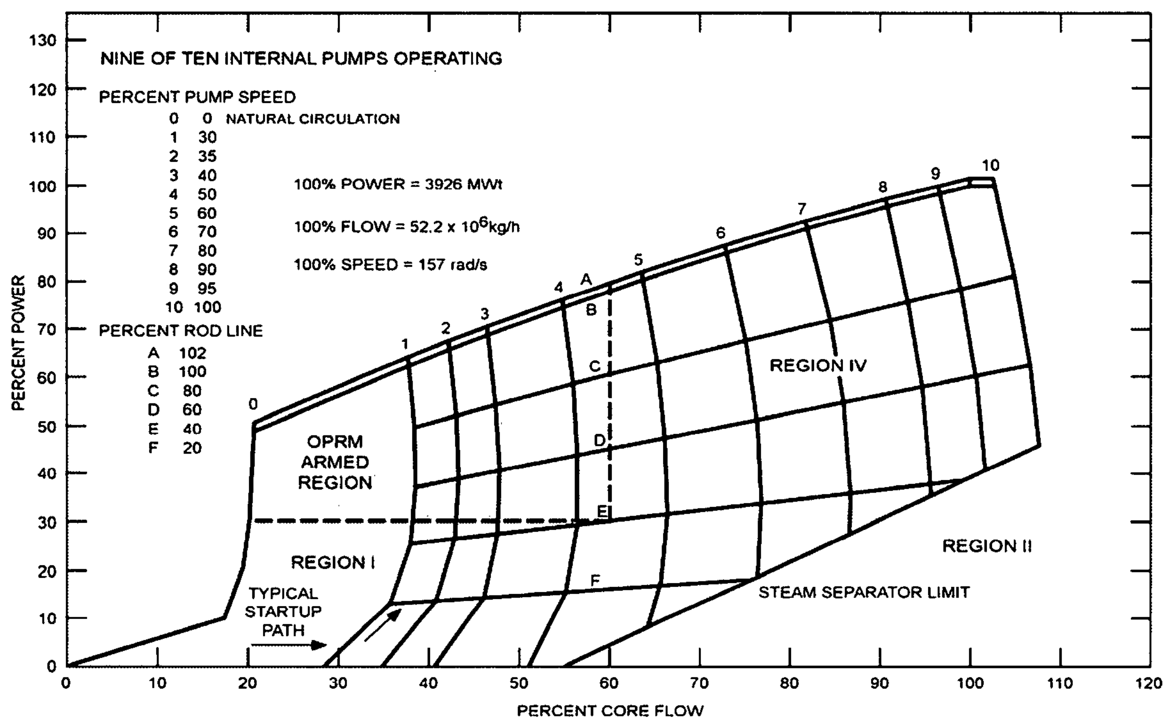


Figure 2 Power-Flow Operating Map Used for System Response Study (9 RIPs Operating)

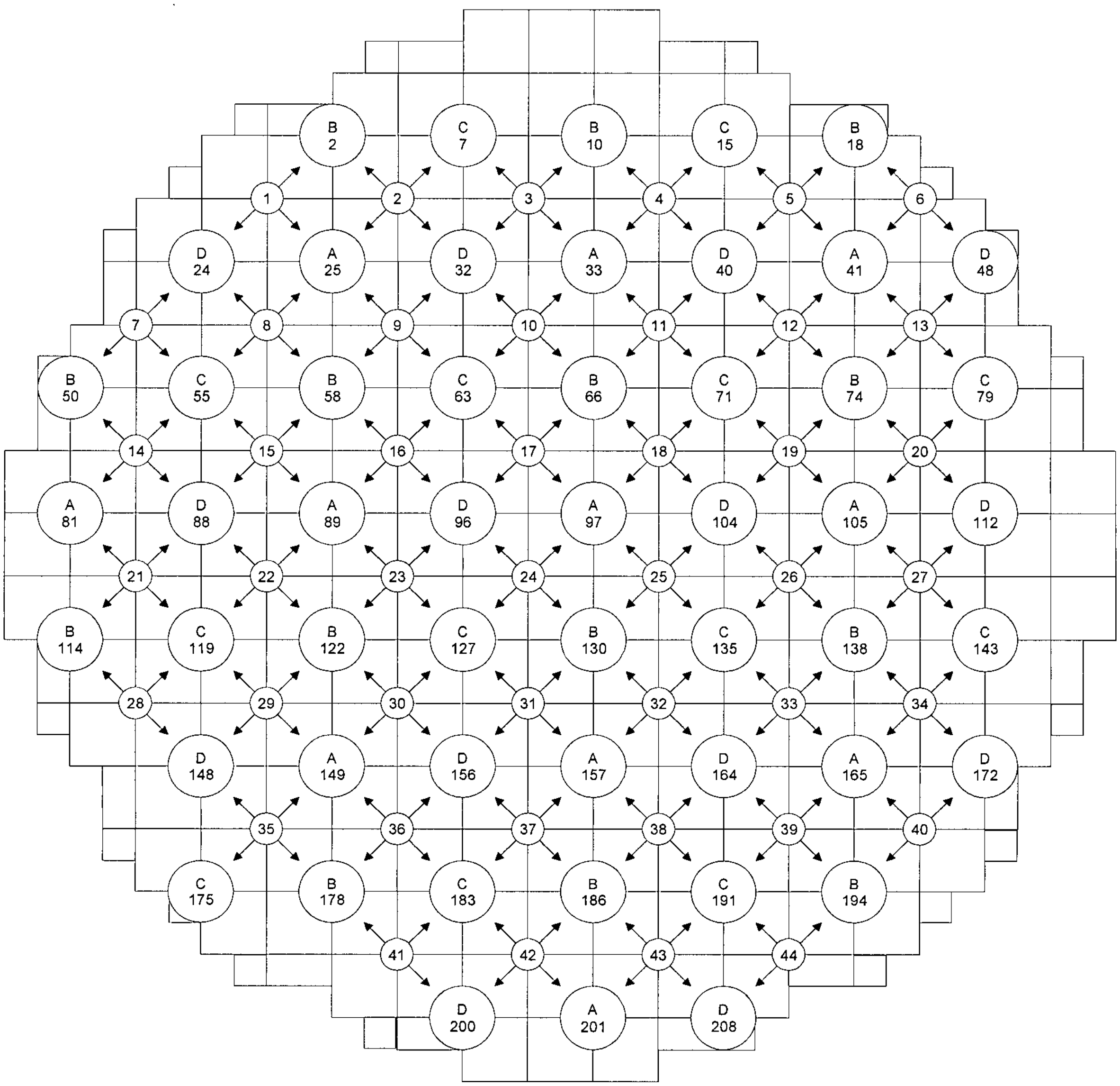


Figure 3. OPRM Assignments (Channel A)

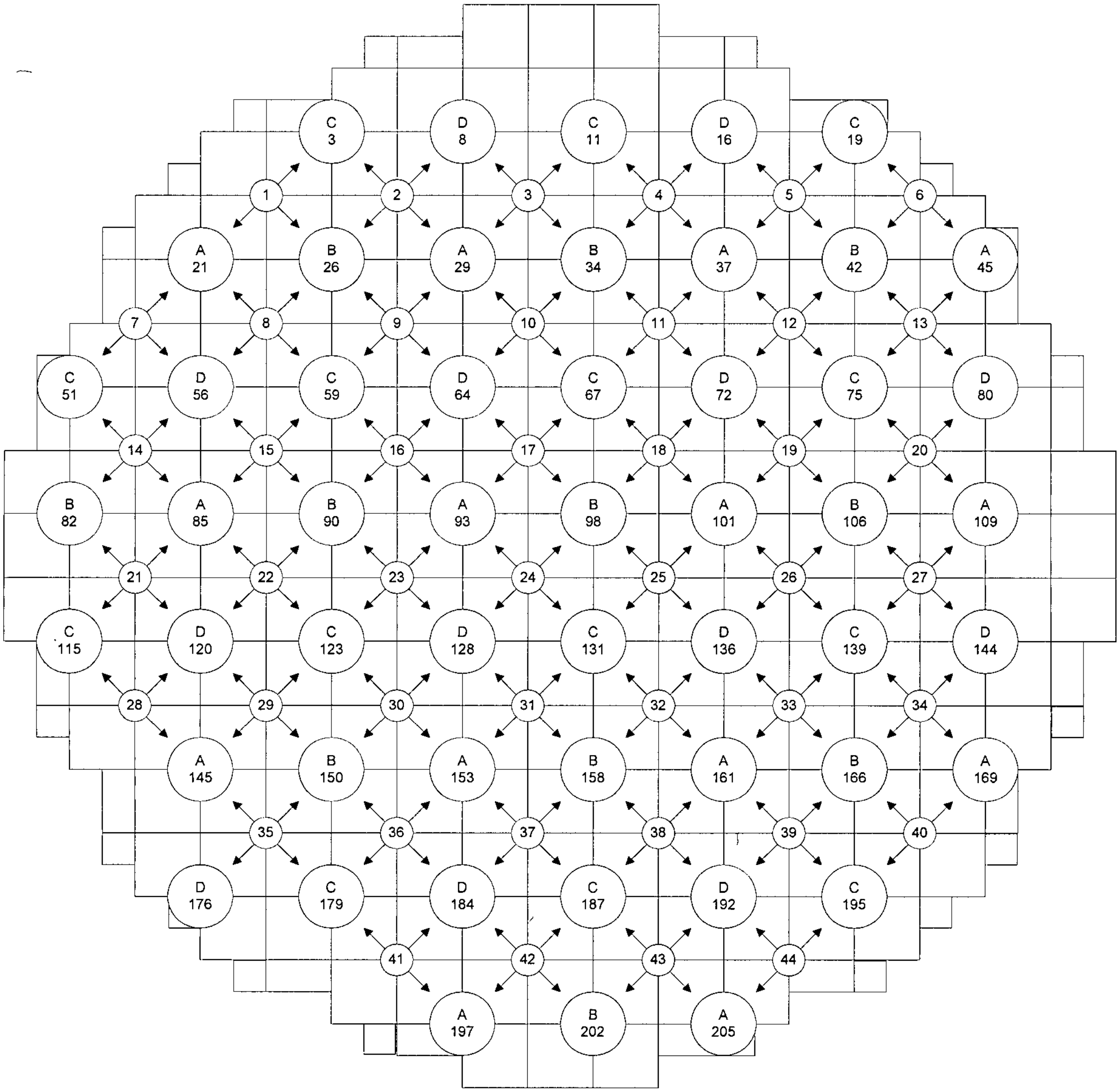


Figure 4. OPRM Assignments (Channel B)

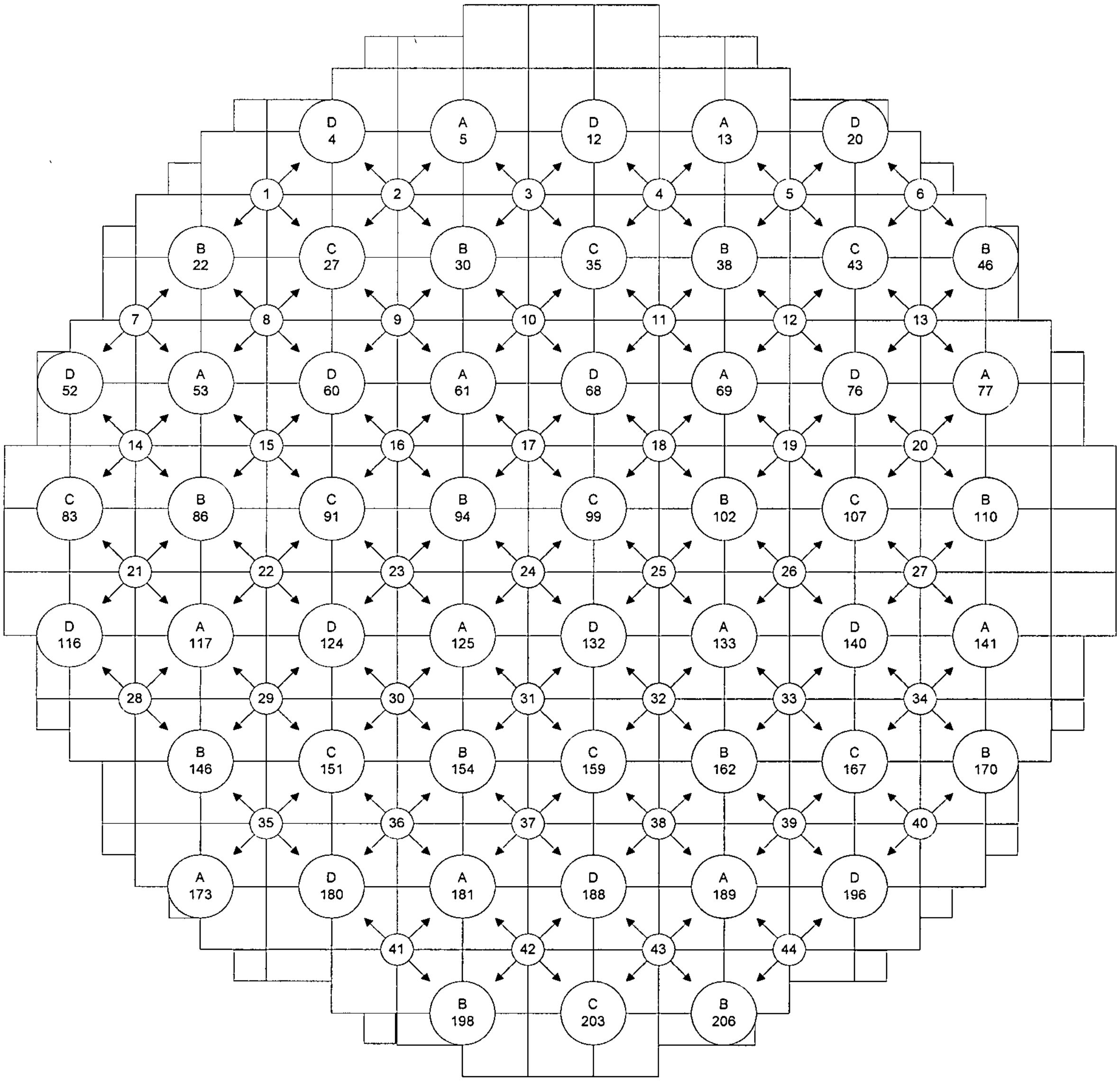


Figure 5. OPRM Assignments (Channel C)

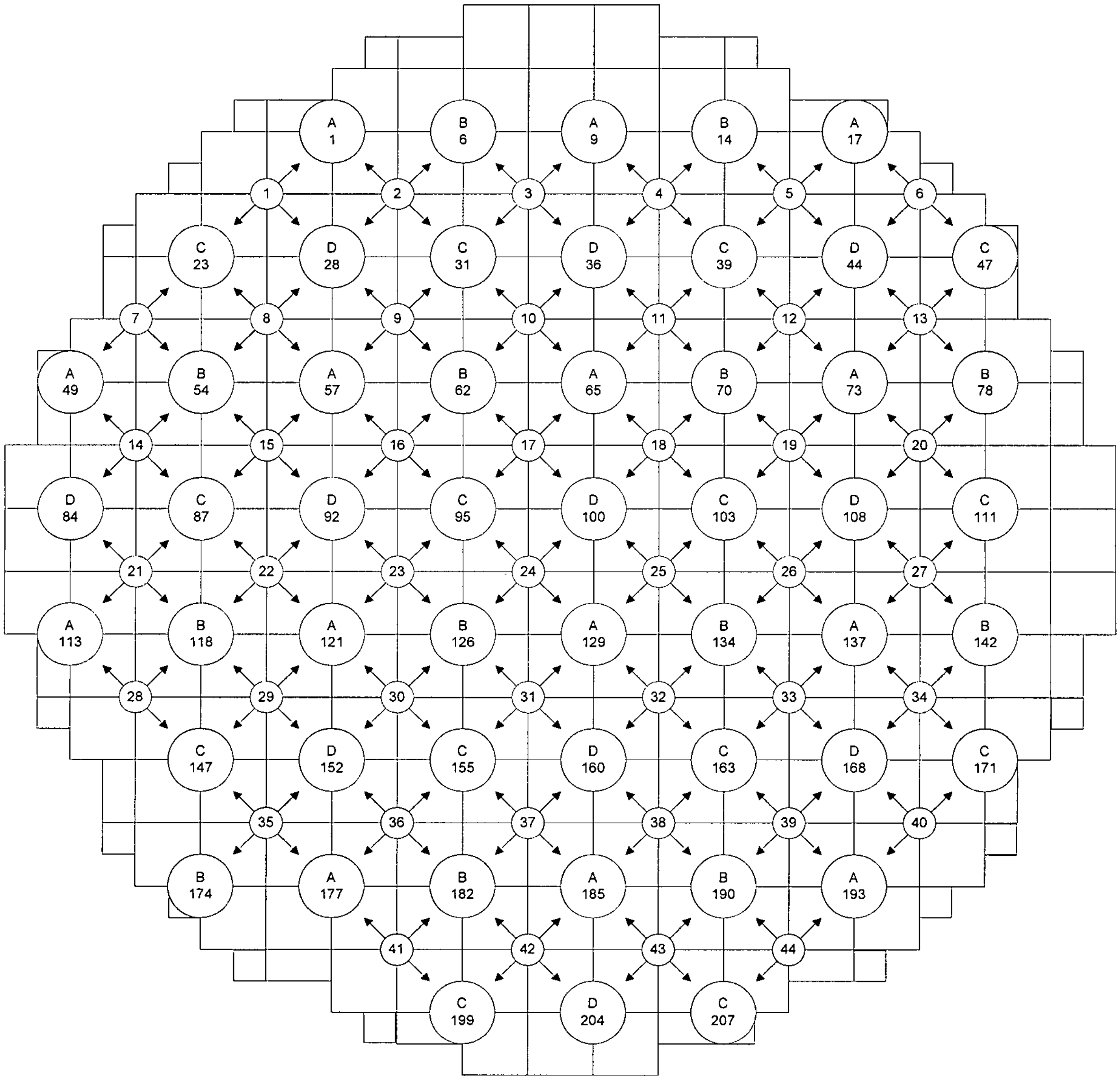


Figure 6. OPRM assignments (Channel D)

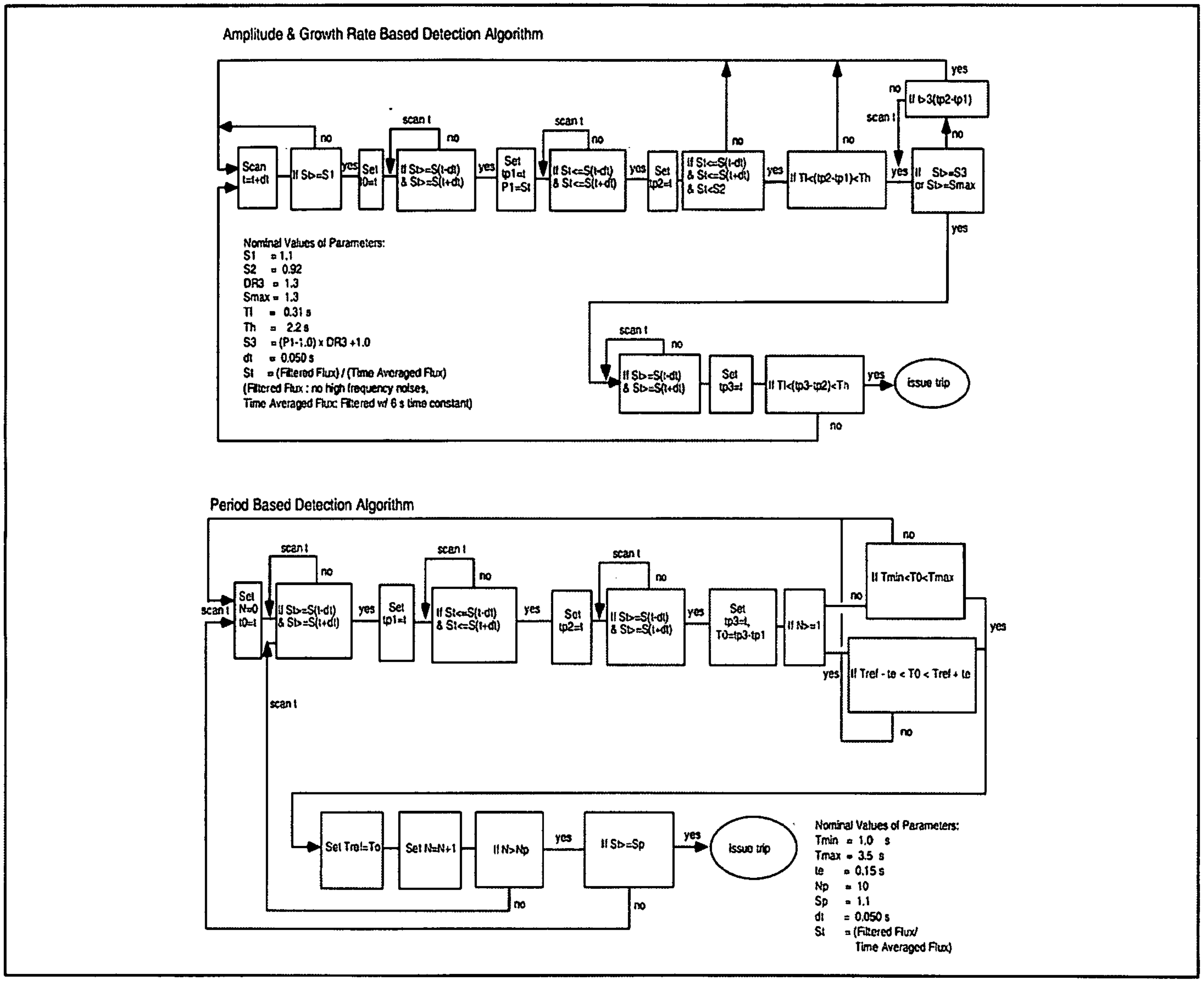


Figure 7. OPRM Logic

Appendix A

ABWR DCD Significant Tier 2 Marked Changes

(a) Average Power Range Monitor (APRM)

The APRMs are safety-related systems. There are four divisions of DMC-based APRM channels located in the control room. Each channel receives 52 LPRM signals as inputs, and averages such inputs to provide a core average neutron flux that corresponds to the core average power. One APRM channel is associated with each trip system of the Reactor Protection System (RPS). However, a trip signal from each APRM division also goes to all other RPS divisions, with proper signal isolation.

(b) Oscillation Power Range Monitor (OPRM)

The OPRM is a functional subsystem of the APRM. There are four safety-related OPRM channels, with each OPRM channel as part of each of the four APRM channels. Each OPRM receives the identical LPRM signals from the corresponding APRM channel as inputs, and forms a special OPRM cell configuration to monitor the neutron flux behavior of all regions of the core. Each OPRM cell represents a combination of four LPRM signals selected from the LPRM strings at the four corners of a four-by-four fuel bundle square region. The OPRM detects thermal hydraulic instability and provides trip functions to the RPS to suppress neutron flux oscillation prior to the violation of safety thermal limits. Insert #1 ~~The OPRM trips are combined with the APRM trips of the same APRM channel, to be sent to the RPS.~~

(2) Power Sources

APRM channels are powered as listed below:

Channels		
A	120 VAC UPS	Bus A (Division I)
B	120 VAC UPS	Bus B (Division II)
C	120 VAC UPS	Bus C (Division III)
D	120 VAC UPS	Bus D (Division IV)

The trip units and LPRM channels as well as the OPRM channel associated with each APRM channel receive power from the same power supply as the APRM channel.

(3) Signal Conditioning

(6) Redundancy

(a) APRM

There are four independent channels of the APRM monitor neutron flux, each channel being associated with one RPS division. Any two of the four APRM channels which indicate an abnormal condition will initiate a reactor scram via the RPS two-out-of-four logic. The redundancy criteria are met so that in the event of a single failure under permissible APRM bypass conditions, a scram signal can be generated in the RPS as required.

(b) OPRM

There are four independent and redundant OPRM channels. The above APRM redundancy condition also applies to OPRM since each OPRM is a subsystem of each of the four APRM channels. Insert #2 ~~The OPRM trip outputs also follow the two-out-of-four logic as the APRM since the OPRM trip outputs are combined with other APRM trip outputs in each APRM channel to provide the final trip outputs to the RPS.~~ In addition, each LPRM string with four LPRM detectors provides one LPRM input to each of the four independent and redundant OPRM channels. This provides core regional monitoring by redundant OPRM channels.

(7) Testability

APRM channels are calibrated using data from previous full-power runs and are tested by procedures in the instruction manual. Each APRM channel can be tested individually for the operability of the APRM scram and rod-blocking functions by introducing test signals. This includes the test for the OPRM trip function. A self-testing feature similar to that described for SSLC is also provided.

(8) Environmental Considerations

All APRM equipment is operated in the environments described in Section 3.11. The APRM is capable of functioning during and after the design basis events in which continued APRM operation is required (Sections 3.10 and 3.11).

7.6.1.1.3 Reactor Operator Information

The man-machine interface of the Neutron Monitoring System provides for the information and controls described in this subsection. The lists provided in Table 7.6-3 consist of major signal information which is also documented in the system IED (Figure 7.6-1) and the system IBD (Figure 7.6-2).

Table 7.6-2 APRM Trip Function Summary

Trip Function	Trip Setpoint (Nominal)	Action
(a) APRM Trip Function		
APRM Upscale Flux Trip	118% power 13% power	Scram (only in RUN) Scram (not in RUN)
APRM Upscale Flux Alarm	Flow biased 10% power	Rod Block (only in RUN) Rod Block (not in RUN)
APRM Upscale Thermal Trip	Flow biased	Scram
APRM Inoperative	1. LPRM input too few	Scram & Rod Block
	2. Module interlocks disconnect	
	3. Electronics Critical Failure	
APRM Downscale	5% Decrease*	Rod Block (only in RUN)
APRM ATWS Permissive	6%	All Modes†
Core Flow Rapid Coastdown*	fixed*	Scram (bypassed with thermal power < 77%)
Core Flow Upscale Alarm	120% (flow)	Rod Block (only in RUN)
(b) OPRM Trip Function		
Growth Rate-Based Trip (S_3)	$S=S_3=(P_1-1.0) \times DR_3+1.0$‡ $DR_3=1.3$	Scram^f
Amplitude-Based Maximum Trip (S_{max})	$S=S_{max}=1.30$‡	Scram^f
Period-Based Trip (S_P)	$S=S_P=1.10$**	Scram^f

* The trip signal is based on a flow-dependent equation. If the flow decreases too fast, the trip signal will reach the fixed trip setpoint and initiate scram. The thermal power signal is only used as a criteria to determine scram bypass condition.

† APRM has to indicate a power level below the setpoint in order to remove the permissive.

‡ P_1 is the last peak reading measured after the signal S exceeds S_1. Other Pre-Trip condition parameters of the algorithm are:

$S_1=1.10$, $S_2=0.92$, $T_1=0.31$ to 2.2 s, $T_2=0.31$ to 2.2 s.
(For details see Figure 7.6-14).

f Automatically bypassed if core power ≤30% or core flow ≥60%

** Other Pre-Trip Condition parameters of the algorithm are:

$T_{min}=1$ s, $T_{max}=3.5$ s, $\pm t_{error}$~~=0.15 s~~ $N_P=10$.
(For details see Figure 7.6-14).

$\boxed{\text{Insert \#3}}$

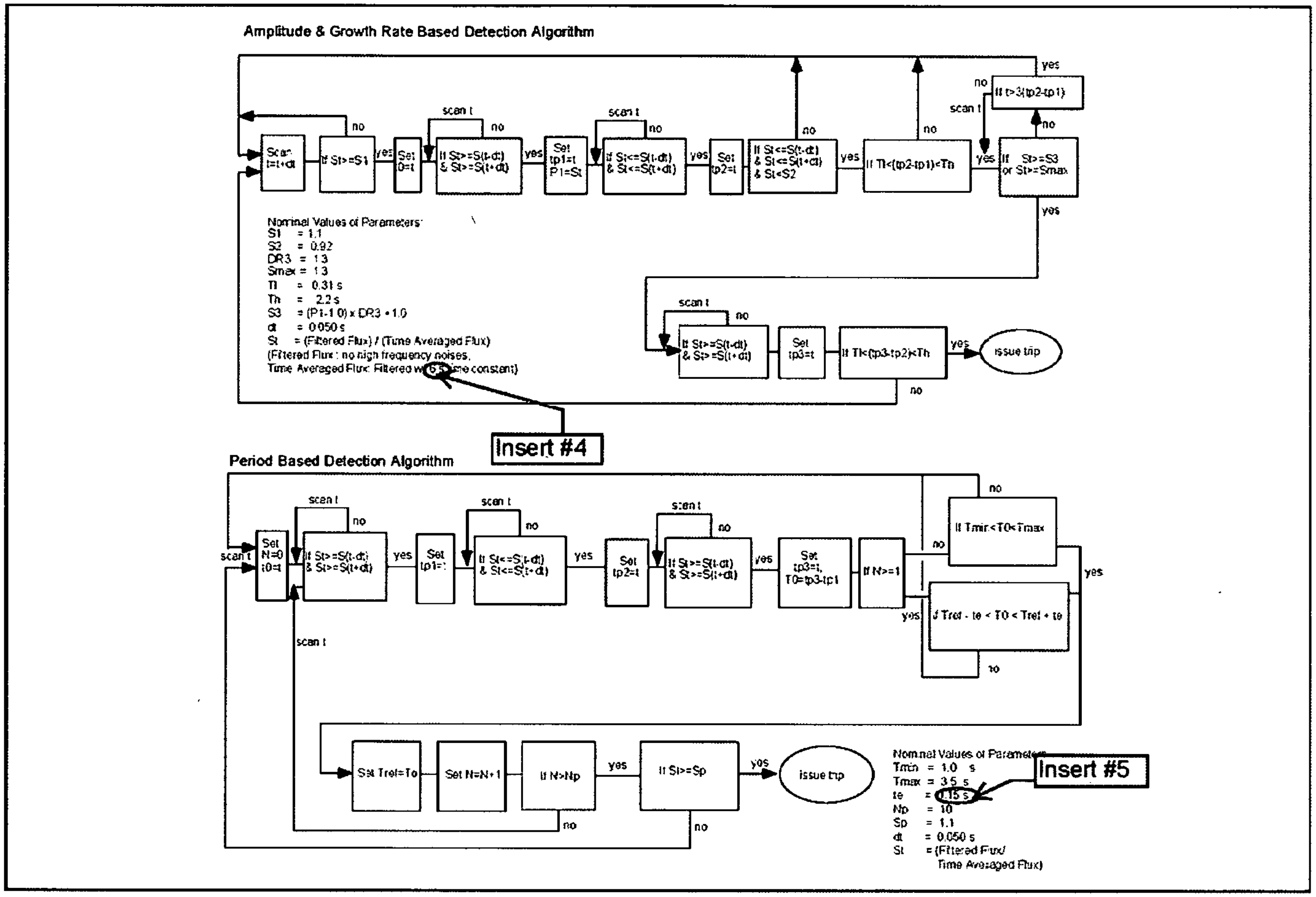
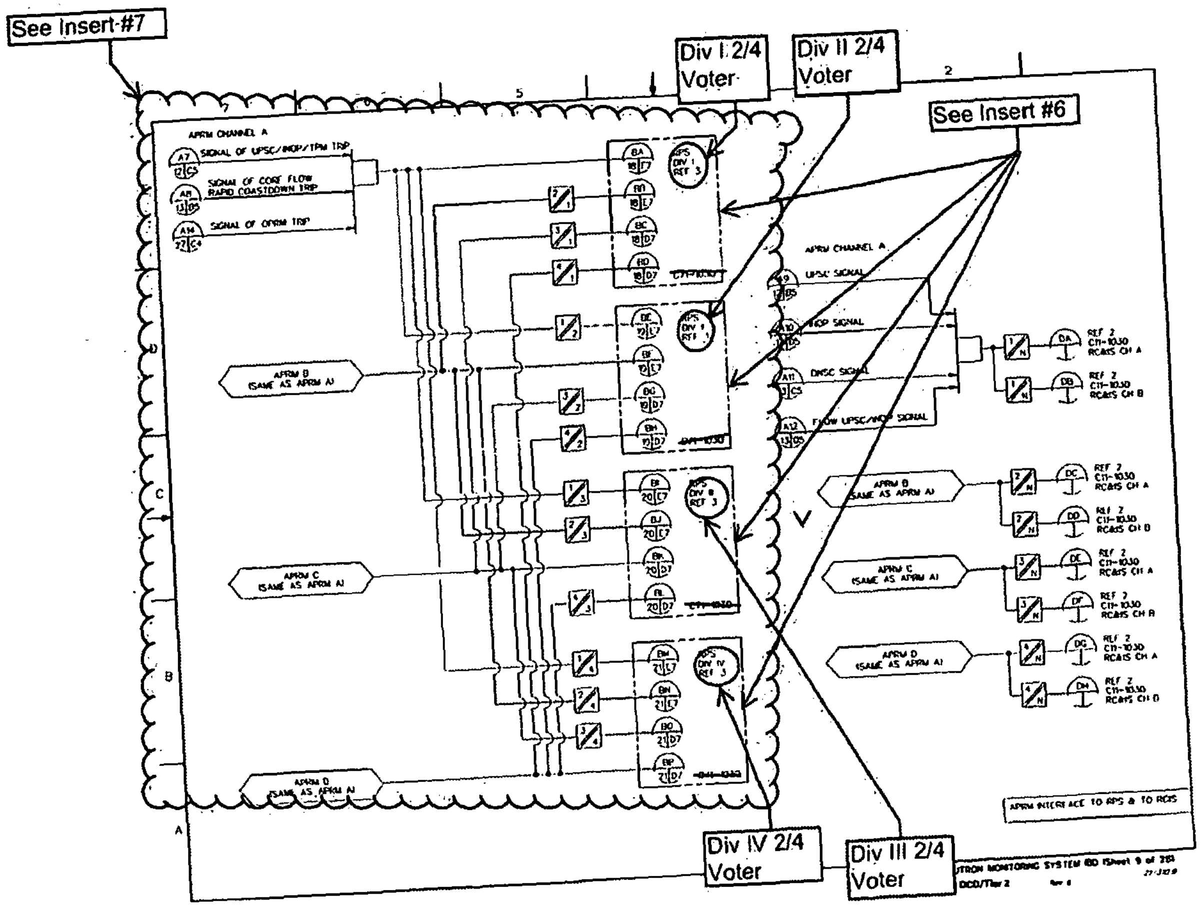


Figure 7.6-14 OPRM Logic


See Insert #7
Div I 2/4 Voter
Div II 2/4 Voter
See Insert #6
Div IV 2/4 Voter
Div III 2/4 Voter

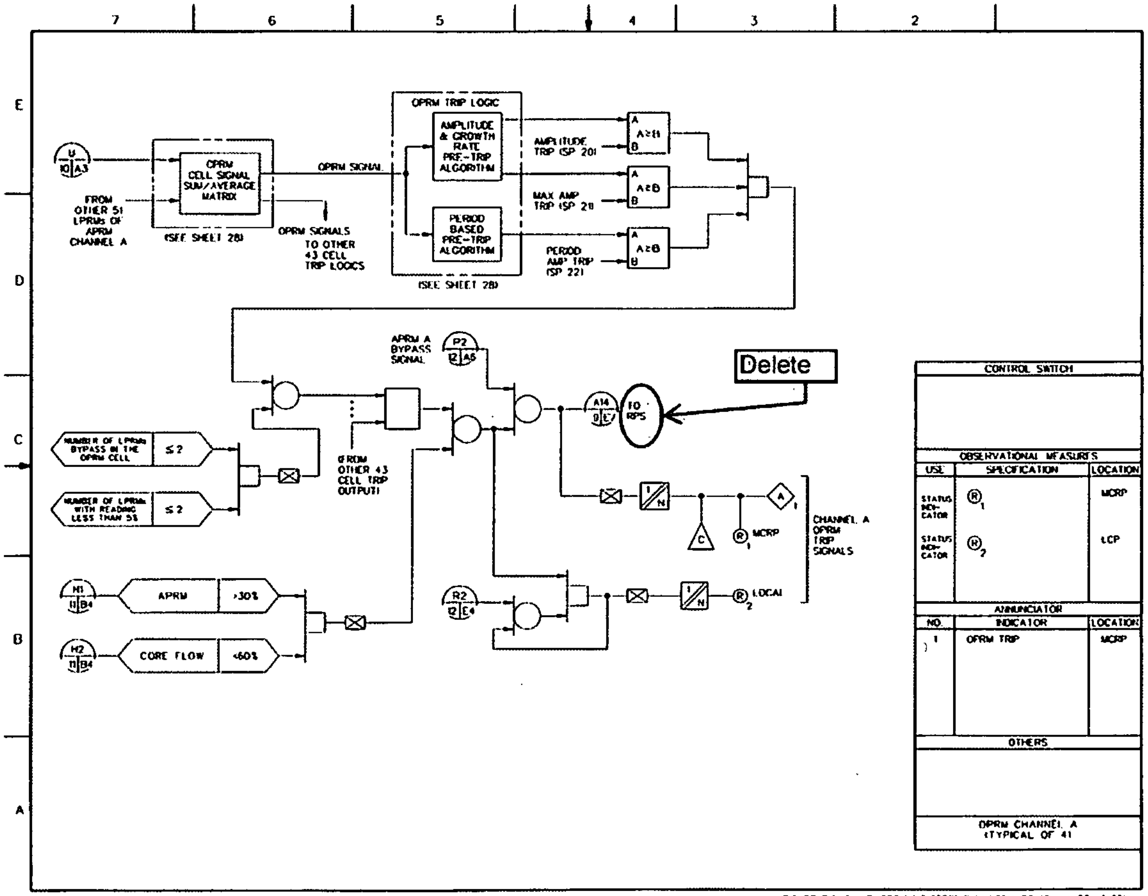


FIGURE 7.6-2 NEUTRON MONITORING SYSTEM IBD (Sheet 27 of 28)
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Insert #1	The OPRM trip logic is performed separately from the APRM trip logic.
Insert #2	The OPRM trip outputs follow the two-out-of-four logic and are independent from the APRM trip outputs to the RPS.
Insert #3	0.1 s
Insert #4	0.95 s
Insert #5	0.1 s
Insert #6	"→ To RPS Div X" is added as output of each APRM divisional 2/4 voter, where X is the division number associated with that voter.
Insert #7	The 2/4 logic as shown will be repeated separately for each of the three APRM signals: APRM Upsc/Inop Trip, Core Flow Rapid Coastdown Trip, and OPRM Trip.