GE Nuclear Energy

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Docket No. STN 52-001

Chet Poslusny, Senior Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: Submittal Supporting Accelerated ABWR Schedule - **Oscillation Power Range Monitor (OPRM)**

Dear Chet:

Enclosed are SSAR markups responding to the NRC Staff request to provide an Oscillation Power Range Monitor (OPRM) for the ABWR. The design is the BWROG LPRM based OPRM (Option III applicable to ABWR).

Please provide a copy of this transmittal to Jim Stewart.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc: Fred Chao (GE)
Alan Beard (GE)
Norman Fletcher (DOE)

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(a) signals to the APRM that are proportional to the local neutron flux at various locations within the rector core;

(b) signals to alarm high or low local neutron flux; and

(c) signals proportional to the local neutron flux to drive indicating meters and auxiliary devices to be used for operator evaluation of power distribution, local heat flux, minimum critical power, and fuel burnup rate.

7.1.2.6.1.4 Average Power Range Monitor (APRM) Subsystem

(1) Safety Design Bases

General Functional Requirements:

The general functional requirements are that, under the worst permitted input LPRM bypass conditions, the APRM shall be capable of generating a trip signal in response to average neutron flux increases in time to prevent fuel damage. The independence and redundancy incorporated into the design of the APRM shall be consistent with the safety design bases of the reactor protection system. The RPS design bases are discussed in Subsection 7.1.2.2.

The APRM generated trip functions with trip inputs to the RPS also include: Simulated thermal power trip, APRM inoperative trip, Core flow rapid decrease trip, and core power oscillation trip of the Oscillation Power range monitor (OPRM). The OPRM design basis is to provide a trip to prevent growing core oscillation flux to prevent thermal limit violation, while discriminate against false signals from other signal fluctuation not related to core instability.

Specific Regulatory Requirements:

The specific regulatory requirements applicable to the controls and instrumentation for the neutron monitoring system are listed in Table 7.1-2.

(2) Nonsafety-Related Design Bases

The APRM shall provide the following functions:

(a) A continuous indication of average reactor power (neutron flux) from a 1% to 125% of rated reactor power which shall overlap with the SRNM range.

(b) Interlock signals for blocking further rod withdrawal to avoid an unnecessary scram actuation;

(c) A reference power level to the reactor recirculation system; and

(d) A simulated thermal power signal derived from each APRM channel which approximates the dynamic effects of the fuel.

(e) A continuous LPRM/APRM display for detection of any neutron flux oscillation in the reactor core. This includes the flux oscillation detection ~~incorporated~~ algorithm incorporated in the APRM.

(f) A reference power level to permit trip in response to a reactor internal pump trip.

7.1.2.6.1.5 Automated Traversing Incore Probe (ATIP) Subsystem

(1) Safety Design Bases

None. The ATIP subsystem portion of the NMS is nonsafety-related and is addressed in Section 7.7

(2) Nonsafety-Related Design Bases

The ATIP shall meet the following power generation design bases:

(a) Provide a signal proportional to the axial neutron flux distribution at the radial core locations of the LPRM detectors (this signal shall be of high precision to allow reliable calibration of LPRM gains) and

(b) Provide accurate indication of the axial position of the flux measurement to allow pointwise or continuous measurement of the axial neutron flux distribution.

(c) Provide a totally automated mode of operation by the computer-based automatic control system.

7.1.2.6.1.6 Multi-Channel Rod Block Monitor (MRBM) Subsystem

(1) Safety Design Basis

None. The MRBM subsystem portion of the NMS is non safety-related and is addressed in Section 7.7.

(2) Non Safety-Related Design Basis

The MRBM shall meet the following power generation design bases.

(a) Provide a signal proportional to the average neutron flux level surrounding the control rod(s) being withdrawn and

(b) Issue a rod block signal if the pre..et setpoint is exceeded by this siganl which is propotional to the average neutron flux level siganl.

7.1.2.6.2 Process Radiation Monitoring System

(1) Safety Design Bases

General Functional Requirements:

(a) Monitor the gross radiation level

TABLE 7.1-1

COMPARISON OF GESSAR II AND ABWR I&C SAFETY SYSTEMS (Continued)

I&C System	GESSAR II Design	ABWR Design
RHR/SHUTDOWN COOLING MODE:	2 shutdown cooling divisions with 1 suction line.	3 shutdown cooling divisions with 3 suction lines (1 per division).
REMOTE SHUTDOWN SYSTEM (RSS):	RCIC controls available at RSS panel	RCIC controls replaced with HPCF controls at RSS panel.
SAFETY RELATED DISPLAY INSTRUMENTATION:	Designed to address Regulatory Guide 1.97, Revision 2.	Designed to address Regulatory Guide 1.97, Revision 3.
NEUTRON MONITORING SYSTEM (NMS):	Class 1E subsystems are IRM, LPRM & APRM.	Class 1E subsystems are SRNM (combines IRM & SRM), LPRM & APRM.
NEUTRON MONITORING SYSTEM (Continued)	Non-Class 1E subsystems are SRM, TIP, and RBM	Non-Class 1E subsystems are ATIP, and MRBM
PROCESS RADIATION MONITORING SYSTEM (PRMS):	---------------	New system definition and organization, i.e., new instrument groupings, locations and ranges.
DRYWELL VACUUM RELIEF SYSTEM:	Electrically operated butterfly valve.	Mechanically operated relief valve.
CONTAINMENT ATMOSPHERE MONITORING SYSTEM (CAMS):	(Not in GESSAR II scope)	New system provided in ABWR scope.
SUPPRESSION POOL TEMPERATURE MONITORING SYSTEM:	4 thermocouples in each of the 4 containment quadrants. 4 X 4 = 16 total T/C's.	4 thermocouples in each of 2 divisions at each of 6 locations. 4 X 2 X 6 = 48 total T/C's. Added suppression pool level monitoring function.

add

GDC 12

APPLICABLE CRITERIA	10CFR50.55	GDC 2	GDC 4	GDC 10	GDC 13	GDC 15	GDC 16	GDC 19	GDC 20	GDC 21	GDC 22	GDC 23	GDC 24	GDC 25	GDC 28	GDC 29	GDC 33	GDC 34	GDC 35	GDC 38	GDC 41	GDC 44
REFERENCE STANDARD (RG.) (IEEE) (ISA)	279																					
Reactor Protection System	X	X	X		X	X		X	X	X	X	X	X	X		X						
Emergency Core Cooling	X	X	X		X	X		X	X	X	X	X	X			X	X	X	X			
Leak Detection & Isolation	X	X	X		X		X	X	X	X	X	X	X			X		X	X	X	X	X
RHR/Wetwell Drywell Spray	X	X	X		X			X	X	X	X	X	X			X				X		X
RHR/Supp. Pool Cooling	X	X	X		X			X	X	X	X	X	X			X				X		X
Standby Gas Treatment *	X	X	X		X			X	X	X	X		X			X					X	
Emergency Diesel Support	X	X	X		X			X														X
Reactor Bldg.Cooling Water	X	X	X		X			X	X	X	X	X	X			X		X	X	X		X
Essential HVAC Systems	X	X	X		X			X	X	X	X	X	X			X						
HVAC Emer.Cooling Wtr	X	X	X		X			X	X	X	X	X	X			X						X
Hi Press. Nitrogen Supply	X	X	X		X			X	X	X	X	X	X			X						
Alternate Rod Insertion					X			X						X								
Standby Liquid Control	X	X	X		X			X														
RHR/Shutdown Cooling	X				X	X		X										X				X
Remote Shutdown System	X	X	X		X			X									X	X	X			X
Safety - Related Display	X	X	X		X			X														
Neutron Monitoring System	X	X	X	X	X			X							X							
Process Rad. Monitoring	X	X	X		X		X	X	X	X	X	X	X		X							
HP/LP System Interlocks	X	X	X	X	X	X		X									X					X
Contmt. Atmos. Monitor	X	X	X		X		X	X													X	
Suppress. Pool Temp.Mon.	X	X	X		X		X	X												X		
Control Systems(Non-IE)					X			X														

APPLICABLE CRITERIA	RG 1.22	RG 1.47	RG 1.53	RG 1.62	RG 1.75	RG 1.97	RG 1.105	RG 1.118	RG 1.151	BTP 3	BTP 12	BTP 20	BTP 21	BTP 22	BTP 26	II. D. 3	II. E. 4.2	II. F. 1	II. F. 3	II. K. 1.23	II. K. 3.13	II. K. 3.15	II. K. 3.18	II. K. 3.21	II. K. 3.22	II. K. 3.23
REFERENCE STANDARD (RG.) (IEEE) (ISA)	279	279	379	279	384		567.04	338	567.02	279	279	279	R.G. 1.47	R.G. 1.22	279				R.G. 1.97							
Reactor Protection System	X	X	X	X	X		X	X			X		X	X	X											
Emergency Core Cooling	X	X	X	X	X		X	X		X		X	X	X		X	X				X	X	X	X	X	
Leak Detection & Isolation	X	X	X	X	X	X	X	X					X	X			X		X							
RHR/Wetwell Drywell Spray	X	X	X	X	X		X	X					X	X			X									
RHR/Supp. Pool Cooling	X	X	X	X	X		X	X					X	X			X									
Standby Gas Treatment *	X	X	X	X	X		X	X					X	X												
Emergency Diesel Support	X	X	X	X	X			X					X	X												
Reactor Bldg.Cooling Water	X	X	X	X	X			X					X	X												
Essential HVAC Systems	X	X	X	X	X			X					X	X												
HVAC Emer.Cooling Wtr	X	X	X	X	X			X					X	X												
Hi Press. Nitrogen Supply	X	X	X	X	X			X					X	X												
Alternate Rod Insertion					X																					
Standby Liquid Control	X	X	X	X	X			X					X	X												
RHR/Shutdown Cooling	X	X	X	X	X		X	X		X		X	X	X												
Remote Shutdown System			X	X	X																					
Safety - Related Display	X	X	X		X	X	X	X	X				X	X		X		X	X	X						X
Neutron Monitoring System	X	X	X		X	X	X	X					X	X												
Process Rad. Monitoring	X	X	X	X	X	X	X	X					X	X					X							
HP/LP System Interlocks	X	X	X	X	X		X	X		X			X	X												
Contmt. Atmos. Monitor	X	X	X		X	X	X	X					X	X				X	X							
Suppress. Pool Temp.Mon.	X	X	X		X	X	X	X					X	X				X	X							
Control Systems(Non-IE)									X																	

* Includes GDC 43 and RG 1.52

add

X

(only for Neutron Monitoring System)

Table 7.1-2
Regulatory Requirements Applicability Matrix for I & C Systems

(10) Operational Considerations

The LPRM is a monitoring system with no special operating considerations.

7.6.1.1.2.2 Average Power Range Monitor Subsystem - Instrumentation and Controls

The Average Power Range Monitor (APRM) includes the Oscillation Power Range Monitor (OPRM) func.

(1) General Description

(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, trip signal from each APRM division also goes to all other RPS divisions, with proper signal isolation.

(b) Oscillation Power Range Monitor (OPRM)

Insert 7.6.1.1.2.2 A

(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

(a) APRM

APRM channel electronic equipment averages the output signals from a selected set of LPRMs. The averaging circuit automatically corrects for the number of unbypassed LPRM amplifiers providing input signals.

Assignment of LPRMs to the APRM channels is shown in Figure 7.6-1. The LPRM detector in the bottom position of a detector assembly is designated Position A. Detectors above A are designated B and C, and the uppermost detector is designated D.

Reactor core flow signals derived from core plate pressure drop signals are used in the APRM to provide the flow biasing for the APRM rod block and thermal power trip setpoint functions. There is also the Core Flow Rapid Coastdown Trip logic in the APRM unit which utilizes the core flow and thermal power information. The core flow signal is also used to provide the flow biasing for the MRBM rod block setpoint functions.

(b) OPRM

Insert 7.6.1.1.2.2 B

~~The APRM signal conditioning unit also includes an algorithm that provides detection of core oscillation resulted from core in-stability. This algorithm uses LPRM signals as input, and is based on a specific detection methodology that relates the fuel thermal response in the fuel assembly to the LPRM signals. It includes a specific method of combining the designated LPRM signals in order to detect localized core power ascillation. The algorithm monitors core power oscillation responses and provides a trip signal if a growing oscillation with sufficient magnitide is detected. The COL applicant will implement the oscillation monitoring logic function in the APRM in accordance with the conclusion of the BWR Owners' Group as required in Subsection 7.6.3.~~

(4) Trip Function

APRM system trips including OPRM trips are summarized in Table 7.6-2. The APRM scram trip function is discussed in Section 7.2. The APRM rod block trip function is discussed in Subsection 7.7.1.2. The APRM channels also provide trip signals indicating when an APRM channel is upscale, downscale, bypassed, or inoperative.

Insert 7.6.1.1.2.2 C

(5) Bypasses and Interlocks

(a) APRM

One APRM channel may be bypassed at any time. The trip logic will in essence become two-out- of-three instead of two-out-of-four.

(b) OPRM

Insert 7.6.1.1.2.2

Insert 7.6.1.1.2.2 C2

(6) Redundancy

(a) APRM

Four independent channels of the APRM monitor neutron flux. 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.

Insert 7.6.1.1.2.2.E

(b) OPRM

(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-

Insert 7.6.1.1.2.2.A

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. The OPRM trips are combined with the APRM trips of the same APRM channel, to be sent to the RPS.

Insert 7.6.1.1.2.2.B

The OPRM utilizes the same set of LPRM signals used by the APRM that this OPRM channel resides with. Assignment of LPRMs to the four OPRM channels is identical to that referred in Figure 7.6-1, which shows the assignment of LPRMs to APRM channels. Figure 7.6-1A shows the detailed LPRM assignments to the four OPRM channels, including the assignment of LPRMs to the OPRM cells. With this configuration, each OPRM cell receives four LPRM inputs from four LPRM strings at the four corners of the 4X4 fuel bundle square. 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 overall axial and radial distribution of these LPRMs between the OPRM channels are uniform. Each OPRM cell has four LPRMs from all four different elevations in the core. 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.

The OPRM trip protection algorithm consists of trip logic depending on signal oscillation magnitude and signal oscillation period. For each cell, the peak to average value of the OPRM signal is determined to evaluate the magnitude of oscillation and to be used in the setpoint algorithm. The OPRM signal sampling and computation frequency is well above the expected thermal-hydraulic oscillation frequency, essentially producing a continuous and simultaneous measurement of all defined OPRM cells.

Insert 7.6.1.1.2.2.C

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 7.6-2A illustrates the trip algorithm logic. The OPRM trip function does not have its own inoperative trip for insufficient number of total LPRM inputs in the channel. It follows the APRM's inoperative trip of insufficient number of LPRMs.

Insert 7.6.1.1.2.2.C.2

The APRM also sends an interlock signal to the SSLC similar to the SRNM "ATWS Permissive" signal (see Table 7.6-2). If this signal is a "high" level indicating the power is above the setpoint, this will allow the SSLC to permit ATWS protection action.

Insert 7.6.1.1.2.2.D

The OPRM channel bypass is controlled by the bypass of the APRM channel it resides with. Bypass of the APRM channel will bypass the OPRM trip function within this APRM channel. The OPRM also has its own separate automatic bypass functions: the OPRM trip output from any cell is bypassed if: i) the APRM reading of the same channel is below 30% of rated power or the core flow reading is above 60% of rated flow; ii) the number of LPRM inputs to this OPRM cell is less than two. Any LPRM input to an OPRM cell is automatically bypassed if this LPRM reading is less than 5% of full scale LPRM reading. There is no requirement as to how many cells per OPRM channel has to be active since this is controlled by the total number of active LPRMs to the APRM channel.

Insert 7.6.1.1.2.2.E

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. The OPRM trip outputs also follows the two-out-of-four logic as the APRM since the OPRM trip output 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.

Insert 7.6.2.1.1 (2)

It also includes a trip from the OPRM subsystem algorithm which will issue a trip if the OPRM algorithm detects a growing neutron flux oscillation indicating core thermal hydraulic instability.

7.6.2 ANALYSIS

7.6.2.1 Neutron Monitoring System - Instrumentation and Controls

The analysis for the trip inputs from the neutron monitoring system (NMS) to the reactor protection (trip) system (RPS) are discussed in Subsection 7.2.2.

The automatic traversing in-core probe (ATIP) is a nonsafety-related subsystem of the NMS and is analyzed along with the other nonsafety subsystems in Section 7.7.2.

This analysis section covers only the safety-related subsystems of the neutron monitoring system (NMS). These include the following:

(1) Startup range neutron monitor subsystem (SRNM)

(2) Power range neutron monitor subsystem (PRNM) which includes:

 (a) Local power range monitor subsystem (LPRM), and

 (b) Average power range monitor subsystem (APRM)

7.6.2.1.1 General Functional Requirements Conformance

(1) Startup range neutron monitors (SRNM)

The SRNM subsystem is designed as a safety-related system that will generate a scram trip signal to prevent fuel damage in the event of any abnormal reactivity insertion transients while operating in the startup power range. This trip signal is generated by either an excessively high neutron flux level, or too fast a neutron flux increase rate, i.e., reactor period. The setpoints of these trips are such that under worst reactivity insertion transients, fuel integrity is always protected. The independence and redundancy requirements are incorporated into the design of the SRNM and are consistent with the safety design bases of the reactor protection system (RPS).

(2) Power range neutron monitors (PRNM)

The PRNM subsystem provides information for monitoring the average power level of the reactor core and for monitoring the local power level when the reactor power is in the power range (above approximately 15% power). It mainly consists of the LPRM and the APRM subsystems.

 (a) LPRM subsystem: The LPRM is designed to provide a sufficient number of LPRM signals to the APRM system such that the safety design basis for the APRM is satisfied. The LPRM itself has no safety design basis. However, it is qualified as a safety-related system.

 (b) APRM subsystem: The APRM is capable of generating a trip signal to scram the reactor in response to excessive and unacceptable neutron flux increase, in time to prevent fuel damage. Such a trip signal also includes a trip from the simulated thermal power signal which is a properly delayed signal from the APRM signal. It also includes a trip from a core flow based algorithim which will issue a trip if the core flow suddenly decreases too fast, called the Core Flow Rapid Coastdown trip. Insert 7.6.2.1.1 (2) All scram function is assured so long as the minimum LPRM input requirement to the APRM is satisfied. If such an input requirement cannot be met, a trip signal shall also be generated. The independence and redundancy requirements are incorporated into the design and are consistent with the safety design basis of the RPS.

7.6.2.1.2 Specific Regulatory Requirements Conformance

Table 7.1-2 identifies the neutron monitoring system (NMS) and the associated codes and standards applied in accordance with the Standard Review Plan. The following analysis lists the applicable criteria in order of the listing on the table, and discusses the degree of conformance for each. Any exceptions or clarifications are so noted.

(1) 10CFR50.55a (IEEE 279):

The safety-related subsystems of the neutron monitoring system consist of four divisions which correspond and interface with those of the reactor protection system (RPS). This independence and redundancy assure that no single failure will interfere with the system operation.

The 10 SRNM channels are divided into four divisions and independently assigned to three bypass groups such that up to three SRNM channels are allowed to be bypassed at any time while still providing the required monitoring and protection capability.

There are 52 LPRM assemblies evenly distributed in the core. There are four LPRM detectors on each assembly, evenly distributed from near the bottom of the fuel region to near the top of the fuel region (Figure 7.6-3). A total of 208 detectors are dividied and assigned to four divisions for the four APRMs. Any single LPRM detector is only assigned to one APRM division. Electrical wiring and physical separation of the division is optimized to satisfy the safety-related system requirement. With the four divisions, redundancy criteria are met since a scram signal can still be initiated with a postulated single failure under allowed APRM bypass conditions. The APRM subsystem as described in 7.6.1.1.2.2 conforms to all applicable requirements of IEEE-279.

All components used for the safety-related functions are qualified for the environments in which they are located (Sections 3.10 and 3.11).

All applicable requirements of IEEE 279 are met with the NMS.

(2) General Design Criteria (GDC):

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, the following GDCs are addressed for the NMS:

(a) Criteria: GDCs 2, 4, 10, 12, 13, 19, and 28.

(b) Conformance: The NMS is in compliance with these GDCs, in part, or as a whole, as applicable. The GDCs are generically addressed in Subsection 3.1.2.

(3) Regulatory Guides (RGs):

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, the following RGs are addressed for the NMS:

(a) RG 1.22 - *Periodic Testing of Protection System Actuation Functions*

(b) RG 1.47 - *Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems*

(c) RG 1.53 - *Application of the Single-Failure Criterion to Nuclear Power Protection Systems*

(d) RG 1.75 - *Physical Independence of Electric Systems*

(e) RG 1.97 - *Instrumentation During and Following an Accident*

(f) RG 1.105 - *Instrument Setpoints for Safety-Related Systems*

(g) RG 1.118 - *Periodic Testing of Electric Power and Protection Systems*

The NMS conforms with all the above-listed RGs assuming the same interpretations and clarifications identified in Subsections 7.2.2.2.1(7), 7.3.2.1.2 and 7.1.2.10.

(4) Branch Technical Positions (BTPs):

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, only BTPs 21 and 22 are considered applicable for the NMS. They are addressed as follows:

(a) BTP ICSB 21 - *Guidance for Application of Regulatory Guide 1.47:*

The ABWR design is a single unit. Therefore, item B-2 of the BTP is not applicable. Otherwise, the NMS is in full compliance with this BTP.

TABLE 7.6-2

APRM TRIP FUNCTION SUMMARY

a) APRM Trip Function

Trip Function	Trip Setpoint (Nominal)	Action
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	LPRM input too few Module interlocks disconnect Electronics Critical Failure	Scram & Rod Block
APRM Downscale	5%	Rod Block (only in RUN)
APRM ATWS Permissive	6 %	All Modes (Note 1)
Core Flow ~~Rapid~~ Coastdown (Note 1)	fixed (Note 2)	Scram (bypassed with thermal power < 77%)
Core Flow Upscale Alarm	120% (flow)	Rod Block (only in RUN)

Notes:

1. APRM has to indicate a power level below the setpoint in order to remove the permissive.
2. 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.

Table 7.6-2

APRM TRIP FUNCTION SUMMARY (Continued)

← b) OPRM TRIP FUNCTION

Trip function	Trip Setpoint (Nominal)	Action
Growth-Rate-Based Trip (S_3)	$S = S_3 = (P_1 - 1.0) \times DR_3 + 1.0$ (NOTE 3) $DR_3 = 1.3$	Scram (NOTE 4)
Amplitude-Based Maximum Trip (S_{max})	$S = S_{max} = 1.30$ (NOTE 3)	Scram (NOTE 4)
Period-Based Trip (S_p)	$S = S_p = 1.10$ (NOTE 5)	Scram (NOTE 4)

NOTES (~~Continued~~):

3. 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 sec, $T_2 = 0.31$ to 2.2 sec

(For details see Figure 7.6-2A)

4. Automatic Bypassed if Core power ≤ 30% and Core flow ≥ 60%

5. Other Pre-Trip Condition parameters of the algorithm are:

$T_{min} = 1$ sec, $T_{max} = 3.5$ sec, $\pm t_{error} = 0.15$ sec

$N_p = 10$

(For details see Figure 7.6-2A)

Table 7.6-5

REACTOR OPERATOR INFORMATION FOR NMS

(1) The NMS provides for the activations of the following annunciations at the main control panel.

(a) SRNM neutron flux upscale reactor trip
(b) SRNM neutron flux upscale rod block
(c) SRNM neutron flux downscale rod block
(d) SRNM short period reactor trip
(e) SRNM short period rod block
(f) SRNM inoperative reactor trip
(g) SRNM period withdrawal permissive alarm
(h) APRM neutron flux upscale reactor trip
(i) APRM simulated thermal power reactor trip
(j) APRM neutron flux upscale rod block
(k) APRM neutron flux downscale rod block
(l) Reference APRM downscale rod block
(m) APRM system inoperative reactor trip
(n) Core flow rapid coastdown reactor trip
(o) APRM core flow upscale rod block
(p) Core flow inoperative alarm
(q) LPRM neutron flux upscale alarm
(r) LPRM neutron flux downscale alarm
(s) ATIP automatic control system (ACS) inoperative
(t) ATIP indexer inoperative
(u) ATIP control function inoperative
(v) ATIP valve control monitor function inoperative
(w) MRBM upscale rod block
(x) MRBM downscale rod block
(y) MRBM inoperative rod block
(z) Core flow abnormal
(aa) OPRM Trip

(2) The NMS provides status information on the dedicated NMS operator interface on the main control panel as follows:

(a) APRM power level
(b) Srnm power level

(3) The dedicated operator interface of the NMS provides logic and operator controls, so that the operator can perform the following functions at the main control panel:

(a) APRM channel bypass
(b) SRNM channel bypass
(c) MRBM main channel bypass
(d) MRBM rod block logic test
(e) MRBM upscale rod block setpoint setup to intermediate/normal

Table 7.6-5

REACTOR OPERATOR INFORMATION FOR NMS (Continued)

(4) Certain NMS - related information, available on the main control panel, is implemented in software which is independent of the process computer. This information is listed below.

(a) SRNM reactor period
(b) SRNM count rate
(c) APRM bypass status
(d) APRM neutron flux upscale trip/inoperative status
(e) APRM neutron flux upscale rod block status
(f) APRM neutron flux downscale rod block status
(g) APRM core flow upscale rod block status
(h) APRM core flow rapid coastdown status
(i) APRM core flow rapid coastdown bypass status
(j) MRBM main channel bypass status
(k) MRBM main channel upscale rod block status
(l) MRBM main channel downscale rod block status
(m) MRBM main channel inoperative rod block status
(n) MRBM main channel core flow abnormal rod block status
(o) OPRM Trip Status

(5) CRT displays, which are part of the performance monitoring and control system, provide certain NMS-related displays and controls on the main control panel which are listed below:

(a) SRNM upscale trip/inoperative status
(b) SRNM reactor period trip status
(c) SRNM upscale rod block status
(d) SRNM reactor period rod block status
(e) SRNM downscale rod block status
(f) SRNM bypass status
(g) SRNM period historical record
(h) SRNM count rate historical record
(i) SRNM period-based permissive
(j) LPRM string selected for status readings
(k) LPRM neutron flux level (Designated group of LPRMs displayed upon selection of certain single rod or gang of control rods)
(l) LPRM bypass status
(m) LPRM neutron flux downscale alarm status
(n) LPRM neutron flux upscale alarm status
(o) Number bypassed LPRMs and APRM channel
(p) APRM simulated thermal power reactor trip status
(q) APRM core flow
(r) Core flow historical record
(s) APRM neutron flux
(t) APRM simulated thermal power trip setpoint
(u) APRM simulated thermal power
(v) APRM simulated thermal power record
(w) Reference APRM downscale rod block status (One for each MRBM main channel)
(x) MRBM main channel block level status
(y) MRBM main channel upscale (normal) rod block setpoint
(z) MRBM main channel upscale (intermediate) rod block setpoint

Table 7.6-5

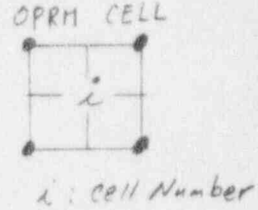
REACTOR OPERATOR INFORMATION FOR NMS (Continued)

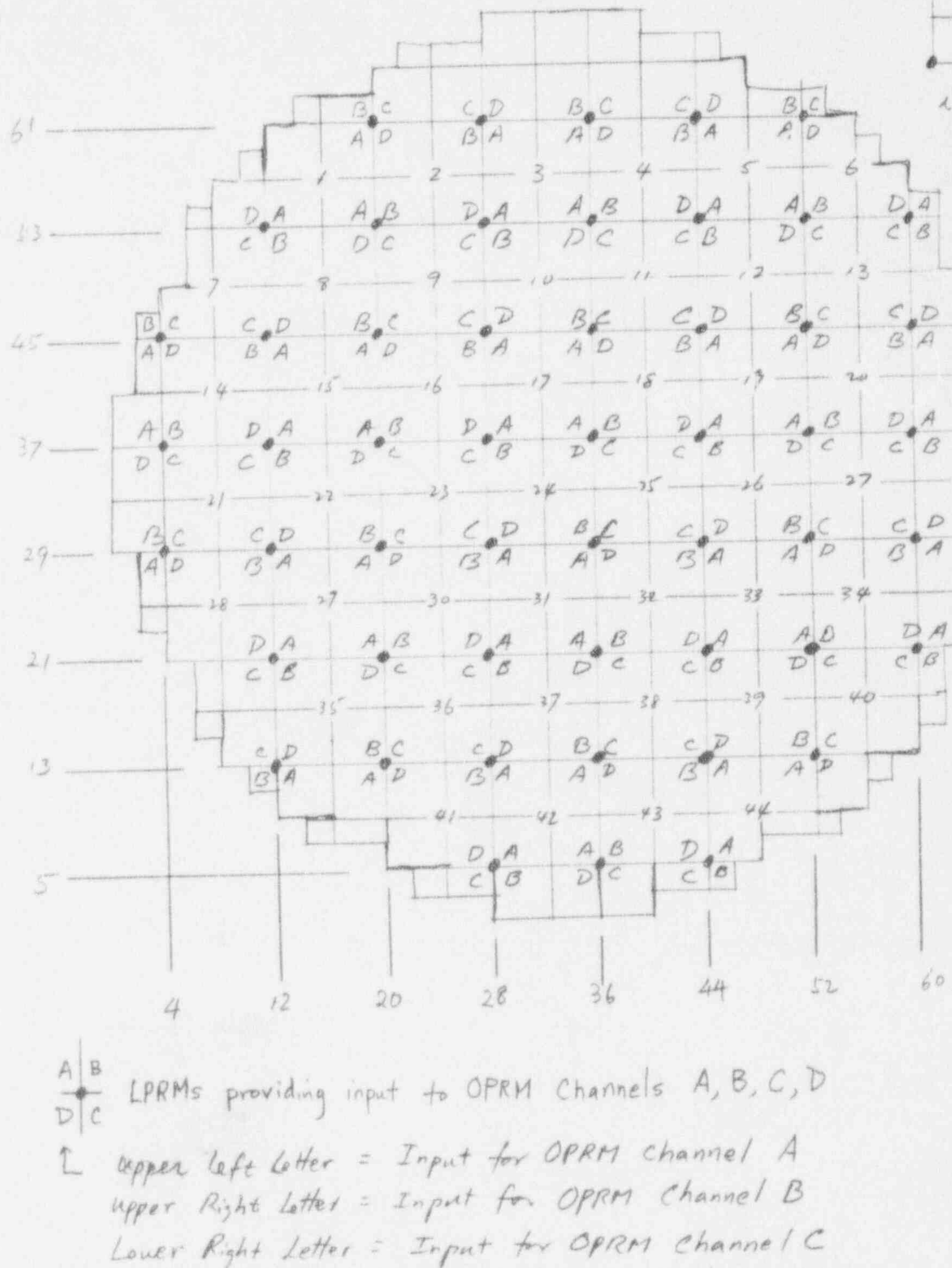
(aa) MRBM main channel upscale (low) rod block setpoint
(ab) MRBM main channel upscale (normal) rod block setpoint historical record
(ac) MRBM main channel upscale (intermediate) rod block setpoint historical record
(ad) MRBM main channel upscale (low) rod block setpoint historical record
(ae) MRBM subchannel inoperative status
(af) MRBM subchannel upscale rod block status
(ag) MRBM subchannel downscale rod block status
(ah) MRBM subchannel intermediate level transfer rate
(ai) MRBM subchannel normal level transfer rate
(aj) MRBM subchannel reading
(ak) MRBM subchannel reading historical record
(al) MRBM subchannel setup permissive
(am) MRBM gain adjustment failed
(an) No rod selected (MRBM)
(ao) Peripheral rod selected (MRBM)

(ap) OPRM Trip setpoint data
(aq) OPRM cell configuration and status of LPRM inputs
(ar) OPRM Trip Status
(as) OPRM signals Record

ACRONYMS

NMS - Neutron Monitoring System
SRNM - Startup Range Neutron Monitor
APRM - Average Power Range Monitor
LPRM - Local Power Range Monitor
ATIP - Automatic Traversing In-Core Probe
MRBM - Multi-channel Rod Block Monitor
CRT - Cathode Ray Tube





A | B
D | C

LPRMs providing input to OPRM Channels A, B, C, D

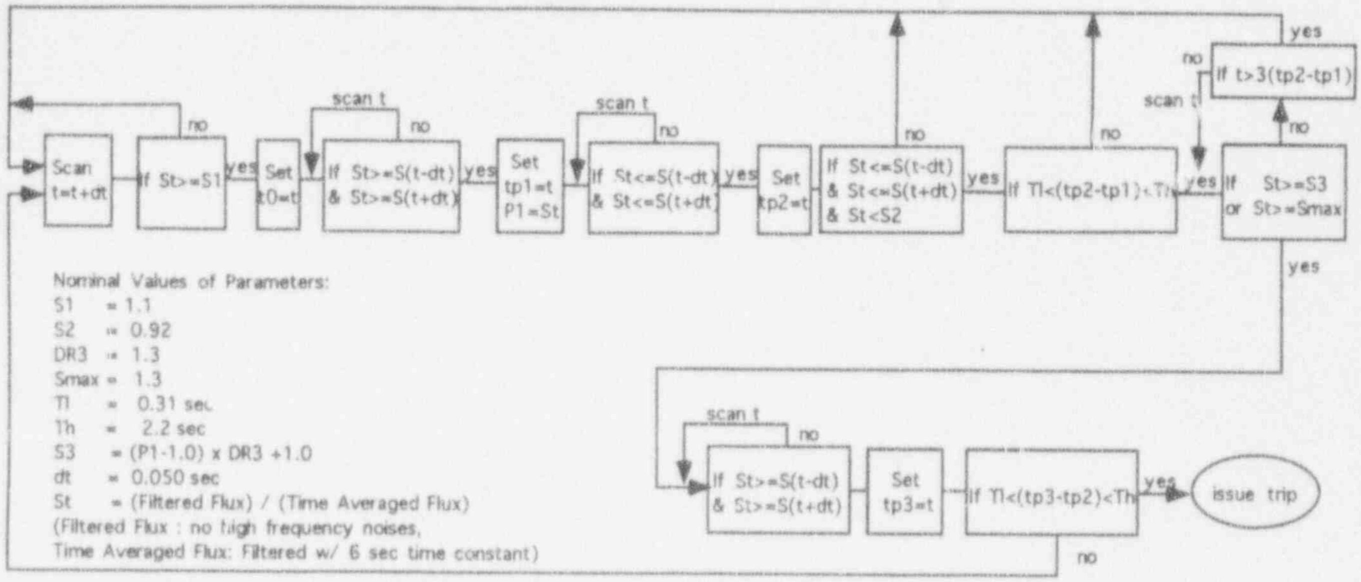
Upper left letter = Input for OPRM channel A
Upper Right Letter = Input for OPRM Channel B
Lower Right Letter = Input for OPRM Channel C
Lower Left letter = Input for OPRM Channel D

(Letters in the Map refer to LPRM Detectors A, B, C, D per Assembly)

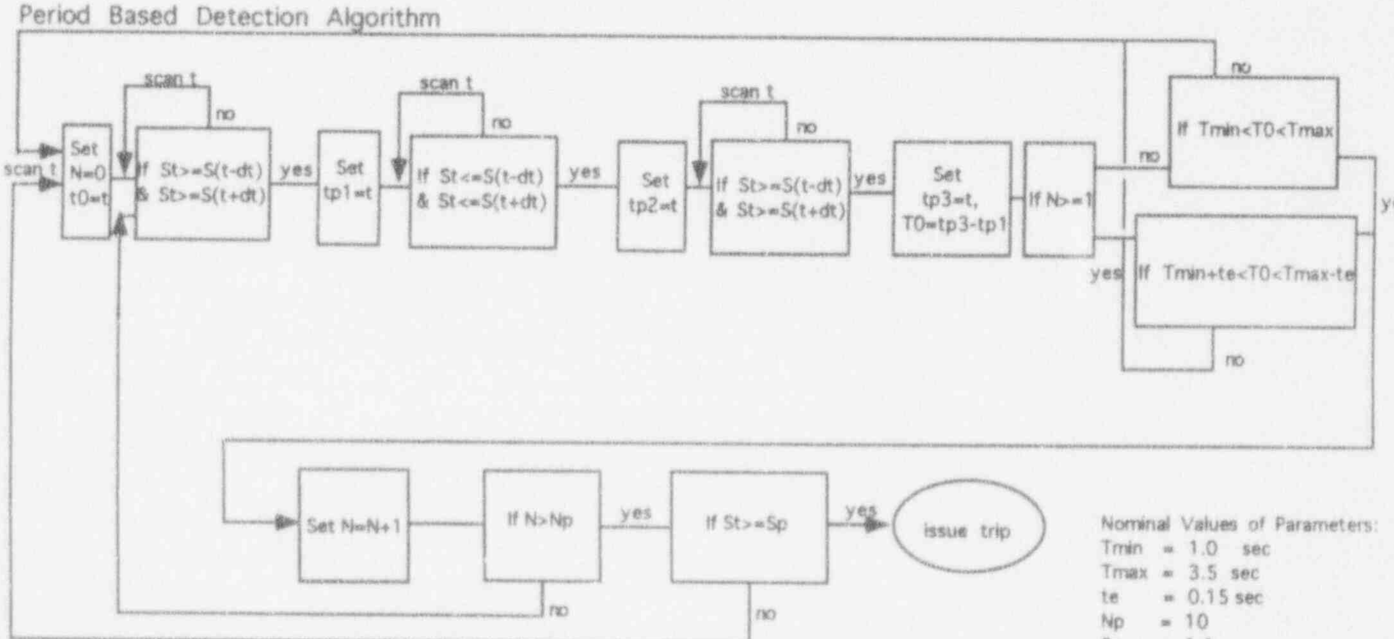
Figure 7.6-1 A

LPRM Detector Assembly Location & Assignment to OPRM System

Amplitude & Growth Rate Based Detection Algorithm



Period Based Detection Algorithm



Nominal Values of Parameters:
Tmin = 1.0 sec
Tmax = 3.5 sec
te = 0.15 sec
Np = 10
Sp = 1.1
dt = 0.050 sec
St = (Filtered Flux/ Time Averaged Flux)

Figure 7.6-2A OPRM Logic

GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

June 28, 1993

Docket No. STN 52-001

Chet Poslusny, Senior Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: Submittal Supporting Accelerated ABWR Schedule - **Oscillation Power Range Monitor (OPRM)**

Dear Chet:

Enclosed are SSAR markups responding to the NRC Staff request to provide an Oscillation Power Range Monitor (OPRM) for the ABWR. The design is the BWROG LPRM based OPRM (Option III applicable to ABWR).

Please provide a copy of this transmittal to Jim Stewart.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc: Fred Chao (GE)
Alan Beard (GE)
Norman Fletcher (DOE)

JF93-211

(a) signals to the APRM that are proportional to the local neutron flux at various locations within the rector core;

(b) signals to alarm high or low local neutron flux; and

(c) signals proportional to the local neutron flux to drive indicating meters and auxiliary devices to be used for operator evaluation of power distribution, local heat flux, minimum critical power, and fuel burnup rate.

7.1.2.6.1.4 Average Power Range Monitor (APRM) Subsystem

(1) Safety Design Bases

General Functional Requirements:

The general functional requirements are that, under the worst permitted input LPRM bypass conditions, the APRM shall be capable of generating a trip signal in response to average neutron flux increases in time to prevent fuel damage. The independence and redundancy incorporated into the design of the APRM shall be consistent with the safety design bases of the reactor protection system. The RPS design bases are discussed in Subsection 7.1.2.2.

The APRM generated trip functions ...th trip inputs ...o the RPS ...lso include: ...mulated thermal ...ower trip, APRM inoperative trip, ...ore flow rapid decrease trip, ...nd core power oscillation trip of ...e ~~oscillation~~ power ...ange monitor (OPRM). The OPRM design ...asis is to provide a ...rip to prevent growing core flux oscillation to prevent thermal limit violation, while discriminate against false signals from other signal fluctuation not related to core instability.

Specific Regulatory Requirements:

The specific regulatory requirements applicable to the controls and instrumentation for the neutron monitoring system are listed in Table 7.1-2.

(2) Nonsafety-Related Design Bases

The APRM shall provide the following functions:

(a) A continuous indication of average reactor power (neutron flux) from a 1% to 125% of rated reactor power which shall overlap with the SRNM range.

(b) Interlock signals for blocking further rod withdrawal to avoid an unnecessary scram actuation;

(c) A reference power level to the reactor recirculation system; and

(d) A simulated thermal power signal derived from each APRM channel which approximates the dynamic effects of the fuel.

(e) A continuous LPRM/APRM display for detection of any neutron flux oscillation in the reactor core. This includes the flux oscillation detection ~~uncorporated~~ algorithm incorporated in the APRM.

(f) A reference power level to permit trip in response to a reactor internal pump trip.

7.1.2.6.1.5 Automated Traversing Incore Probe (ATIP) Subsystem

(1) Safety Design Bases

None. The ATIP subsystem portion of the NMS is nonsafety-related and is addressed in Section 7.7

(2) Nonsafety-Related Design Bases

The ATIP shall meet the following power generation design bases:

(a) Provide a signal proportional to the axial neutron flux distribution at the radial core locations of the LPRM detectors (this signal shall be of high precision to allow reliable calibration of LPRM gains) and

(b) Provide accurate indication of the axial position of the flux measurement to allow pointwise or continuous measurement of the axial neutron flux distribution.

(c) Provide a totally automated mode of operation by the computer-based automatic control system.

7.1.2.6.1.6 Multi-Channel Rod Block Monitor (MRBM) Subsystem

(1) Safety Design Basis

None. The MRBM subsystem portion of the NMS is non safety-related and is addressed in Section 7.7.

(2) Non Safety-Related Design Basis

The MRBM shall meet the following power generation design bases.

(a) Provide a signal proportional to the average neutron flux level surrounding the control rod(s) being withdrawn and

(b) Issue a rod block signal if the preset setpoint is exceeded by this siganl which is propotional to the average neutron flux level siganl.

7.1.2.6.2 Process Radiation Monitoring System

(1) Safety Design Bases

General Functional Requirements:

(a) Monitor the gross radiation level

TABLE 7.1-1

COMPARISON OF GESSAR II AND ABWR I&C SAFETY SYSTEMS (Continued)

I&C System	GESSAR II Design	ABWR Design
RHR/SHUTDOWN COOLING MODE:	2 shutdown cooling divisions with 1 suction line.	3 shutdown cooling divisions with 3 suction lines (1 per division).
REMOTE SHUTDOWN SYSTEM (RSS):	RCIC controls available at RSS panel	RCIC controls replaced with HPCF controls at RSS panel.
SAFETY RELATED DISPLAY INSTRUMENTATION:	Designed to address Regulatory Guide 1.97, Revision 2.	Designed to address Regulatory Guide 1.97, Revision 3.
NEUTRON MONITORING SYSTEM (NMS):	Class 1E subsystems are IRM, LPRM & APRM.	Class 1E subsystems are SRNM (combines IRM & SRM), LPRM & APRM.
NEUTRON MONITORING SYSTEM (Continued)	Non-Class 1E subsystems are SRM, TIP, and RBM	Non-Class 1E subsystems are ATIP, and MRBM
PROCESS RADIATION MONITORING SYSTEM (PRMS):	--------------	New system definition and organization, i.e., new instrument groupings, locations and ranges.
DRYWELL VACUUM RELIEF SYSTEM:	Electrically operated butterfly valve.	Mechanically operated relief valve.
CONTAINMENT ATMOSPHERE MONITORING SYSTEM (CAMS):	(Not in GESSAR II scope)	New system provided in ABWR scope.
SUPPRESSION POOL TEMPERATURE MONITORING SYSTEM:	4 thermocouples in each of the 4 containment quadrants. 4 X 4 = 16 total T/C's.	4 thermocouples in each of 2 divisions at each of 6 locations. 4 X 2 X 6 = 48 total T/C's. Added suppression pool level monitoring function.

add
GDC 12

APPLICABLE CRITERIA	10CFR50.55	GDC 2	GDC 4	GDC 10	GDC 13	GDC15	GDC 16	GDC 19	GDC 20	GDC 21	GDC 22	GDC 23	GDC 24	GDC 25	GDC 28	GDC 29	GDC 33	GDC 34	GDC 35	GDC 38	GDC 41	GDC 44	RG 1.22	RG 1.47	RG 1.53	RG 1.62	RG 1.75	RG 1.97	RG 1.105	RG 1.118	RG 1.151	BTP 3	BTP 12	BTP 20	BTP 21	BTP 22	BTP 26	II. D. 3	II. E. 4.2	II. F. 1	II. F. 3	II. K. 1.23	II. K. 3.13	II. K. 3.15	II. K. 3.18	II. K. 3.21	II. K. 3.22	II. K. 3.23
REFERENCE STANDARD (RG) (IEEE) (ISA)	279																						279	279	279	279	384		S67.04	338	S67.02	279	279	279	R.G. 1.47	R.G. 1.22	279				R.G. 1.97							
Reactor Protection System	X	X	X		X	X		X	X	X	X	X	X	X		X							X	X	X	X	X		X	X			X		X	X	X											
Emergency Core Cooling	X	X	X		X	X		X	X	X	X	X	X			X	X	X	X				X	X	X	X	X		X	X		X		X	X	X		X	X				X	X	X	X	X	
Leak Detection & Isolation	X	X	X		X		X	X	X	X	X	X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X					X	X			X		X							
RHR/Wetwell Drywell Spray	X	X	X		X			X	X	X	X	X	X			X				X		X	X	X	X	X	X		X	X					X	X			X									
RHR/Supp. Pool Cooling	X	X	X		X			X	X	X	X	X	X			X				X		X	X	X	X	X	X		X	X					X	X			X									
Standby Gas Treatment *	X	X	X		X			X	X	X	X		X			X					X		X	X	X	X	X		X	X					X	X												
Emergency Diesel Support	X	X	X		X			X														X	X	X	X	X	X			X					X	X												
Reactor Bldg.Cooling Water	X	X	X		X			X	X	X	X	X	X			X		X	X	X		X	X	X	X	X	X			X					X	X												
Essential HVAC Systems	X	X	X		X			X	X	X	X	X	X			X							X	X	X	X	X			X					X	X												
HVAC Emer.Cooling Wtr	X	X	X		X			X	X	X	X	X	X			X						X	X	X	X	X	X			X					X	X												
Hi Press. Nitrogen Supply	X	X	X		X			X	X	X	X	X	X			X							X	X	X	X	X			X					X	X												
Alternate Rod Insertion					X			X						X													X																					
Standby Liquid Control	X	X	X		X			X															X	X	X	X	X			X					X	X												
RHR/Shutdown Cooling	X				X	X		X										X				X	X	X	X	X	X		X	X		X		X	X	X												
Remote Shutdown System	X	X	X		X			X									X	X	X			X			X	X	X																					
Safety - Related Display	X	X	X		X			X															X	X	X		X	X	X	X	X				X	X		X		X	X	X						X
Neutron Monitoring System	X	X	X	X	X			X							X								X	X	X		X	X	X	X					X	X												
Process Rad. Monitoring	X	X	X		X		X	X	X	X	X	X	X		X								X	X	X	X	X	X	X	X					X	X					X							
HP/LP System Interlocks	X	X	X	X	X	X		X									X					X	X	X	X	X	X		X	X		X			X	X												
Contmt. Atmos. Monitor	X	X	X		X		X	X													X		X	X	X		X	X	X	X					X	X				X	X							
Suppress. Pool Temp.Mon.	X	X	X		X		X	X												X			X	X	X		X	X	X	X					X	X				X	X							
Control Systems(Non-IE)					X			X																							X																	

* Includes GDC 43 and RG 1.52

add
X
(only for Neutron Monitoring System)

Table 7.1-2
Regulatory Requirements Applicability Matrix for I & C Systems

(10) Operational Considerations

The LPRM is a monitoring system with no special operating considerations.

7.6.1.1.2.2 Average Power Range Monitor Subsystem - Instrumentation and Controls

The Average Power Range Monitor (APRM) includes the Oscillation Power Range Monitor (OPRM) functions.

(1) General Description

(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, trip signal from each APRM division also goes to all other RPS divisions, with proper signal isolation.

(b) Oscillation Power Range Monitor (OPRM)

Insert 7.6.1.1.2.2 A

(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

(a) APRM

APRM channel electronic equipment averages the output signals from a selected set of LPRMs. The averaging circuit automatically corrects for the number of unbypassed LPRM amplifiers providing input signals.

Assignment of LPRMs to the APRM channels is shown in Figure 7.6-1. The LPRM detector in the bottom position of a detector assembly is designated Position A. Detectors above A are designated B and C, and the uppermost detector is designated D.

Reactor core flow signals derived from core plate pressure drop signals are used in the APRM to provide the flow biasing for the APRM rod block and thermal power trip setpoint functions. There is also the Core Flow Rapid Coastdown Trip logic in the APRM unit which utilizes the core flow and thermal power information. The core flow signal is also used to provide the flow biasing for the MRBM rod block setpoint functions.

(b) OPRM

Insert 7.6.1.1.2.2 B

~~The APRM signal conditioning unit also includes an algorithm that provides detection of core oscillation resulted from core in-stability. This algorithm uses LPRM signals as input, and is based on a specific detection methodology that relates the fuel thermal response in the fuel assembly to the LPRM signals. It includes a specific method of combining the designated LPRM signals in order to detect localized core power ascillation. The algorithm monitors core power oscillation responses and provides a trip signal if a growing oscillation with sufficient magnitide is detected. The COL applicant will implement the oscillation monitoring logic function in the APRM in accordance with the conclusion of the BWR Owners' Group as required in Subsection 7.6.3.~~

(4) Trip Function

APRM system trips including OPRM trips are summarized in Table 7.6-2. The APRM scram trip function is discussed in Section 7.2. The APRM rod block trip function is discussed in Subsection 7.7.1.2. The APRM channels also provide trip signals indicating when an APRM channel is upscale, downscale, bypassed, or inoperative.

Insert 7.6.1.1.2.2 C

(5) Bypasses and Interlocks

(a) APRM

One APRM channel may be bypassed at any time. The trip logic will in essence become two-out- of-three instead of two-out-of-four.

(b) OPRM

Insert 7.6.1.1.2.2

Insert 7.6.1.1.2.2 C2

(6) Redundancy

(a) APRM

Four independent channels of the APRM monitor neutron flux. 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.

Insert 7.6.1.1.2.2.E

(8) OPRM

(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-

Insert 7.6.1.1.2.2.A

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. The OPRM trips are combined with the APRM trips of the same APRM channel, to be sent to the RPS.

Insert 7.6.1.1.2.2.B

The OPRM utilizes the same set of LPRM signals used by the APRM that this OPRM channel resides with. Assignment of LPRMs to the four OPRM channels is identical to that referred in Figure 7.6-1, which shows the assignment of LPRMs to APRM channels. Figure 7.6-1A shows the detailed LPRM assignments to the four OPRM channels, including the assignment of LPRMs to the OPRM cells. With this configuration, each OPRM cell receives four LPRM inputs from four LPRM strings at the four corners of the 4X4 fuel bundle square. 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 overall axial and radial distribution of these LPRMs between the OPRM channels are uniform. Each OPRM cell has four LPRMs from all four different elevations in the core. 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.

The OPRM trip protection algorithm consists of trip logic depending on signal oscillation magnitude and signal oscillation period. For each cell, the peak to average value of the OPRM signal is determined to evaluate the magnitude of oscillation and to be used in the setpoint algorithm. The OPRM signal sampling and computation frequency is well above the expected thermal-hydraulic oscillation frequency, essentially producing a continuous and simultaneous measurement of all defined OPRM cells.

Insert 7.6.1.1.2.2.C

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 7.6-2A illustrates the trip algorithm logic. The OPRM trip function does not have its own inoperative trip for insufficient number of total LPRM inputs in the channel. It follows the APRM's inoperative trip of insufficient number of LPRMs.

Insert 7.6.1.1.2.2.C.2

The APRM also sends an interlock signal to the SSLC similar to the SRNM "ATWS Permissive" signal (see Table 7.6-2). If this signal is a "high" level indicating the power is above the setpoint, this will allow the SSLC to permit ATWS protection action.

Insert 7.6.1.1.2.2.D

The OPRM channel bypass is controlled by the bypass of the APRM channel it resides with. Bypass of the APRM channel will bypass the OPRM trip function within this APRM channel. The OPRM also has its own separate automatic bypass functions: the OPRM trip output from any cell is bypassed if: i) the APRM reading of the same channel is below 30% of rated power or the core flow reading is above 60% of rated flow; ii) the number of LPRM inputs to this OPRM cell is less than two. Any LPRM input to an OPRM cell is automatically bypassed if this LPRM reading is less than 5% of full scale LPRM reading. There is no requirement as to how many cells per OPRM channel has to be active since this is controlled by the total number of active LPRMs to the APRM channel.

Insert 7.6.1.1.2.2.E

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. The OPRM trip outputs also follows the two-out-of-four logic as the APRM since the OPRM trip output 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.

Insert 7.6.2.1.1. (2)

It also includes a trip from the OPRM subsystem algorithm which will issue a trip if the OPRM algorithm detects a growing neutron flux oscillation indicating core thermal hydraulic instability.

7.6.2 ANALYSIS

7.6.2.1 Neutron Monitoring System - Instrumentation and Controls

The analysis for the trip inputs from the neutron monitoring system (NMS) to the reactor protection (trip) system (RPS) are discussed in Subsection 7.2.2.

The automatic traversing in-core probe (ATIP) is a nonsafety-related subsystem of the NMS and is analyzed along with the other nonsafety subsystems in Section 7.7.2.

This analysis section covers only the safety-related subsystems of the neutron monitoring system (NMS). These include the following:

(1) Startup range neutron monitor subsystem (SRNM)

(2) Power range neutron monitor subsystem (PRNM) which includes:

(a) Local power range monitor subsystem (LPRM), and

(b) Average power range monitor subsystem (APRM)

7.6.2.1.1 General Functional Requirements Conformance

(1) Startup range neutron monitors (SRNM)

The SRNM subsystem is designed as a safety-related system that will generate a scram trip signal to prevent fuel damage in the event of any abnormal reactivity insertion transients while operating in the startup power range. This trip signal is generated by either an excessively high neutron flux level, or too fast a neutron flux increase rate, i.e., reactor period. The setpoints of these trips are such that under worst reactivity insertion transients, fuel integrity is always protected. The independence and redundancy requirements are incorporated into the design of the SRNM and are consistent with the safety design bases of the reactor protection system (RPS).

(2) Power range neutron monitors (PRNM)

The PRNM subsystem provides information for monitoring the average power level of the reactor core and for monitoring the local power level when the reactor power is in the power range (above approximately 15% power). It mainly consists of the LPRM and the APRM subsystems.

(a) LPRM subsystem: The LPRM is designed to provide a sufficient number of LPRM signals to the APRM system such that the safety design basis for the APRM is satisfied. The LPRM itself has no safety design basis. However, it is qualified as a safety-related system.

(b) APRM subsystem: The APRM is capable of generating a trip signal to scram the reactor in response to excessive and unacceptable neutron flux increase, in time to prevent fuel damage. Such a trip signal also includes a trip from the simulated thermal power signal which is a properly delayed signal from the APRM signal. It also includes a trip from a core flow based algorithim which will issue a trip if the core flow suddenly decreases too fast, called the Core Flow Rapid Coastdown trip. All scram function is assured so long as ~~the~~ minimum LPRM input requirement to the APRM is satisfied. If such an input requirement cannot be met, a trip signal shall also be generated. The independence and redundancy requirements are incorporated into the design and are consistent with the safety design basis of the RPS.

Insert 7.6.2.1.1 (2)

7.6.2.1.2 Specific Regulatory Requirements Conformance

Table 7.1-2 identifies the neutron monitoring system (NMS) and the associated codes and standards applied in accordance with the Standard Review Plan. The following analysis lists the applicable criteria in order of the listing on the table, and discusses the degree of conformance for each. Any exceptions or clarifications are so noted.

(1) 10CFR50.55a (IEEE 279):

The safety-related subsystems of the neutron monitoring system consist of four divisions which correspond and interface with those of the reactor protection system (RPS). This independence and redundancy assure that no single failure will interfere with the system operation.

The 10 SRNM channels are divided into four divisions and independently assigned to three bypass groups such that up to three SRNM channels are allowed to be bypassed at any time while still providing the required monitoring and protection capability.

There are 52 LPRM assemblies evenly distributed in the core. There are four LPRM detectors on each assembly, evenly distributed from near the bottom of the fuel region to near the top of the fuel region (Figure 7.6-3). A total of 208 detectors are dividied and assigned to four divisions for the four APRMs. Any single LPRM detector is only assigned to one APRM division. Electrical wiring and physical separation of the division is optimized to satisfy the safety-related system requirement. With the four divisions, redundancy criteria are met since a scram signal can still be initiated with a postulated single failure under allowed APRM bypass conditions. The APRM subsystem as described in 7.6.1.1.2.2 conforms to all applicable requirements of IEEE-279.

All components used for the safety-related functions are qualified for the environments in which they are located (Sections 3.10 and 3.11).

All applicable requirements of IEEE 279 are met with the NMS.

(2) General Design Criteria (GDC):

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, the following GDCs are addressed for the NMS:

(a) Criteria: GDCs 2, 4, 10, 12, 13, 19, and 28.

(b) Conformance: The NMS is in compliance with these GDCs, in part, or as a whole, as applicable. The GDCs are generically addressed in Subsection 3.1.2.

(3) Regulatory Guides (RGs):

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, the following RGs are addressed for the NMS:

(a) RG 1.22 - *Periodic Testing of Protection System Actuation Functions*

(b) RG 1.47 - *Bypassed and Inoperable Status Indication for Nucleur Power Plant Safety Systems*

(c) RG 1.53 - *Application of the Single-Failure Criterion to Nuclear Power Protection Systems*

(d) RG 1.75 - *Physical Independence of Electric Systems*

(e) RG 1.97 - *Instrumentation During and Following an Accident*

(f) RG 1.105 - *Instrument Setpoints for Safety-Related Systems*

(g) RG 1.118 - *Periodic Testing of Electric Power and Protection Systems*

The NMS conforms with all the above-listed RGs assuming the same interpretations and clarifications identified in Subsections 7.2.2.2.1(7), 7.3.2.1.2 and 7.1.2.10.

(4) Branch Technical Positions (BTPs):

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, only BTPs 21 and 22 are considered applicable for the NMS. They are addressed as follows:

(a) BTP ICSB 21 - *Guidance for Application of Regulatory Guide 1.47:*

The ABWR design is a single unit. Therefore, item B-2 of the BTP is not applicable. Otherwise, the NMS is in full compliance with this BTP.

TABLE 7.6-2

APRM TRIP FUNCTION SUMMARY

a) APRM Trip Function

Trip Function	Trip Setpoint (Nominal)	Action
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	LPRM input too few Module interlocks disconnect Electronics Critical Failure	Scram & Rod Block
APRM Downscale	5%	Rod Block (only in RUN)
APRM ATWS Permissive	6 %	All Modes (Note 1)
Core Flow ~~Rapid~~ Coastdown (Note 1)	fixed (Note 2)	Scram (bypassed with thermal power ~~< 77%~~)
Core Flow Upscale Alarm	120% (flow)	Rod Block (only in RUN)

Notes:

1. APRM has to indicate a power level below the setpoint in order to remove the permissive.
2. 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.

Table 7.6-2

APRM TRIP FUNCTION SUMMARY (Continued)

b) OPRM TRIP FUNCTION

Trip Function	Trip Setpoint (Nominal)	Action
Growth Rate-Based Trip (S_3)	$S = S_3 = (P_1 - 1.0) \times DR_3 + 1.0$ (NOTE 3) $DR_3 = 1.3$	Scram (NOTE 4)
Amplitude-Based Maximum Trip (S_{max})	$S = S_{max} = 1.30$ (NOTE 3)	Scram (NOTE 4)
Period-Based Trip (S_P)	$S = S_P = 1.10$ (NOTE 5)	Scram (NOTE 4)

NOTES (~~Continued~~):

3. 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 sec, $T_2 = 0.31$ to 2.2 sec
(For details see Figure 7.6-2A)

4. Automatic Bypassed if Core power ≤ 30% and Core flow ≥ 60%

5. Other Pre-Trip Condition parameters of the algorithm are:
$T_{min} = 1$ sec, $T_{max} = 3.5$ sec, $\pm t_{error} = 0.15$ sec
$N_P = 10$
(For details see Figure 7.6-2A)

Table 7.6-5

REACTOR OPERATOR INFORMATION FOR NMS

(1) The NMS provides for the activations of the following annunciations at the main control panel.

(a) SRNM neutron flux upscale reactor trip
(b) SRNM neutron flux upscale rod block
(c) SRNM neutron flux downscale rod block
(d) SRNM short period reactor trip
(e) SRNM short period rod block
(f) SRNM inoperative reactor trip
(g) SRNM period withdrawal permissive alarm
(h) APRM neutron flux upscale reactor trip
(i) APRM simulated thermal power reactor trip
(j) APRM neutron flux upscale rod block
(k) APRM neutron flux downscale rod block
(l) Reference APRM downscale rod block
(m) APRM system inoperative reactor trip
(n) Core flow rapid coastdown reactor trip
(o) APRM core flow upscale rod block
(p) Core flow inoperative alarm
(q) LPRM neutron flux upscale alarm
(r) LPRM neutron flux downscale alarm
(s) ATIP automatic control system (ACS) inoperative
(t) ATIP indexer inoperative
(u) ATIP control function inoperative
(v) ATIP valve control monitor function inoperative
(w) MRBM upscale rod block
(x) MRBM downscale rod block
(y) MRBM inoperative rod block
(z) Core flow abnormal
(aa) OPRM Trip

(2) The NMS provides status information on the dedicated NMS operator interface on the main control panel as follows:

(a) APRM power level
(b) Srnm power level

(3) The dedicated operator interface of the NMS provides logic and operator controls, so that the operator can perform the following functions at the main control panel:

(a) APRM channel bypass
(b) SRNM channel bypass
(c) MRBM main channel bypass
(d) MRBM rod block logic test
(e) MRBM upscale rod block setpoint setup to intermediate/normal

Table 7.6-5

REACTOR OPERATOR INFORMATION FOR NMS (Continued)

(4) Certain NMS - related information, available on the main control panel, is implemented in software which is independent of the process computer. This information is listed below.

(a) SRNM reactor period
(b) SRNM count rate
(c) APRM bypass status
(d) APRM neutron flux upscale trip/inoperative status
(e) APRM neutron flux upscale rod block status
(f) APRM neutron flux downscale rod block status
(g) APRM core flow upscale rod block status
(h) APRM core flow rapid coastdown status
(i) APRM core flow rapid coastdown bypass status
(j) MRBM main channel bypass status
(k) MRBM main channel upscale rod block status
(l) MRBM main channel downscale rod block status
(m) MRBM main channel inoperative rod block status
(n) MRBM main channel core flow abnormal rod block status
(o) OPRM Trip Status

(5) CRT displays, which are part of the performance monitoring and control system, provide certain NMS-related displays and controls on the main control panel which are listed below:

(a) SRNM upscale trip/inoperative status
(b) SRNM reactor period trip status
(c) SRNM upscale rod block status
(d) SRNM reactor period rod block status
(e) SRNM downscale rod block status
(f) SRNM bypass status
(g) SRNM period historical record
(h) SRNM count rate historical record
(i) SRNM period-based permissive
(j) LPRM string selected for status readings
(k) LPRM neutron flux level (Designated group of LPRMs displayed upon selection of certain single rod or gang of control rods)
(l) LPRM bypass status
(m) LPRM neutron flux downscale alarm status
(n) LPRM neutron flux upscale alarm status
(o) Number bypassed LPRMs and APRM channel
(p) APRM simulated thermal power reactor trip status
(q) APRM core flow
(r) Core flow historical record
(s) APRM neutron flux
(t) APRM simulated thermal power trip setpoint
(u) APRM simulated thermal power
(v) APRM simulated thermal power record
(w) Reference APRM downscale rod block status (One for each MRBM main channel)
(x) MRBM main channel block level status
(y) MRBM main channel upscale (normal) rod block setpoint
(z) MRBM main channel upscale (intermediate) rod block setpoint

Table 7.6-5

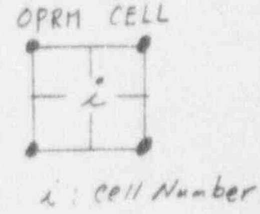
REACTOR OPERATOR INFORMATION FOR NMS (Continued)

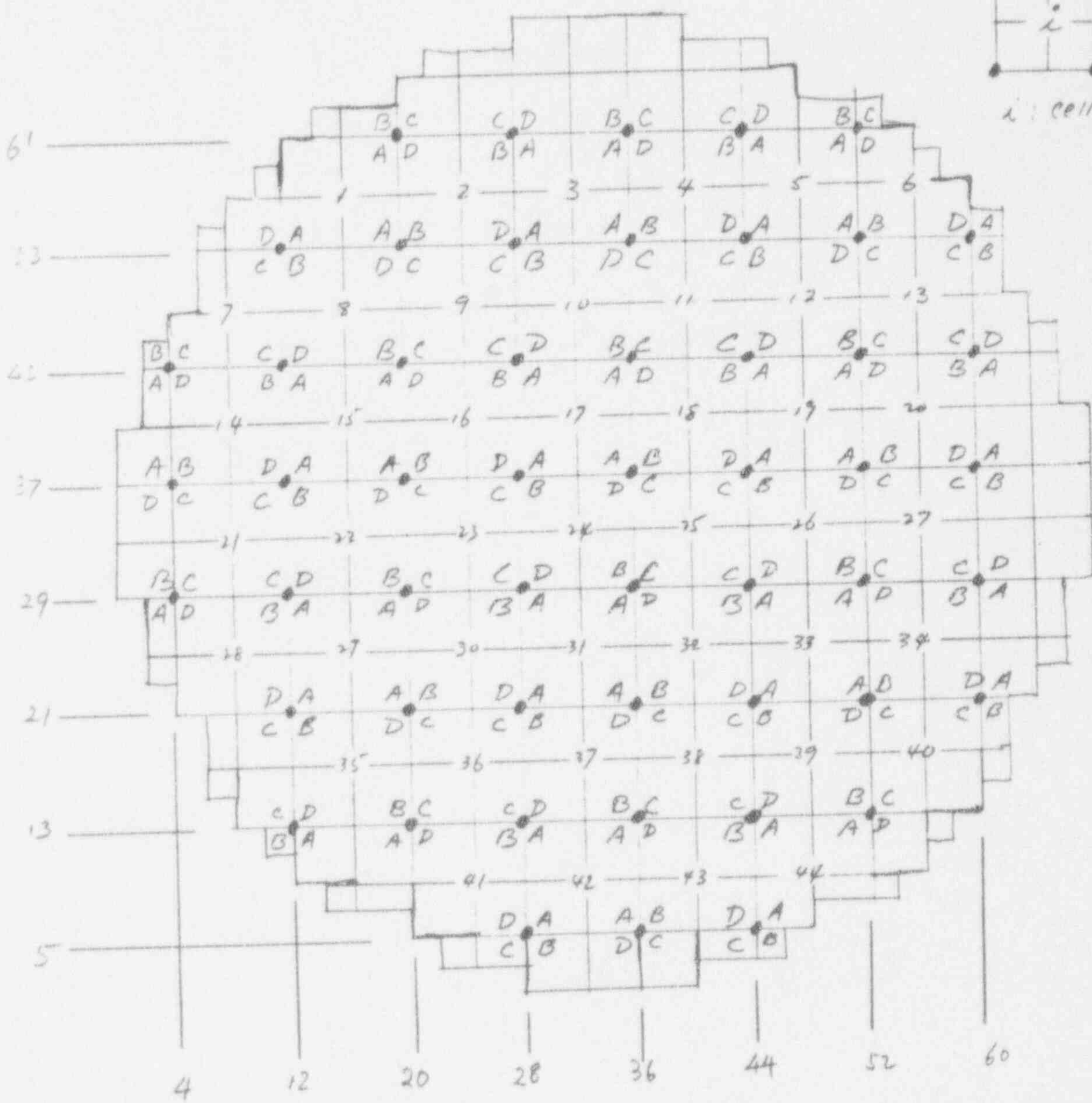
(aa) MRBM main channel upscale (low) rod block setpoint
(ab) MRBM main channel upscale (normal) rod block setpoint historical record
(ac) MRBM main channel upscale (intermediate) rod block setpoint historical record
(ad) MRBM main channel upscale (low) rod block setpoint historical record
(ae) MRBM subchannel inoperative status
(af) MRBM subchannel upscale rod block status
(ag) MRBM subchannel downscale rod block status
(ah) MRBM subchannel intermediate level transfer rate
(ai) MRBM subchannel normal level transfer rate
(aj) MRBM subchannel reading
(ak) MRBM subchannel reading historical record
(al) MRBM subchannel setup permissive
(am) MRBM gain adjustment failed
(an) No rod selected (MRBM)
(ao) Peripheral rod selected (MRBM)

(ap) OPRM Trip setpoint data
(aq) OPRM cell configuration and status of LPRM inputs
(ar) OPRM Trip Status
(as) OPRM signals Record

ACRONYMS

NMS - Neutron Monitoring System
SRNM - Startup Range Neutron Monitor
APRM - Average Power Range Monitor
LPRM - Local Power Range Monitor
ATIP - Automatic Traversing In-Core Probe
MRBM - Multi-channel Rod Block Monitor
CRT - Cathode Ray Tube





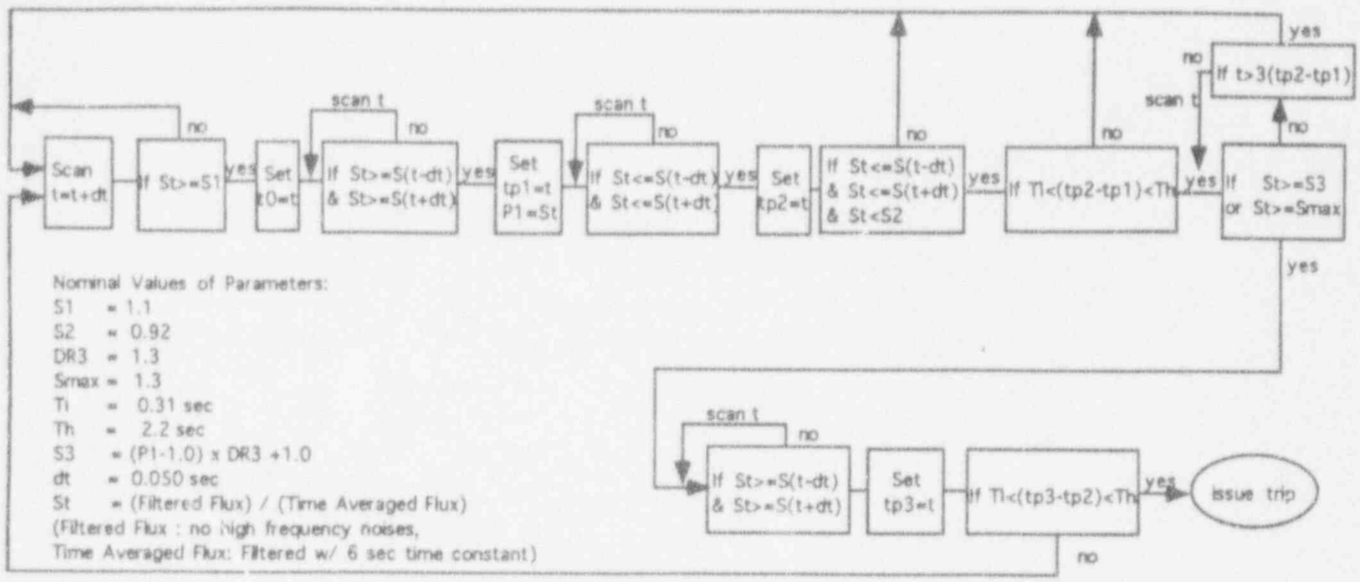
A | B
D | C
LPRMs providing input to OPRM Channels A, B, C, D

Upper left Letter = Input for OPRM Channel A
Upper Right Letter = Input for OPRM Channel B
Lower Right Letter = Input for OPRM Channel C
Lower left Letter = Input for OPRM Channel D
(Letters in the Map refer to LPRM Detectors A, B, C, D per Assembly)

Figure 7.6-1 A

LPRM Detector Assembly Location & Assignment to OPRM System

Amplitude & Growth Rate Based Detection Algorithm



Period Based Detection Algorithm

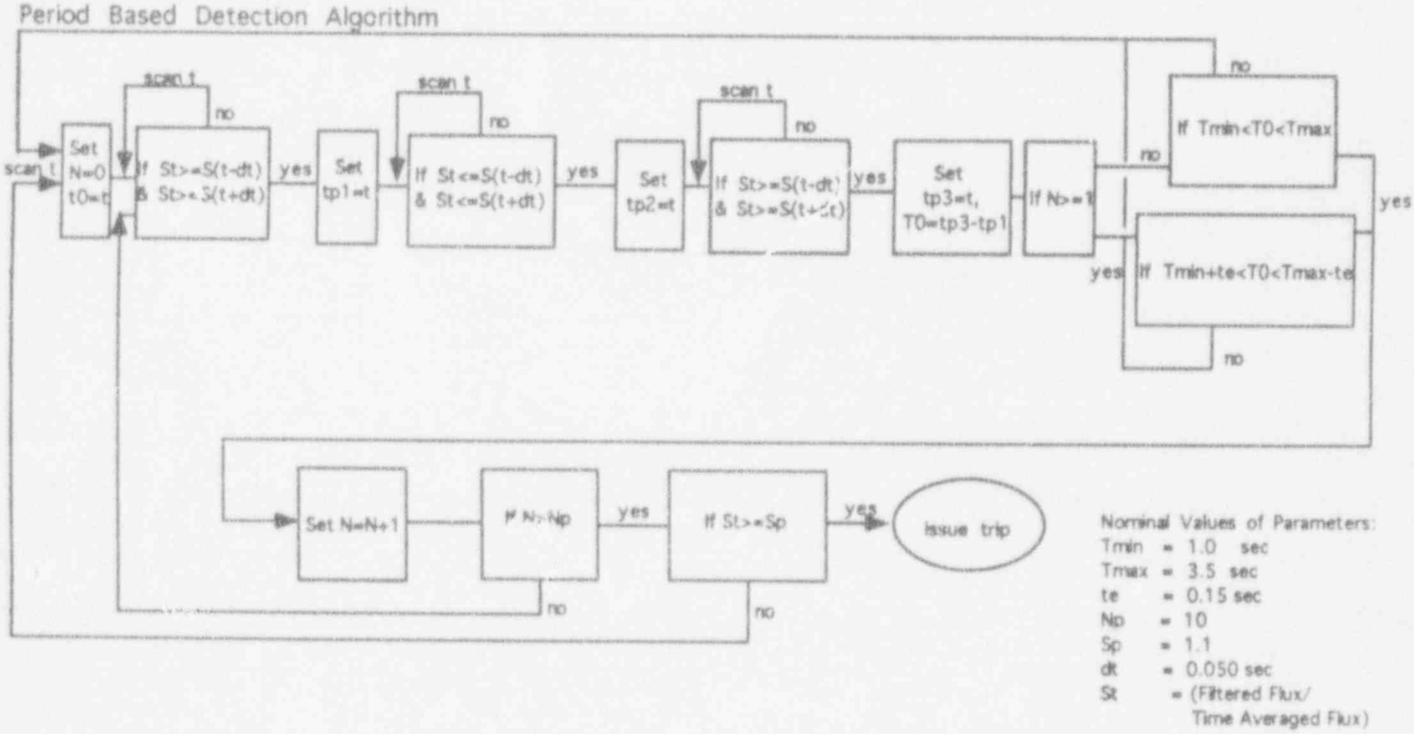


Figure 7.6-2A OPRM Logic