

7.6 All Other Instrumentation Systems Required for Safety

The information in this section of the reference ABWR DCD, including all subsections, tables, and figures, is incorporated by reference with the following departures and supplements.

STD DEP T1 2.2-1 (Table 7.6-5 and Figure 7.6-2)

STD DEP T1 2.14-1

STD DEP T1 3.4-1 (Table 7.6-5 and Figures 7.6-1, 7.6-2, 7.6-4a)

STP DEP 1.1-2

STD DEP 7.1-1

STD DEP 7.1-2 (Table 7.6-5)

STD DEP 7.1-3 (Table 7.6-5 and Figure 7.6-1)

STD DEP 7.2-1 (Table 7.6-5 and Figures 7.6-1, 7.6-2)

STD DEP 7.6-1 (Table 7.6-2 and Figures 7.6-2, 7.6-14)

STD DEP 7.6-2 (Table 7.6-5)

STD DEP 7.6-3 (Figures 7.6-9, 7.6-11, 7.6-12)

STD DEP 7.6-4

STD DEP 11.5-1 (Figure 7.6-5)

STD DEP Admin

7.6.1.1 Neutron Monitoring System-Instrumentation and Controls

STD DEP T1 3.4-1

(1) *System Identification*

The purpose of the Neutron Monitoring System (NMS) is to monitor power generation and, for the safety function part of the NMS, to provide trip signals to the Reactor Protection System (RPS) to initiate reactor scram under excessive neutron flux (and power) increase condition (high level) or neutron flux fast rising (short period) condition. The NMS also provides power information of operation and control of the reactor to the Plant ~~Process Computer System (PCS)~~ Functions (PCF) and the rod block monitor. A block diagram showing a typical NMS division is shown in Figure 7.6-4a. The operating ranges of the various detectors are shown in Figure 7.6-4b.

7.6.1.1.1 Startup Range Neutron Monitor Subsystem-Instrumentation and Controls

STD DEP T1 3.4-1

STD DEP 7.2-1

(3) *Physical Arrangement*

The 10 detectors are all located at fixed elevation slightly above the midplane of the fuel region, and are evenly distributed throughout the core. The SRNM locations in the core, together with the neutron source locations, are shown in Figure 7.6-1. Each detector is contained within a pressure barrier dry tube inside the core, with signal output exiting the bottom of the dry tube undervessel. Detector cables then penetrate the primary containment and are connected to preamplifiers located in the Reactor Building. The SRNM preamplifier signals are then transmitted to the SRNM DMC (digital measurement and control) units in the control room. The DMC units provide algorithms for signal processing, flux, and power calculations, period trip margin and period calculations, and provide various outputs for local and control console displays, recorder, and to the plant process computer system function. There are also the alarm and trip digital outputs for both high flux and short period conditions, and the instrument inoperative trip to be sent to the RPS and RCIS separately. The electronics for the SRNMs and their bypasses are located in four separate cabinets.

(6) *Bypasses and Interlocks*

The 10 SRNM channels are divided into three bypass groups. With such bypass grouping, up to three SRNM channels can be bypassed at any time, with any one channel from each bypass group bypassed. There is no additional SRNM bypass capability at the divisional level. If a SRNM divisional out of service is required, this will generate a half trip to the RPS SRNM divisional alarm (not an RPS trip) if the SRNM channel is not bypassed. For SRNM calibration or repair, the bypass can be done for each individual channel separately. There are separate bypass functions for the SRNM and the APRM in the NMS (i.e., there is no single NMS divisional bypass which will affect both the SRNM and the APRM). Any APRM bypass will not force a SRNM bypass. ~~The SRNM and APRM bypasses are separate logics to the RPS, each interfacing with the RPS independently.~~ Also, ~~all~~ All NMS bypass logic control functions are located within the NMS, not in the RPS. The SRNM bypass switches are mounted on the control room panel.

The SRNM also sends an interlock signal to the ~~safety system logic control (SSLC) system~~ ESF Logic and Control System (ELCS). This signal is called "ATWS Permissive" and is a binary signal indicating whether the SRNM power level is above or below a specific setpoint level (Table 7.6-1). If this signal is a "high" level indicating the power is above the setpoint, this will allow the ~~SSLC~~ ELCS to permit ATWS protection action such as permission to inject liquid poison.

(7) *Redundancy and Diversity*

The 10 SRNM channels are arranged into four divisions such that each of the four RPS divisions receives input signals from ~~each and all of the four~~ its associated SRNM divisions. Failure of a single SRNM channel, once bypassed, will not cause a trip to the RPS. Such failure will not prevent proper operation of the remaining trip channels in performing their safety functions (Subsection 7.2.1.1.4.2 (1)).

7.6.1.1.2 Power Range Neutron Monitor Subsystem—Instrumentation and Controls

7.6.1.1.2.1 Local Power Range Neutron Monitor Subsystem—Instrumentation and Controls

STD DEP T1 3.4-1

(4) Signal Processing

The LPRM detector outputs are connected by coaxial cables from under the vessel pedestal region and routed through the primary containment penetration, and through the Reactor Building to be processed for signal conditioning analog-to-digital conversion function in the control room. The LPRM signals are connected to the APRM units in the control room, where the signals are amplified. Such amplified voltage is proportional to the local neutron flux level. The LPRM signals are then used by the APRM to produce APRM signals. The 208 LPRM detectors are separated and divided into four groups to provide four independent APRM signals. Individual LPRM signals are also transmitted through dedicated interface units (for isolation) to various systems such as the RCIS, and the plant ~~process~~ computer functions.

7.6.1.1.2.2 Average Power Range Monitor Subsystem—Instrumentation and Controls

STD DEP 7.6-1

STD DEP T1 3.4-1

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

(1) General Description

(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. ~~The OPRM trips are combined with the APRM trips of~~

~~the same APRM channel, to be sent to the RPS.~~ The OPRM trips logic is performed separately from the APRM trips logic.

(4) Trip Function

~~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 7.6-14 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.~~ The OPRM function has its own inoperative trip when the channel has less than the required minimum operable cells, or there is an OPRM self-test fault, or the APRM instrument firmware/software timer has timed out, if there is a loss of power to the APRM instrument.

(5) Bypasses and Interlocks

(a) APRM

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

(6) Redundancy

(b) OPRM

(i) ~~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 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. The OPRM trip outputs also follow the two-out-of-four logic as the APRM but independent from the APRM 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~~ ELCS is also provided.

7.6.1.1.3 Reactor Operator Information

STD DEP Admin

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 7.6-5 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).

7.6.1.3 High Pressure/Low Pressure Systems Interlock Protection Functions

STD DEP 7.1-1

(14) Setpoints

See Chapter 16 for setpoints and margin. The safety system setpoints are listed in the Instrument Setpoint Summary Report as described in 7.1.2.1.4.1.

7.6.1.6 Containment Atmospheric Monitoring (CAM) System-Instrumentation and Controls

STD DEP 11.5-1

STD DEP T1 2.14-1

(1) System Identification

The CAM System (Figures 7.6-7 and 7.6-8) consists of two independent but redundant Class 1E divisions (I and II) of radiation channels, which are electrically and physically separated, and a non-safety H₂/O₂ monitoring subsystem. Each CAM ~~division~~ divisional radiation channel has the capability of monitoring the total gamma-ray dose rate. CAMS also has the capability of monitoring ~~and~~ concentration of hydrogen and oxygen (H₂/O₂) in the drywell and/or the suppression chamber during plant operation, and following a LOCA event.

There are two radiation monitoring channels per division; one for monitoring the radiation level in the drywell and the other for monitoring the radiation level in the suppression chamber. Each monitoring channel consists of ~~an ion chamber a~~ detector and a digital log radiation monitor, and a recorder. Each radiation monitoring channel provides alarm indication in the control room on high radiation levels and also if the channel becomes inoperative. The monitor also provides data for the historian function.

The H₂/O₂ monitoring subsystem is located within a H₂/O₂ analyzer panel. Each H₂/O₂ analyzer panel consists ~~Each divisional H₂/O₂ monitoring channel consists~~ of valves, pumps, and pipes used to extract samples of the atmosphere in the drywell or the suppression chamber and feed the extracted air sample into an analyzer and monitor for measurement, ~~recording~~, and for alarm indication on high concentration

of gas levels. The H2/O2 monitoring subsystem is non-safety and is physically and electrically separate from the safety related components of the system.

The piping within the panels used for the gas extraction is made of stainless steel and utilizes heat tracing to keep the pipes dry and free of moisture condensation.

(2) Power Sources

Each CAM Subsystem radiation channel is powered from divisional 120 VAC instrument bus. The same Class 1E divisional 120 VAC power source also supplies the heat tracing blanket used for the sampling lines. The H2/O2 subsystem is powered from non-safety equipment.

(3) Initiating Circuits

Each divisional gamma radiation monitoring channel can be energized manually by the operator, ~~or automatically by the LOCA signal.~~ For the manual mode, the The gamma radiation monitor is on continuously during plant operation and remains on until power is turned off by the operator.

~~In the power off mode, the channel will be activated automatically in the presence of a LOCA (high drywell pressure or low reactor water level).~~

Each ~~divisional~~ H2/O2 monitoring subsystem (except for the two sampling pumps) is powered continuously during plant operation. ~~One pump~~ Each subsystem is controlled by an operator and is used during reactor operation and ~~the other is can~~ also be turned on by the LOCA signal to allow measurement during an accident.

The heat tracing used in each H2/O2 sample line is located within the panel and is temperature controlled to prevent moisture condensation in the pipes.

Each ~~divisional~~ H2/O2 analyzer and monitor can selectively measure the atmosphere in the drywell or the suppression chamber.

~~Division I and II~~ LOCA signals are provided to the CAM System from the RHR System. These signals are based on two-out-of-four logic signals for the high drywell pressure or low reactor water level.

(4) Redundancy and Diversity

The CAM Subsystems, Divisions I and II radiation channels, are independent and are redundant to each other.

(5) Divisional Separation

The two CAM Subsystems radiation monitoring channel divisions are electrically and physically separated so that no single design basis event is capable of damaging equipment in more than one CAM division. No single failure or test, calibration, or maintenance operation can prevent function of more than one division.

(8) Operational Considerations

The following information is available to the reactor operator:

- (a) Each gamma radiation channel consists of ~~an ion chamber a detector, and a log radiation monitor, and a recorder.~~ Each channel has a range of 0.01 ~~Gy/h~~ mSv/h to 10^5 ~~mSv/h~~ Gy/h. Each channel will initiate an alarm on high radiation level or on an inoperative channel.
- (b) Each hydrogen/oxygen monitoring ~~channel uses~~ panel contains a sampling rack for extracting the atmosphere from the drywell or the suppression chamber and for analyzing the contents for both H₂/O₂ concentration. The gaseous measurements are made by volume on a wet basis after humidity correction (dry basis before humidity correction). Separate monitors are provided for oxygen and hydrogen indications.

Each H₂/O₂ analyzer ~~rack has a series of~~ panel has alarms to indicate a high concentration of hydrogen and of oxygen, and to alert the operator of any abnormal system parameter. Refer to Figure 7.6-8 for definition of these alarms.

7.6.1.7 Suppression Pool Temperature Monitoring System-Instrumentation and Controls

7.6.1.7.1 System Identification

STD DEP 7.6-2

STD DEP T1 3.4-1

The Suppression Pool Temperature Monitoring (SPTM) System is a subsystem of the Reactor Trip and Isolation System (RTIS). It is provided to monitor suppression pool temperature. Monitoring of suppression pool temperature is provided so that trends in suppression pool temperature may be established in sufficient time for proper cooling of the suppression pool water and for reactor scram due to high suppression pool temperature and for reactor power control based upon symptom- based emergency operating procedures.

7.6.1.7.3 Equipment Design

STD DEP 7.6-3

STD DEP T1 3.4-1

The SPTM System configuration is shown in Figures 7.6-9 and 7.6-10. There are eight temperature circumferential sensor locations (Figure 7.6-9), which are chosen based upon the following considerations:

- (2) Each SRV discharge line quencher is in direct sight of two sets of temperature sensors within 9 meters.

Electrical wiring for each sensor is terminated, for sensor replacement or maintenance, in the wetwell. This termination is sealed for moisture protection from condensation or wetwell sprays. Division I, II, III and IV sensors are wired through Division I, II, III or IV electrical penetrations, respectively. ~~Division I, II, III or IV~~ I and II sensor signals are wired to for the Remote Shutdown System are directly hardwired. ~~all~~ All other sensor signals are transmitted ~~multiplexed~~ to the main control room via the respective Division I, II, III or IV essential- ~~multiplexers~~ Data Communication Function (DCF).

7.6.2 Analysis

7.6.2.1 Neutron Monitoring System-Instrumentation and Controls

7.6.2.1.1 General Functional Requirements Conformance

STD DEP 7.6-4

(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%~~ 5% power). It mainly consists of the LPRM and the APRM Subsystems.

7.6.2.1.2 Specific Regulatory Requirements Conformance

STP DEP 1.1-2

(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~~ two units do not share NMS equipment. Therefore, Item B-2 of the BTP is not applicable. Otherwise, the NMS is in full compliance with this BTP.

7.6.2.2 Process Radiation Monitoring System-Instrumentation and Controls

7.6.2.2.2 Specific Regulatory Requirements Conformance

STP DEP 1.1-2

(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 PRM safety-related subsystems. They are addressed as follows:

- (a) BTP ICSB 21- “Guidance for Application of Regulatory Guide 1.47”

The ABWR design is a single unit two units do not share PRM equipment. Therefore, Item B-2 of the BTP is not applicable. Otherwise, the PRM System is in full compliance with this BTP.

7.6.2.6 Containment Atmospheric Monitoring System-Instrumentation and Controls

7.6.2.6.2 Specific Regulatory Requirements Conformance

STP DEP 1.1-2

- (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 addressed for the CAMS as follows:

- (a) BTP ICSB 21- “Guidance for Application of Regulatory Guide 1.47”

The ABWR design is a single unit two units do not share CAMS equipment. Therefore, Item B-2 of the BTP is not applicable. Otherwise, the CAMS is in full compliance with this BTP.

7.6.2.7 Suppression Pool Temperature Monitoring System-Instrumentation and Controls

7.6.2.7.2 Specific Regulatory Requirements Conformance

STP DEP 1.1-2

- (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 need be addressed for the SPTM System. They are as follows:

- (a) BTP ICSB 21- “Guidance for Application of Regulatory Guide 1.47”

The ABWR design is a single unit two units do not share SPTM equipment. Therefore, Item B-2 of the BTP is not applicable. Otherwise, the SPTM System is in full compliance with this BTP.

7.6.3 COL License Information

7.6.3.1 APRM Oscillation Monitoring Logic

The following standard supplement addresses COL License Information Item 7.2.

The APRM oscillation logic is implemented as described in the Licensing Topical Report, NEDO-33328 “Advanced Boiling Water Reactor (ABWR) APRM Oscillation Monitoring Logic,” dated March 2007 which provides additional description of this function.

Table 7.6-2 APRM Trip Function Summary

Trip Function	Trip Setpoint (Nominal)	Action
(b) OPRM Trip Function	S=S _p =1.10**	Scram ^f
Period-Based Trip (S _p)		

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

T_{min}=1 s, T_{max}=3.5 s, ±t_{error}=0.15 s 0.1 N_p=10.
(For details see Figure 7.6-14).

Table 7.6-5 Reactor Operator Information for NMS

<p>(1) The NMS provides for the activations of the following annunciations at the main control panel:</p> <p>(j) APRM neutron flux simulated thermal power upscale rod block</p> <p>(vv) ATIP containment isolation valve open</p>
<p>(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:</p> <p>(d) MRBM rod block logic reset</p>
<p>(4) Certain NMS-related information, available on the main control panel, is implemented in software which is independent of the process computer plant computer functions. This information is listed below.</p> <p>(5) CRTVDU 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:</p> <p>(iii) SRNM ATWS permissive</p>
<p>(qq) APRM ATWS permissive</p> <p>(w) Reference APRM downscale rod block status (for each MRBM main channel) MRBM subchannel auto-bypassed</p>
<p>Acronyms</p> <p>CRTVDU <i>Cathode-Ray Tube</i> Video Display Unit</p>

The following figures are located in Chapter 21:

Figure 7.6-1 Neutron Monitoring System IED (Sheets 1 & 3)

Figure 7.6-2 Neutron Monitoring System IBD (Sheets 1,3,6,9,25-27)

Figure 7.6-5 Process Radiation Monitoring System IED (Sheets 1-9)

Figure 7.6-11 Suppression Pool Temperature Monitoring System IED (Sheets 1,3)

Figure 7.6-12 Suppression Pool Temperature Monitoring System IBD (Sheets 1-5)

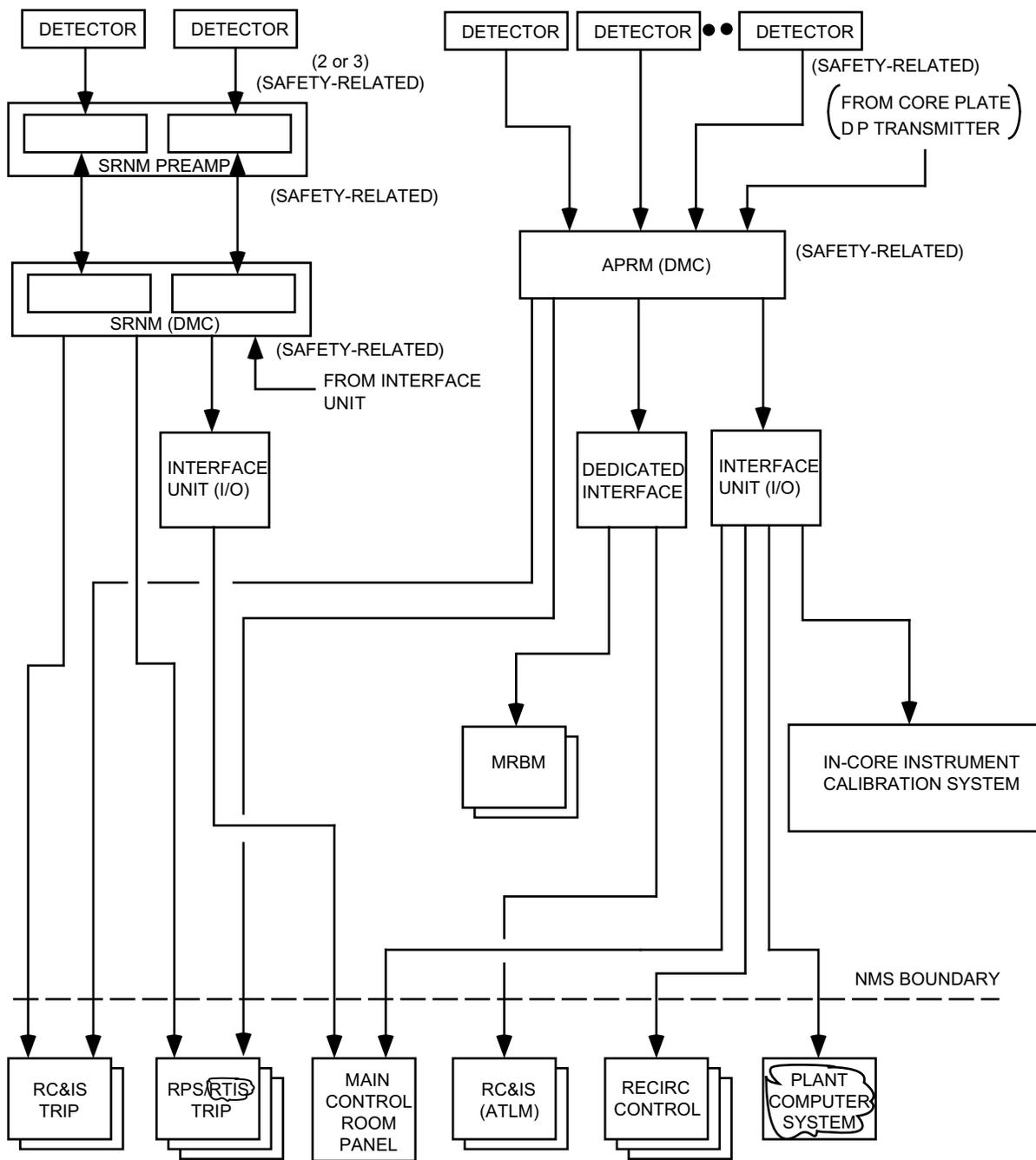
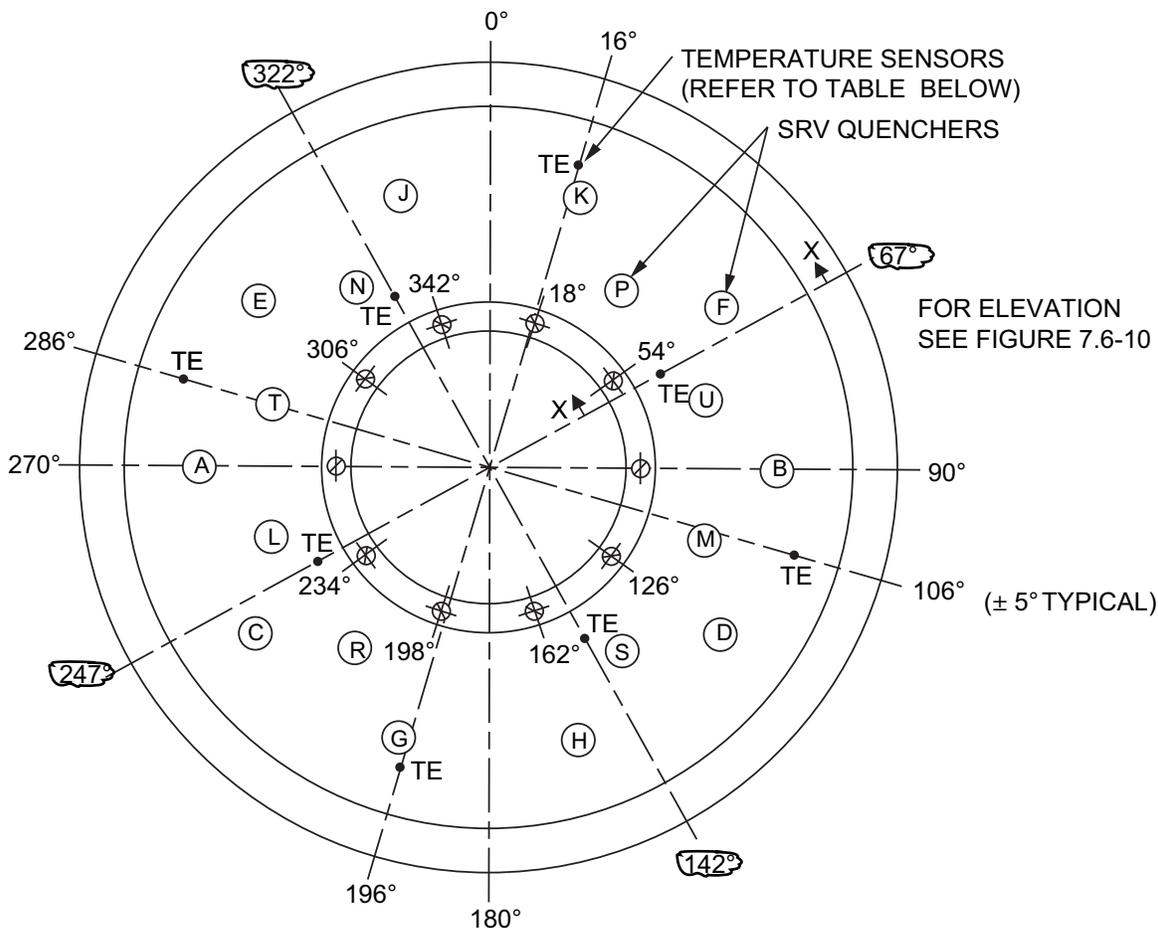


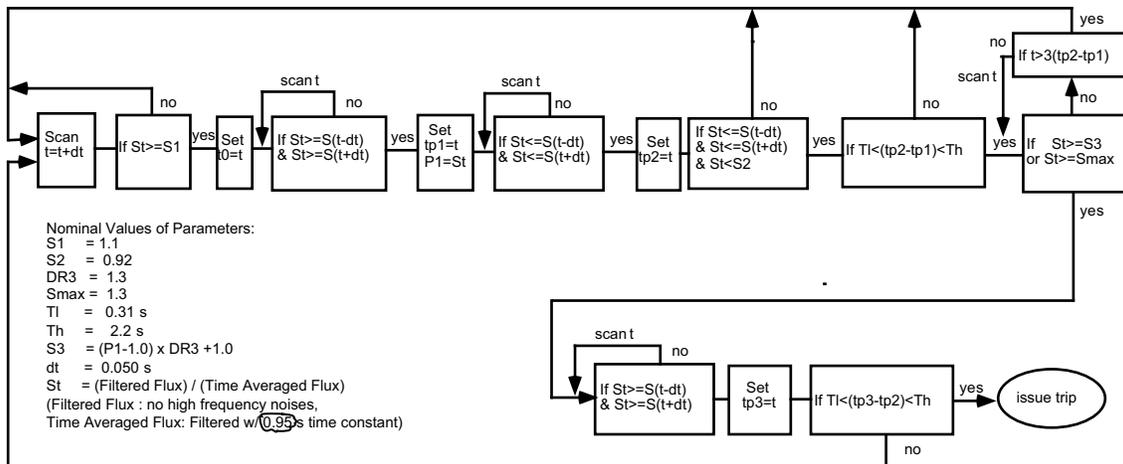
Figure 7.6-4a Basic Configuration of a Typical Neutron Monitoring System Division



	DIVISION I	DIVISION II	DIVISION III	DIVISION IV
16°	TE-001A,E,J,N		TE-001C,G,L,R	
67°		TE-002B,F,K,P		TE-002D,H,M,S
106°		TE-003B,F,K,P		TE-003D,H,M,S
142°	TE-004A,E,J,N		TE-004C,G,L,R	
196°	TE-005A,E,J,N		TE-005C,G,L,R	
247°		TE-006B,F,K,P		TE-006D,H,M,S
286°		TE-007B,F,K,P		TE-007D,H,M,S
322°	TE-008A,E,J,N		TE-008C,G,L,R	

Figure 7.6-9 Instrumentation Location Definition for the Suppression Pool Temperature Monitoring System

Amplitude & Growth Rate Based Detection Algorithm



Period Based Detection Algorithm

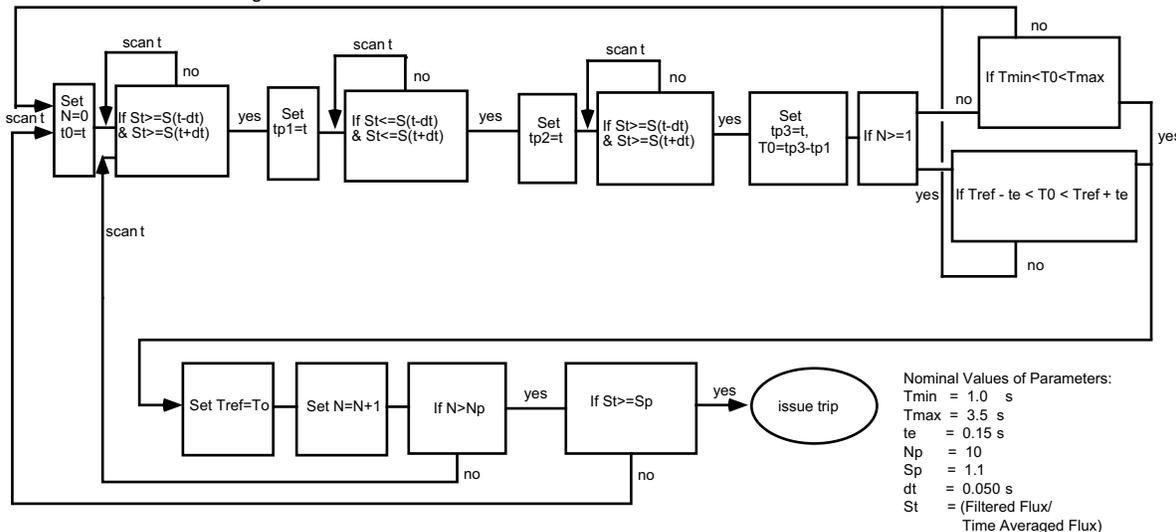


Figure 7.6-14 OPRM Logic

