7.6 All Other Instrumentation Systems Required for Safety

7.6.1 Description

This section will examine and discuss the instrumentation and control aspects of the following plant systems:

- Neutron Monitoring System (SRNM, LPRM, and APRM)
- Process Radiation Monitoring System
- HP/LP interlocks
- Drywell Vacuum Relief System (Chapter 6)
- Containment Atmosphere Monitoring System
- Suppression Pool Temperature Monitoring System

A number of observations are cited relative to the evaluation of the instrumentation and control (I&C) portions of the subject systems:

(1) The systems themselves and their I&C portion serve design bases that are both safety and power generation.

(2) Some systems inherently perform mechanical or containment safety functions but need little I&C protective support.

(3) Some systems provide protective functions in selective minor events and are not required for other major plant occurrences.

(4) Some systems have only a small portion of their I&C participating in safety functions.

(5) The HP/LP interlocks in this section are an integral part of various modes of the RHR System functions described in other sections.

(6) A system/safety function, qualitative-level nuclear safety operational analysis (NSOA) is presented in Chapter 15. The interrelated design bases of the various safety system functions are also analyzed in this chapter.

7.6.1.1 Neutron Monitoring System-Instrumentation and Controls

The Neutron Monitoring System (NMS) consists of various safety-related subsystems: Startup Range Neutron Monitor (SRNM), Local Power Range Monitor (LPRM), and Average Power Range Monitor (APRM) subsystems. The non-safety-related ATIP and MRBM Subsystems of the NMS are discussed in Section 7.7. The LPRM and the APRM, together, are also called the Power Range Neutron Monitor (PRNM).

(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 Computer 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.

(2) System Safety Classification

The SRNM and PRNM (includes LPRM and APRM) Subsystems provide a safety function, and have been designed to meet the applicable design criteria.

The NMS is classified as shown in Table 3.2-1. The safety-related subsystems are qualified in accordance with Sections 3.10 and 3.11.

The ATIP and MRBM Subsystems of the NMS are non-safety-related and are discussed in Section 7.7.

(3) Power Sources

The power sources for each system are discussed in the individual circuit descriptions.

7.6.1.1.1 Startup Range Neutron Monitor Subsystem—Instrumentation and Controls

(1) General Description

The startup range neutron monitor (SRNM) monitors neutron flux from the source range (1.E+3 neutron/cm^2) to 15% of the rated power. The SRNM Subsystem has 10 SRNM channels, each having one fixed in-core regenerative fission chamber sensor (Figures 7.6-1 and 7.6-2).

(2) Power Sources

SRNM channels are powered as listed below:

Channels

A,E,J	120 VAC UPS	Bus A (Division I)
B,F	120 VAC UPS	Bus B (Division II)
C,G,L	120 VAC UPS	Bus C (Division III)
D,H	120 VAC UPS	Bus D (Division IV)

Loss of a power supply bus will cause the loss of the SRNM channels in a division, but will result in loss of only one division of instrumentation.

(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 units in the control room. The SRNM 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, and to the plant computer functions. 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.

(4) Signal Processing

Over the 10-decade power monitoring range, two monitoring methods are used: (1) for the lower ranges the counting method which covers from 1.E+3 neutron/cm^2 to 1.E+9 neutron/cm^2, and (2) for the higher ranges, the Campbelling technique (mean square voltage, or MSV) which covers from 1.E+8 neutron/cm^2 to 1.E+13 neutron/cm^2 of neutron flux. In the counting range, the discrete pulses produced by the sensors are applied to a discriminator after preamplification. The discriminator, together with other digital noise-limiter features, separates the neutron pulses from gamma radiation and other noise pulses. The neutron pulses are then counted. The reactor power is proportional to the count rate. In the MSV range, where it is difficult to distinguish the pulses, a DC voltage proportional to the mean square value of the input signal is produced. The reactor power is proportional to this mean square voltage. In the mid-range overlapping region, where the two methods are changed over, the SRNM calculates the neutron flux based on a weighted interpolation of the two flux values calculated by both methods. A continuous and smooth flux reading transfer is achieved in this manner. There is also the calculation algorithm of the period-based trip circuitry that generates trip margin setpoint for the period trip protection function.

(5) Trip Functions

The SRNM scram trip functions are discussed in Section 7.2; rod block trip functions are discussed in Subsection 7.7.1.2. The SRNM channels also provide trip signals indicating when a SRNM channel is upscale, down-scale, inoperative, or bypassed. The SRNM trips are shown in Table 7.6-1.

(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. 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 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. 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 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 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)).

(8) Testability

Each SRNM channel is tested and calibrated using the procedures listed in the SRNM instruction manual. Each SRNM channel can be checked to ensure that the SRNM high flux and period scram functions are operable.

(9) Environmental Considerations

The wiring, cables, and connectors located within the drywell are designed for continuous duty in the conditions described in Section 3.11.

The SRNM preamplifiers which are located in the Reactor Building, and the monitors, which are located in the control room, are designed to operate under design basis normal and abnormal conditions in those areas. The SRNM System components are designed to operate during and after certain design basis events such as earthquakes, accidents, and anticipated operational occurrences. Environmental qualification is discussed in Section 3.11.

(10) SRNM Operational Considerations

The SRNM has no special operating considerations.

7.6.1.1.2 Power Range Neutron Monitor Subsystem—Instrumentation and Controls

The PRNM Subsystem consists of a Local Power Range Monitor (LPRM) Subsystem and an Average Power Range Monitor (APRM) Subsystem.

7.6.1.1.2.1 Local Power Range Neutron Monitor Subsystem—Instrumentation and Controls

(1) General Description

The local power range monitor (LPRM) monitors local neutron flux in the power range. The LPRM provides input signals to the APRM Subsystem (Subsection 7.6.1.1.2.2) and to the plant computer function (Subsection 7.7.1.5). See Figures 7.6-1 and 7.6-2.

(2) Uninterruptible Power Supply (UPS)

Alternating-current (AC) power for the LPRM circuitry is supplied by four 120 VAC uninterruptible power supply (UPS) buses A, B, C, and D. Each bus supplies approximately one fourth of the detectors.

Each LPRM detector has a DC power supply in each division which furnishes the detector polarizing potential.

(3) Physical Arrangement

The LPRM Subsystem consists of 52 detector assemblies, each assembly consisting of four fission chamber detectors evenly spaced at four axial positions along the fuel bundle vertical direction. The assemblies are distributed throughout the whole core in evenly spaced locations such that each assembly is located at every fourth intersection of the water channels around fuel bundles not containing a control rod blade. The LPRM detector location is illustrated in Figure 7.6-3.

The LPRM detector is a fission chamber with a polarizing potential of approximately 100 VDC. The four detectors comprising a detector assembly are contained in a common tube that houses the automatic traversing in-core probe (ATIP) calibration tube. The enclosing housing tube contains holes to allow coolant flow for detector cooling. The whole assembly is installed or removed from the top of the reactor vessel, with the reactor vessel head removed. It is referred to as the top entry LPRM assembly. The upper end of the assembly is held under the top fuel guide plate with a spring plunger. A permanently installed in-core guide tube and housing is located below the lower core plate to confine the assembly and to provide a sealing surface under the reactor vessel.

(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 computer functions.

(5) Trip Functions

The LPRM channels provide alarm signals indicating when an LPRM is upscale, down-scale, or bypassed. However, such signals are not sent to the RPS for scram trip or RCIS for rod block.

(6) Bypasses and Interlocks

Each LPRM channel may be individually bypassed. When the maximum allowed number of bypassed LPRMs associated with any APRM channel has been exceeded, an inoperative trip is generated by that APRM.

(7) Redundancy

The LPRM detector assemblies are divided into groups. The redundancy criteria are met in the event of a single failure under permissible APRM bypass conditions. A scram signal is generated in the Reactor Protection System (RPS) as required if the inoperative trip of the APRM is generated as described in (6).

(8) Testability

LPRM channels are calibrated using ATIP and data from previous full-power runs, and are tested using procedures in the applicable instruction manual.

(9) Environmental Considerations

The detector and detector assembly are designed to operate up to 8.27 MPaG at an ambient temperature of 302°C. The wiring, cables, and connector located within the drywell are designed for continuous duty. The LPRMs are capable of functioning during and after certain design basis events, including earthquakes and anticipated operational occurrences (Sections 3.10 and 3.11).

(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).

(1) General Description

(a) Average Power Range Monitor (APRM)

The APRMs are safety-related systems. There are four divisions of 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. The OPRM trips are separate from the APRM trips of the same APRM channel 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

(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 biassing for the MRBM rod block setpoint functions.

(b) OPRM

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 to in Figure 7.6-1 which shows the assignment of LPRMs to APRM channels. Figure 7.6-13 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 that 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 an 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.

(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.

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 function has its own inoperative trip when the channel has less than the required minimum operable cells, when there is an OPRM self-diagnostic fault, when the

APRM instrument watchdog timer has timed out, or if there is a loss of power to the APRM instrument.

(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.

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

(b) OPRM

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: (1) the APRM reading of the same channel is below 25% of rated power or the core flow reading is above 60% of rated flow; (2) 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.

(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 channel is associated with one RPS division. The OPRM trip outputs are provided separately from the APRM trips to RPS and follow the RPS two-out-of-four logic. 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 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 7.6-5 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).

7.6.1.2 Process Radiation Monitoring System—Instrumentation and Controls

A number of radiation monitoring functions are provided on process lines, HVAC ducts, and vents that may serve as discharge routes for radioactive materials. These include the following:

(1) Main steamline tunnel area

(2) Reactor Building ventilation exhaust (including fuel handling area)

(3) Control Building air intake supply

(4) Drywell sumps liquid discharge

(5) Radwaste liquid discharge

(6) Offgas discharge (pre-treated and post-treated)

(7) Gland steam condenser offgas discharge

(8) Plant stack discharge

(9) Turbine Building vent exhaust

(10) Standby gas treatment ventilation exhaust

(11) Radwaste Building ventilation exhaust

The process radiation subsystems are shown in the system design IED (Figure 7.6-5). Subsystems (2) through (4) are classified nuclear safety-related, while subsystems (1) and (5) through (11) are classified as non-safety-related. System descriptions and requirements are described in detail in Section 11.5.

7.6.1.3 High Pressure/Low Pressure Systems Interlock Protection Functions

(1) Function Identification

The low pressure modes of the RHR System which connect to the reactor coolant pressure boundary (RCPB) and the instrumentation which protects them from overpressurization are discussed in this section. Such high pressure/low pressure (HP/LP) interfaces with the reactor vessel are exclusive to the RHR System for the ABWR. The RHR P&ID is shown on Figure 5.4-10. The RHR IBD may be found on Figure 7.3-4.

(2) Power Sources

The power for the interlocks is provided from the essential power supplies used for the RHR System and its various modes of operation.

(3) Equipment Design

Refer to Table 7.6-3 for a list of HP/LP interfaces and the rationale for valve interlock equipment.

(4) Circuit Description

At least two valves are provided in series in each of these lines. The RHR shutdown cooling supply valves have independent sets of interlocks to prevent the valves from being opened when the primary system pressure is above the subsystem design pressure or when reactor water level is below Level 3. These valves also receive a signal to close when reactor pressure is above system pressure, or reactor water level is below Level 3. An additional interlock is RHR equipment area ambient temperature (not shown on Table 7.6-3).

The RHR shutdown cooling/LPFL injection valve is interlocked to prevent valve opening whenever the reactor pressure is above the subsystem design pressure, and automatically closes whenever the reactor pressure exceeds the subsystem design pressure. This valve must operate for long-term cooling, and has a remote testable check valve downstream. The check valve position can be confirmed at any time.

(5) Logic and Sequencing

The logic for the pressure and level sensor inputs is two-out-of-four high pressure or low level signals for valve closure. The additional RHR equipment area temperature signals for the shutdown suction valves consist of a single input channel for each valve.

(6) Bypasses and Interlocks

There are no additional bypasses or interlocks in the HP/LP interlocks themselves.

(7) Redundancy and Diversity

Each process line has two valves in series which are redundant in assuring the interlock. Each shutdown cooling supply and return valve has independent and diverse interlocks to prevent the valves from being opened under the following conditions (Subsection 7.4.2.3.2 (4a)):

(a) Reactor pressure is above the RHR System design pressure.

(b) Reactor water level is below Level 3.

(c) RHR equipment area ambient temperature is above setpoint.

(8) Actuated Devices

The motor-operated valves are the actuated devices.

(9) Separation

Separation is maintained in the instrumentation portion of the HP/LP interlocks by assigning the signals for the electrically controlled valves to ESF separation divisions. The pressure and level sensors are supplied from the Nuclear Boiler System and are shared with other systems. There is one sensor from each of the four divisions, whose signal is passed through optical isolators and then the two-out-of-four voting logic (in combination with the signals from the other three divisions). The resultant signal is used to actuate each valve. Each division has its own isolation and two-out-of-four voting logic hardware (sheet 2 of RHR IBD, Figure 7.3-4).

(10) Testability

Since the HP/LP interlock valves are specifically designed to close under all conditions for normal reactor pressure, they cannot be tested during reactor operation. However, the sensors and logic can be tested during reactor operation in the same manner that the LPFL sensors and logic are tested. Refer to Subsection 7.3.1.1.1.4, 3(g) for a discussion of typical LPFL testing.

(11) Environmental Considerations

The instrumentation and controls for the HP/LP interlocks are qualified as Class 1E equipment. The sensors are mounted on local instrument panels and the control circuitry is housed in control panels in the control room.

(12) Operational Considerations

The HP/LP interlocks are strictly automatic. There is no manual bypass capability. If the operator initiates the RHR System, the interlocks will prevent RHR System exposure to high reactor pressure.

(13) Reactor Operator Information

The status of each valve providing the HP/LP boundary is indicated in the control room. The state of the sensors is also indicated in the control room.

(14) Setpoints

Chapter 16 describes the methods for calculating setpoints and margins.

7.6.1.4 Not Used

7.6.1.5 Wetwell-to-Drywell Vacuum Breaker System—Instrumentation and Controls

This system is described in Chapter 6.

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

(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 H_2/O_2 monitoring subsystem. Each CAM divisional radiation channel has the capability of monitoring the total gamma-ray dose rate. CAMS also has the capability of monitoring concentration of hydrogen and oxygen (H_2/O_2) 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 a detector and a digital log radiation monitor. 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 H_2/O_2 monitoring subsystem has two channels and 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 H_2/O_2 monitoring subsystem is non-safety and is physically and electrically separate from the safety-related components of the system.

The piping 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 radiation channel is powered from divisional 120 VAC instrument bus. The H_2/O_2 subsystem is powered from non-safety equipment.

(3) Initiating Circuits

Each divisional gamma radiation monitoring channel can be energized manually by the operator. The gamma radiation monitor is on continuously during plant operation and remains on until power is turned off by the operator.

Each H_2/O_2 monitoring subsystem channel (except for the two sampling pumps) is powered continuously during plant operation. Each subsystem channel is controlled by an operator and is used during reactor operation and can also be turned on by the LOCA signal to allow measurement during an accident.

The heat tracing used in each H_2/O_2 sample line is temperature controlled to prevent moisture condensation in the pipes.

Each H_2/O_2 analyzer and monitor can selectively measure the atmosphere in the drywell or the suppression chamber.

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 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.

(6) Testability and Calibration

Each CAM Subsystem can be tested separately during plant operation to determine the operational availability of the system. Each CAM Subsystem can be tested and calibrated separately.

Gas calibration sources are provided to check the hydrogen/oxygen sensors during normal plant operation and after an accident.

(7) Environmental Consideration

The CAM System radiation monitoring channels are qualified Seismic Category I and are designed for operability during normal and post-accident environments.

(8) Operational Considerations

The following information is available to the reactor operator:

(a) Each gamma radiation channel consists of a detector and a log radiation monitor. Each channel has a range of 0.01 Sv/h to 10^5 Sv/h. Each channel will initiate an alarm on high radiation level or on an inoperative channel.

(b) Each hydrogen/oxygen monitoring subsystem channel contains a sampling rack for extracting the atmosphere from the drywell or the suppression chamber and for analyzing the contents for both H_2/O_2 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 H_2/O_2 analyzer subsystem channel 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.

(9) Control and Protective Functions

The CAM System does not provide control signals either to trip or to actuate other safety-related systems. However, the CAM System utilizes internal safeguards to affect system operation, alert the operator of abnormal performance, and protect equipment from damage.

7.6.1.7 Suppression Pool Temperature Monitoring System—Instrumentation and Controls

7.6.1.7.1 System Identification

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.

The SPTM System also provides information on the post-LOCA condition of the suppression pool.

The SPTM system IED is shown on Figure 7.6-11. Control system logic is shown on the IBD (Figure 7.6-12).

7.6.1.7.2 Power Sources

The instrumentation and controls of the SPTM System are powered by four divisionally separated 120 VAC buses (Divisions I, II, III and IV).

7.6.1.7.3 Equipment Design

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:

(1) To reliably measure the average bulk temperature of the suppression pool under normal plant operating conditions.

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

(3) The sensors are not in direct paths of jet impingement such as horizontal vent flow and SRV quencher discharge.

(4) The sensors can be located without structural interference from the two equipment and personnel access tunnels.

Each temperature sensor location has a flexibility of ±5° in the azimuthal direction so that any interference with other equipment in the pool such as suction pipelines or undesirable locations such as proximity to a horizontal vent may be avoided.

At each temperature sensor location, there are two groups of sensors; one group for each of two divisions (Divisions I and III or Divisions II and IV) of sensors. Each group has four sensors located at different elevations in the suppression pool. At each sensor location, the two groups of sensors are to be separated by 15-30 cm in the azimuthal direction. The sensor envelope is given in Figure 7.6-9 and a cross section of a typical sensor location is given in Figure 7.6-10. The location of the temperature sensors are chosen based upon the following considerations:

(1) Sensors are located away from jet paths from horizontal vents and SRV discharge.

(2) Sensors are located at least 1m away from any wall or 160 mm structural member.

(3) Sufficient flexibility is allowed to facilitate sensor location and installation.

(4) Sensors are located to provide redundancy in measuring the average bulk suppression pool temperature.

(5) Sufficient sensors are located to measure the average bulk suppression pool temperature under accident conditions when the pool level drops to a level where complete condensation of vent flow and SRV discharge is still assured (i.e., 610 mm above the top of the first row of horizontal vents).

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 and II sensor signals for the Remote Shutdown System are directly hardwired.

7.6.1.7.4 Signal Conditioning

The suppression pool temperatures within a division are average to determine a mean temperature of the pool. The average is corrected for failed sensors. Sensors exposed to air temperature are also excluded.

7.6.1.7.5 Trip Function

The SPTM system provides trip signals for each of the four divisions (for two-out-of-four logic) indicating when the suppression pool temperature has exceeded the high limit.

7.6.1.7.6 Bypasses and Interlocks

The SPTM System has no bypasses and interlocks. A division of sensors can be bypassed to allow maintenance.

7.6.1.7.7 Control Action

The SPTM System initiates RHR suppression pool cooling, RCW load shedding and RPS scram signaling. It also provides measurement, indication, and recording, and initiates alarms in the main control room and in the remote shutdown panel.

7.6.1.7.8 Divisional Separation

The four SPTM System divisions are electrically separated so that no single design basis event is capable of damaging equipment in more than one division. No single failure or test, calibration, or maintenance operation can prevent function of more than one division.

7.6.1.7.9 Signal Processing

Processing of temperature signals is performed by a configurable logic device for each instrument division. For each of the four instrument divisions, the temperature signals are arithmetically averaged to yield an average bulk suppression pool temperature. Provisions are incorporated to detect sensor failures. When failure of a sensor is detected, its output is not added to the sum of all other sensors in the division and the number of sensors is correspondingly reduced in computing the average temperature. In addition, the narrow range suppression pool water level signal from the Atmospheric Control System (ACS) is used to detect uncovery of the first set of sensors below the pool surface. After sensor installation, the elevation for each sensor is to be established with respect to a common reference elevation. When the suppression pool water level drops below the elevation of a particular sensor, that sensor signal is not used in computing the average. The wide range level signal from the ACS is utilized for this purpose for the remaining sensors.

7.6.1.7.10 Output Signals

For each division of the SPTM System, each temperature sensor output and the average bulk suppression pool temperature can be individually addressable for display. These signals can also be selectable and provided for continuous recording. The recording device need not be a Class 1E device.

For each SPTM division, high bulk average temperature is annunciated. Four sensors from Division I and four sensors from Division II are sent to the remote shutdown panel.

In addition to the system display recording, and alarm functions, outputs from the SPTM System to other systems are provided as shown in Table 7.6-4.

When signals are provided from the SPTM System to other systems, signal isolation is provided between one instrument division to another division. For example, the Division I suppression pool high bulk average temperature signal to Division II and III of the RHR System is optically isolated via its fiber-optic interface medium.

7.6.1.7.11 Testability and Calibration

Each SPTM System division is testable during plant operation to determine the operational availability of the system. Each SPTM division has the capability for test, calibration, and adjustments.

7.6.1.7.12 Environmental Consideration

The SPTM System local equipment is designed to be continuously operable during normal and post-accident environments. Indicating and recording equipment located in the main control room is designed to operate in the environment of the control room.

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 are discussed in Subsection 7.2.2.

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

This analysis section covers only the safety-related subsystems of the 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)
- (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 5% 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 algorithm which will issue a trip if the core flow suddenly decreases too fast, called the Core Flow Rapid Coastdown trip. 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. All scram functions are 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-603)

The safety-related subsystems of the neutron monitoring system consist of four divisions which correspond and interface with those of the 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 divided 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 OPRM subsystem as described in Subsection 7.6.1.1.2.2 conforms to all applicable requirements of IEEE-603.

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-603 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.

* See Subsection 7.1.2.10.9.

(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.

(b) BTP ICSB 22— "Guidance for Application of Regulatory Guide 1.22"

The NMS is continuously operating during reactor operation. The accuracy of the sensors can be verified by cross-comparison of the various channels within the four redundant divisions. The bypass of any RPS division will cause the two-out-of-four trip voting logic to revert to two-out-of-three. Therefore, the NMS fully meets this BTP.

(5) TMI Action Plan Requirements (TMI)

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, there are no TMI action plan requirements applicable to the NMS. However, all TMI requirements are addressed in Appendix 1A.

7.6.2.2 Process Radiation Monitoring System—Instrumentation and Controls

This analysis section covers only the safety-related subsystems of the Process Radiation Monitoring (PRM) System as identified in Subsection 7.6.1.2.

7.6.2.2.1 General Functional Requirements Conformance

The Process Radiation Monitoring (PRM) System samples and/or monitors the radioactivity levels in process and effluent streams, initiates protective actions to prevent further release of radioactive material to the environment, and activates alarms in the control room to alert operating personnel to the high radiation activity.

7.6.2.2.2 Specific Regulatory Requirements Conformance

Table 7.1-2 identifies the PRM System 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-603):

Each safety-related PRM subsystem, except for the drywell sump discharge radiation monitor, utilizes four redundant divisional channels in a two-out-of-four voting logic to initiate the protective action. This redundancy satisfies the single-failure criterion such that a failure of a single element will not interfere with the system to perform its intended safety function. The drywell sump discharge radiation monitor consists of one channel per drywell sump, and is used to terminate the transfer of the liquid waste to the Radwaste Building when the high radiation level is detected in the discharged liquid waste. Failure of this channel to isolate the drain line is not considered detrimental to plant safety or operation. Failure of the radiation channel will be indicated by the monitor and the operator will be alerted in time to take corrective action.

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

Electrical separation is maintained between the redundant divisions. All applicable requirements of IEEE-603 are met by the safety-related subsystem of the PRM System.

(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 PRM:

(a) **Criteria—**GDCs 2, 4, 13, 16, 19, 20, 21, 22, 23, 24, and 28.

(b) **Conformance—**The safety-related PRM subsystems are 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 PRM safety-related subsystems:

(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 1.62— “Manual Initiation of Protective Actions”

(e) RG 1.75— “Physical Independence of Electric Systems”

(f) RG 1.97— “Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident”

(g) RG 1.105— “Instrument Setpoints for Safety-Related Systems”

(h) RG 1.118— “Periodic Testing of Electric Power and Protection Systems”

The PRM safety-related subsystems conform with all the above-listed RGs assuming the same interpretations and clarifications identified in Subsections 7.3.2.1.2 and 7.1.2.10. A generic assessment of RG 1.97 is provided in Section 7.5.

(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. Therefore, Item B-2 of the BTP is not applicable. Otherwise, the PRM System is in full compliance with this BTP.

(b) BTP ICSB 22— “Guidance for Application of Regulatory Guide 1.22”

The PRM monitors are continuously operating and are self-tested during reactor operation. Self-test is continuous and detected faults are indicated and/or annunciated.

(5) TMI Action Plan Requirements (TMI)

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, only TMI II.F.3— “Instrumentation for Monitoring Accident Conditions” is considered applicable for the PRM System.

This and all other TMI action plan requirements are addressed in Appendix 1A. A generic assessment of Regulatory Guide 1.97 is presented in Section 7.5.

7.6.2.3 High Pressure/Low Pressure Systems Interlock Function

The ABWR has only one low pressure system, the RHR System, which interfaces with the reactor pressure boundary and requires HP/LP interlock protection. However, the RHR System has several modes of operation which are addressed in other Tier 2 sections.

7.6.2.3.1 General Functional Requirements Conformance

The HP/LP interlocks provide an interface between the low pressure RHR System and reactor pressure. When reactor pressure is low enough to not be harmful to the low pressure system, the valves open and expose the low pressure system to reactor pressure. The interlocks are automatic and the operator is given indication of their status.

Each HP/LP interface consists of two valves in series; one inside and one outside the drywell wall. The injection lines are used for both the Low Pressure Flooder mode (LPFL), and the Shutdown Cooling (SDC) mode. The isolation valves on these lines consist of a motor-operated valve (MOV) in series with a check valve. The suction lines have MOVs on both inboard and outboard sides.

Redundancy is integrated into the design by placing the inboard and outboard shutdown cooling suction valves on different electrical power divisions for each RHR loop. A diversity of signals (high reactor pressure or low reactor water level) is used to actuate closure of the two motor-operated suction valves. This is further described in 4(a) of Subsection 7.4.2.3.2.

7.6.2.3.2 Specific Regulatory Requirements Conformance

Table 7.1-2 identifies the HP/LP interlocks 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-603)

The HP/LP interlocks are an integral part of the RHR System, which is designed to meet the requirements of IEEE-603 as discussed in Subsections 7.4.2.3.2 and 7.3.2.1.2.

(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 HP/LP interlocks:

(a) **Criteria—**GDCs 2, 4, 10, 13, 15, 19, 33, and 44.

(b) **Conformance—**The HP/LP interlocks are 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 HP/LP interlocks:

(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 1.62— "Manual Initiation of Protective Actions"

(e) RG 1.75— "Physical Independence of Electric Systems"

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

(g) RG 1.118— "Periodic Testing of Electric Power and Protection Systems"

The HP/LP interlocks are designed to assure that the HP/LP isolation valves close when reactor pressure exceeds the design pressure for the low pressure RHR System. Since this function is deliberately designed so that it cannot be bypassed, it is not possible to test these interlocks nor the associated valves during the higher pressure conditions of the normally operating reactor. However, they can be routinely tested when the reactor is shut down.

Otherwise, the interlocks are designed to meet the same requirements as the RHR System, as addressed in Subsections 7.3.2.1.2 and 7.4.2.3.2.

(4) Branch Technical Positions (BTPs):

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, the following BTPs are considered applicable to the HP/LP interlocks:

(a) BTP ICSB 3— "Isolation of Low Pressure Systems from the High Pressure Reactor Coolant System"

(b) BTP ICSB 21— "Guidance for Application of Regulatory Guide 1.47"

(c) BTP ICSB 22— "Guidance for Application of Regulatory Guide 1.22"

These BTPs are addressed with respect to the HP/LP interlocks in Subsection 7.4.2.3.2 (4).

(5) TMI Action Plan Requirements (TMI):

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, there are no TMI action plan requirements applicable to the HP/LP interlocks. However, all TMI requirements are addressed in Appendix 1A.

7.6.2.4 Not Used

7.6.2.5 Wetwell-to-Drywell Vacuum Breaker System—Instrumentation and Controls

This system is passive and has no electrical interface. It is described in Subsection 6.2.1.1.4.1.

7.6.2.6 Containment Atmospheric Monitoring System—Instrumentation and Controls

7.6.2.6.1 General Functional Requirements Conformance

The Containment Atmospheric Monitoring System (CAMS) provides normal plant operation and post-accident monitoring for gross gamma radiation and hydrogen/oxygen concentration levels in both the drywell and suppression chamber. Main control room display and annunciation indicate the gamma and hydrogen/oxygen levels to the plant personnel.

7.6.2.6.2 Specific Regulatory Requirements Conformance

Table 7.1-2 identifies the CAMS 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-603)

The safety-related CAMS radiation channels consists of two divisions which are redundantly designed so that failure of any single element will not interfere with the system operation. Electrical separation is maintained between the redundant divisions.

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

The system can be actuated manually by the operator, or it is automatically initiated by a LOCA signal (high drywell pressure or low reactor water level).

The CAMS does not actuate nor interface with the actuation of any other safety-related system. Therefore, any portion of IEEE-603 which pertains to such interfaces is not applicable. All other applicable requirements of IEEE-603 are met with the CAMS.

(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 CAMS:

(a) **Criteria—**GDCs 2, 4, 13, 16, 19, and 41.

(b) **Conformance—**With regard to GDC 41, the CAMS is not designed to control or clean up the containment atmosphere. It merely monitors such, and indicates levels and initiates alarms on high levels. The Standby Gas Treatment System (SGTS) controls fission products sufficient for the inerted containment (Subsections 7.3.1.1.5 and 7.3.2.5).

Conformance with the above listed GDCs is met as a whole, or in part, as applicable. All 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 CAMS:

(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 for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions 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"

Regulatory Guide 1.22 is not applicable to the CAMS because the CAMS does not actuate or provide controls to any protective system. The CAMS is in conformance with all other RGs listed, assuming the same interpretations and clarifications identified in Subsections 7.3.2.1.2 and 7.1.2.10. A generic assessment of RG 1.97 is provided in Section 7.5.

(4) Branch Technical Positions (BTPs)

* See Subsection 7.1.2.10.9.

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. Therefore, Item B-2 of the BTP is not applicable. Otherwise, the CAMS is in full compliance with this BTP.

(b) BTP ICSB 22— "Guidance for Application of Regulatory Guide 1.22"

CAMS performs no actuation functions. Therefore, this BTP is not applicable to the CAMS.

(5) TMI Action Plan Requirements (TMI)

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, the following TMI action plan requirements are addressed for the CAMS:

(a) TMI II.F.1— "Accident Monitoring Instrumentation Positions"

(b) TMI II.F.3— "Monitoring Accident Conditions (RG 1.97)"

The CAMS provides safety-related instrumentation for use during and after LOCA events and is in compliance with RG 1.97. These TMIs are addressed generically in Appendix 1A. An assessment of RG 1.97 is presented in Section 7.5.

7.6.2.7 Suppression Pool Temperature Monitoring System—Instrumentation and Controls

7.6.2.7.1 General Functional Requirements Conformance

Instrumentation is provided for automatic reactor scram or automatic suppression pool cooling initiation. Visual indications for operator awareness of pool temperature under all operating and accident conditions is also provided. The system is automatically initiated and continuously monitors pool temperatures during reactor operation.

7.6.2.7.2 Specific Regulatory Requirements Conformance

Table 7.1-2 identifies the SPTM System 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-603)

The SPTM System consists of four divisions which are redundantly designed so that failure of any single element will not interfere with the system operation. There are four levels of temperature monitoring within each division. Electrical separation is maintained between the redundant divisions.

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

The SPTM system continuously operates during plant operation. It does, however, automatically initiate RHR for suppression pool cooling, initiates RCW for load shedding to increase suppression pool cooling and generates four divisional trip signals for RPS. Therefore, the portions of IEEE-603 which pertain to actuation of safety functions apply through RHR and RPS. All other applicable requirements of IEEE-603 are met with the SPTM system.

(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 SPTM System:

(a) **Criteria**—GDCs 2, 4, 13, 16, 19, 20, 21, 22, 23, 24, 29 and 38.

(b) **Conformance**—With regard to GDC 20, 21, 22, 23, 24 and 29, the SPTM System generates four division trip signals for RPS and RPS generates the scram signal for the reactor trip.

With regard to GDC 38, the SPTM is not designed to control or remove heat from the containment. It monitors the suppression pool temperatures, generates operator displays, initiates alarms, and automatically initiates the suppression pool cooling mode of RHR. The SPC mode of the RHR System is sufficient to remove heat from the suppression pool (Subsections 7.3.1.1.4 and 7.3.2.4).

Conformance with the above listed GDCs is met as a whole, or in part, as applicable. All 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 SPTM System:

(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 for Light Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions 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 System”

The SPTM System is in conformance with all RGs listed, assuming the same interpretations and clarifications identified in Subsections 7.3.2.1.2 and 7.1.2.10. For RG 1.22, actuation is through RPS as stated in Subsection 7.6.2.7.2(1). A generic assessment of RG 1.97 is provided in Section 7.5.

(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. Therefore, Item B-2 of the BTP is not applicable. Otherwise, the SPTM System is in full compliance with this BTP.

(b) BTP ICSB 22— “Guidance for Application of Regulatory Guide 1.22”

As indicated in Subsection 7.6.2.7.2(1), the SPTM System performs no actuation functions; actuation is through RPS.

(5) TMI Action Plan Requirements (TMI)

In accordance with the Standard Review Plan for Section 7.6, and with Table 7.1-2, the following TMI action plan requirements are addressed for the SPTM System:

(a) TMI II.F.1— “Accident Monitoring Instrumentation Positions”

(b) TMI II.F.3— “Monitoring Accident Conditions (RG 1.97)”

The SPTM System provides safety-related instrumentation for use during and after LOCA events. However, these TMIs are addressed generically in Appendix 1A. An assessment of RG 1.97 is presented in Section 7.5.

7.6.3 COL License Information

7.6.3.1 APRM Oscillation Monitoring Logic

The COL applicant will implement the APRM oscillation monitoring logic function as described in Subsection 7.6.1.1.2.2.

Table 7.6-1 SRNM Trip Function Summary

Trip Function	Trip Setpoint (Nominal)	Action
SRNM Upscale Flux Trip	45% power*	Scram (bypassed in RUN)
SRNM Upscale Flux Alarm	35% power†	Rod Block (bypassed in RUN)
SRNM Short Period Trip	11 seconds	Scram‡ (bypassed in RUN) (no scram function in counting range)
SRNM Short Period Alarm	21 seconds	Rod Block (bypassed in RUN)
SRNM Period Withdrawal Permissive	56 seconds	Warning*ƒ* (bypassed in RUN)
SRNM Inop	Module interlock disconnect HV voltage low Electronics Criteria Failure	Scram & Rod Block (bypassed in RUN)
SRNM Downscale	3 cps	Rod Block
SRNM ATWS Permissive	6%	All Modes**
SRNM Noncoincidence Upscale Flux Trip	5E+5 cps	Scram (activated by manual switch in RPS)*ƒ*
SRNM Noncoincidence Upscale Flux Alarm	1E + 5 cps	Rod Block (activated by manual switch in RPS)

* This scram setpoint is functionally equivalent to the upscale scram on the last range of BWR/5 IRM, at the 120/125 level.

† This rod block setpoint is functionally equivalent to the upscale rod block on the last range of BWR/5 IRM, at the 108/125 level.

‡ Scram action only active in MSV range, which is defined as above 1 x 10^{-4}% power.

ƒ Conditions for activation will be defined in the technical specifications.

** All SRNM channels within each division have to indicate a power level below the setpoint in order to remove the permissive.

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*ƒ*
Amplitude-Based Maximum Trip (S_{max})	$S=S_{max}=1.30$‡	Scram*ƒ*
Period-Based Trip (S_P)	$S=S_P=1.10$**	Scram*ƒ*
OPRM Inoperative Trip	1. LPRM input too few 2. Self-test fault 3. Watchdog timer timed out 4. Loss of power	Scram*ƒ*

* 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).

ƒ Automatically bypassed if core power < 25%% or core flow >60%

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

$T_{min}=1$ s, $T_{max}=3.5$ s, $\pm t_{error}=0.10$ s to 0.30 s $N_P=10$.
(For details see Figure 7.6-14).

Table 7.6-3 High Pressure/Low Pressure System Interlock Interfaces

Interlocked Process Line	Type	Valve	Parameter Sensed	Purpose
RHR Shutdown Cooling Supply	MO MO	E11-F010 E11-F011	Reactor pressure, low level	Prevents valve opening until reactor pressure is low and level is above Level 3.*
RHR Shutdown Cooling/LPFL Injection	Check MO	E11-F006 E11-F005	N/A Reactor pressure	N/A Prevents valve opening until reactor pressure is low.†

* Recloses valve if pressure is high, or level drops below Level 3.

† Recloses valve if pressure is high.

Table 7.6-4 Outputs From SPTM System to Other Systems

Signal	Utilization
1. Division I suppression pool bulk average high temperature signal to RHR Divisions I, II & III	1. Alarm and initiation of RHR suppression pool cooling
2. Division II suppression pool bulk average high temperature signal to RHR Divisions I, II & III	2. Alarm and initiation of RHR suppression pool cooling
3. Division III suppression pool bulk average high temperature signal to RHR Divisions I, II & III	3. Alarm and initiation of RHR suppression pool cooling
4. Division IV suppression pool bulk average high temperature signal to RHR Divisions I, II & III	4. Alarm and initiation of RHR suppression pool cooling
5. Isolated composite Divisions I, II, III and IV suppression pool bulk average mean temperature signal to RCW	5. Initiation of RCW for load shedding to increase suppression pool cooling
6. Division I suppression pool bulk average high temperature trip signal to RPS Division I	6. Alarm and RPS trip signal
7. Division II suppression pool bulk average high temperature trip signal to RPS Division II	7. Alarm and RPS trip signal
8. Division III suppression pool bulk average high temperature trip signal to RPS Division III	8. Alarm and RPS trip signal
9. Division IV suppression pool bulk average high temperature trip signal to RPS Division IV	9. Alarm and RPS trip signal

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

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
VDU	-	Video Display Unit
OPRM	-	Oscillation Power Range Monitor

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 plant computer functions. 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) VDU 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
- (ii) SRNM ATWS 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

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
VDU	-	Video Display Unit
OPRM	-	Oscillation Power Range Monitor

Table 7.6-5 Reactor Operator Information for NMS (Continued)

(5) (Continued)
- (p) APRM simulated thermal power reactor trip status
- (q) APRM core flow
- (qq) APRM ATWS permissive
- (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
- (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
VDU	-	Video Display Unit
OPRM	-	Oscillation Power Range Monitor

The following figures are located in Chapter 21:

Figure 7.6-1 Neutron Monitoring System IED (Sheets 1-4)

Figure 7.6-2 Neutron Monitoring System IBD (Sheets 1-28, including 9a and 9b)

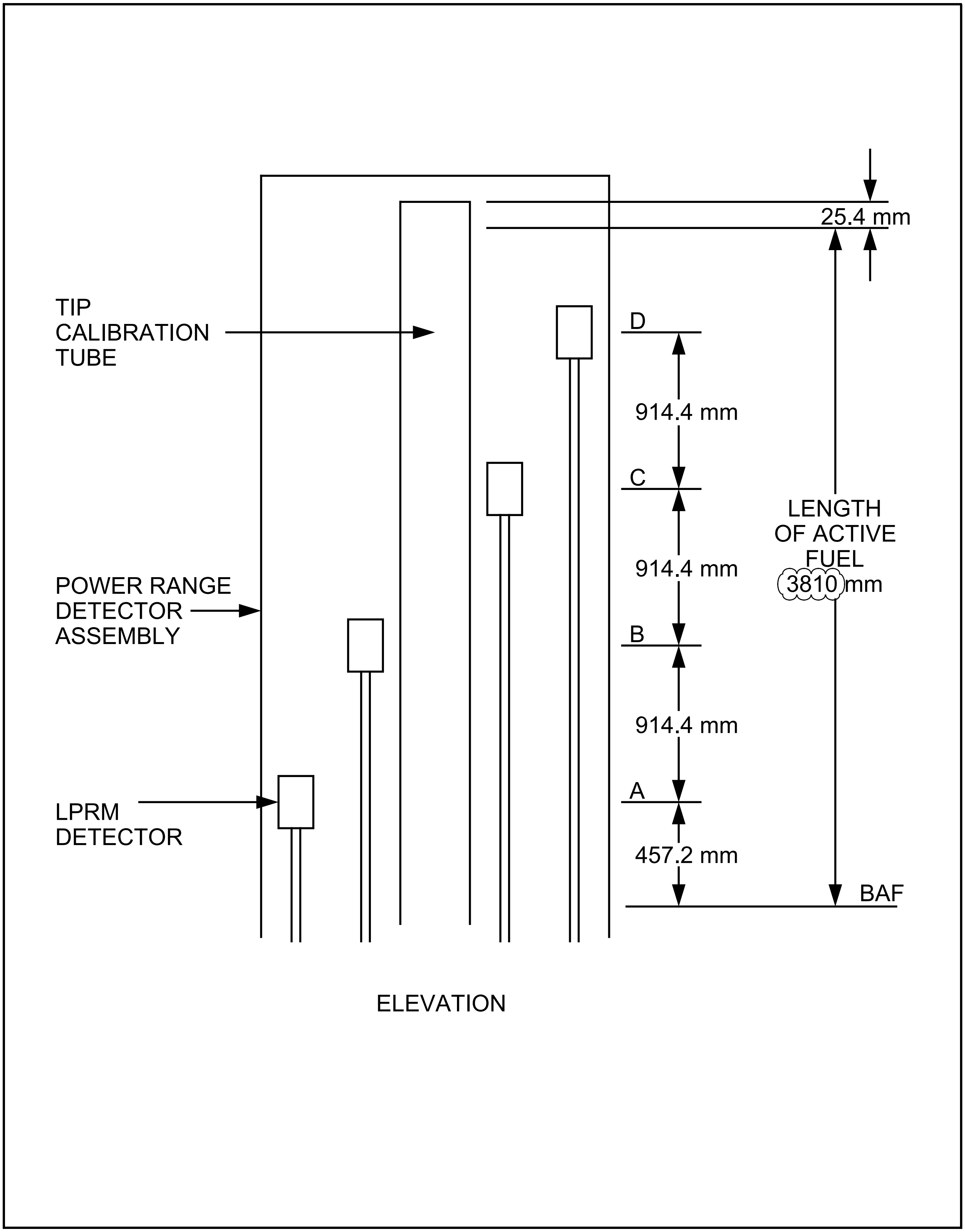


Figure 7.6-3 LPRM Detector Location

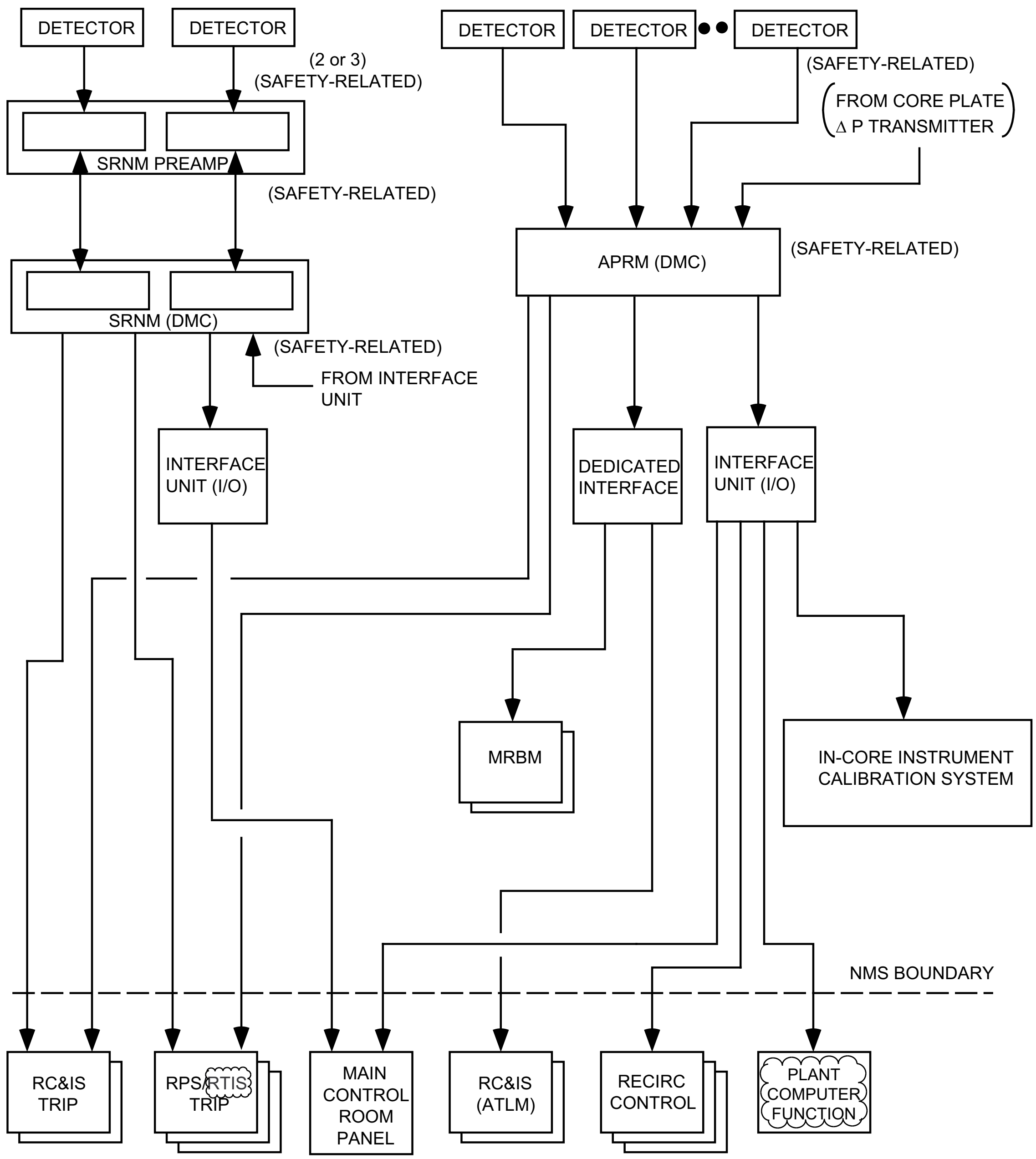


Figure 7.6-4a
Basic Configuration of a Typical Neutron Monitoring System Division

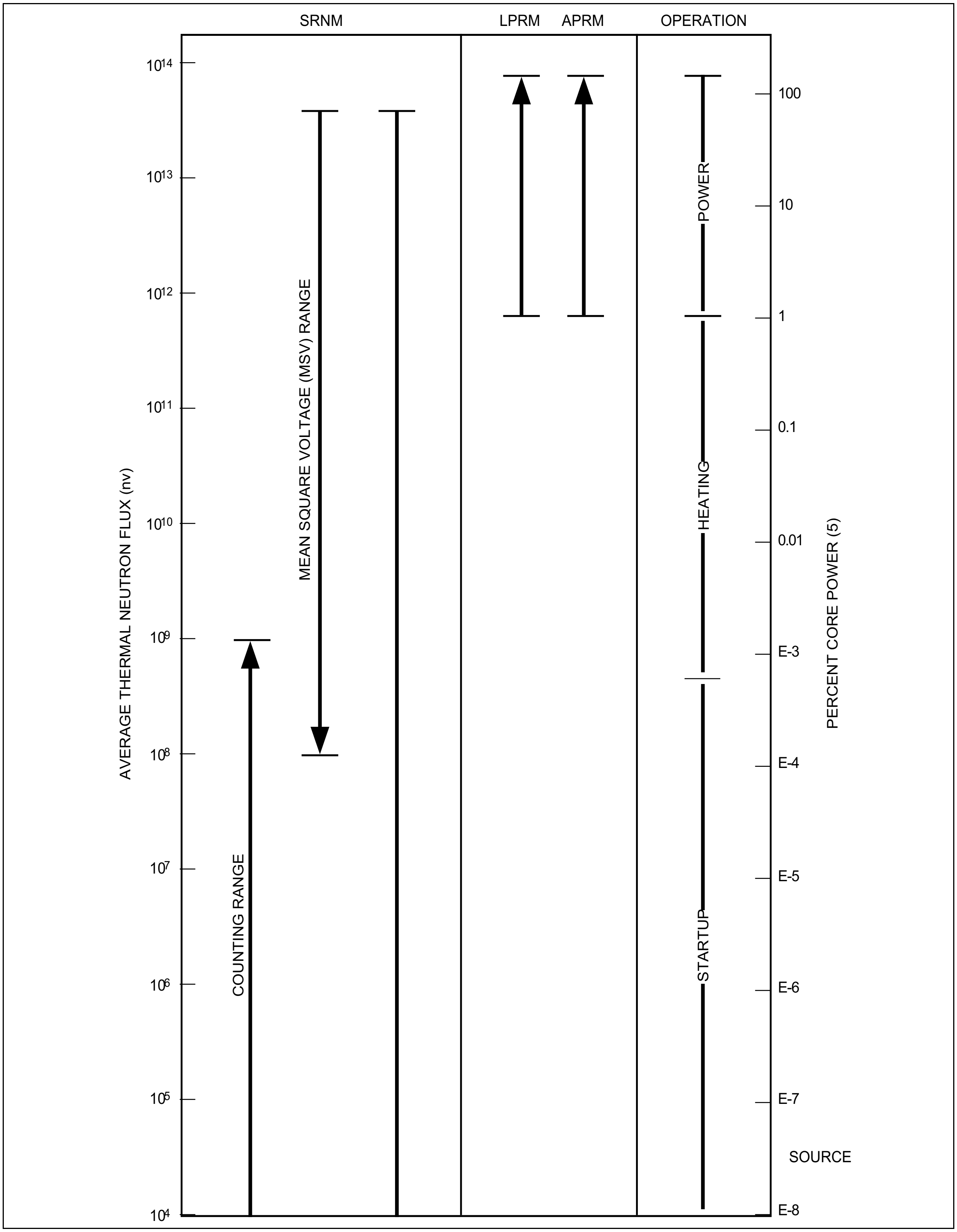


Figure 7.6-4b Neutron Flux Monitoring Range

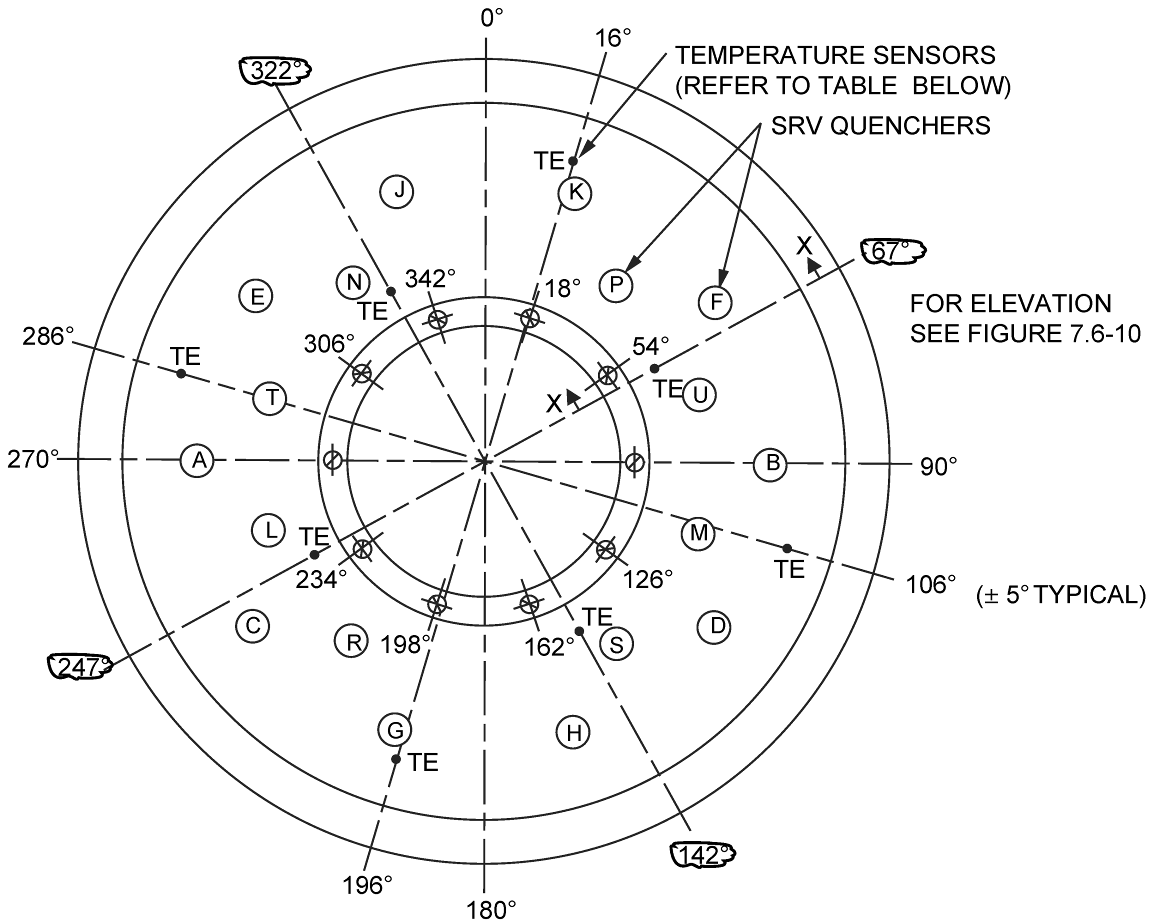
The following figures are located in Chapter 21:

Figure 7.6-5 Process Radiation Monitoring System IED (Sheets 1-11)

Figure 7.6-6 Not Used

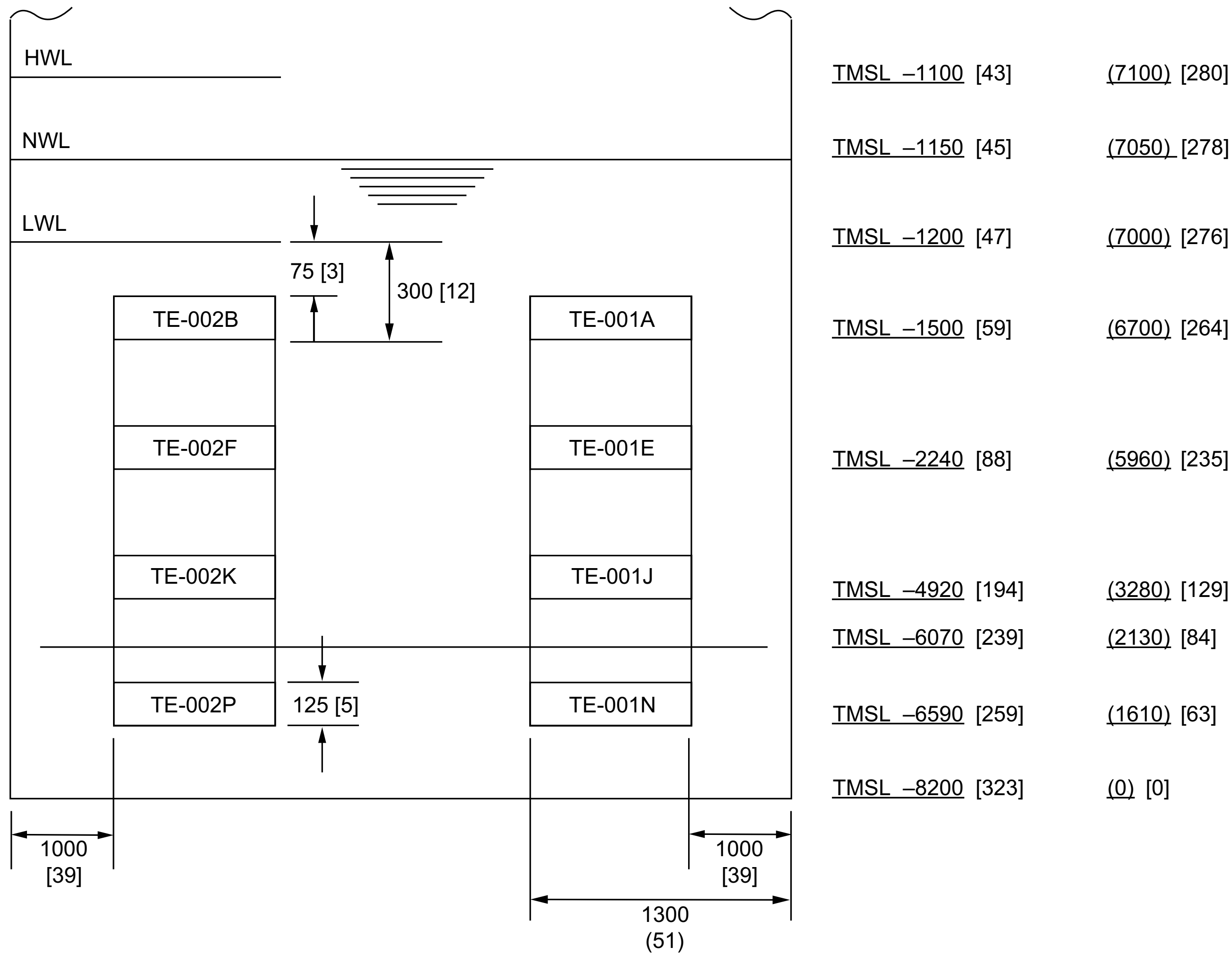
Figure 7.6-7 Containment Atmospheric Monitoring System IED (Sheets 1-4)

Figure 7.6-8 Containment Atmospheric Monitoring System IBD (Sheets 1-10)



	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



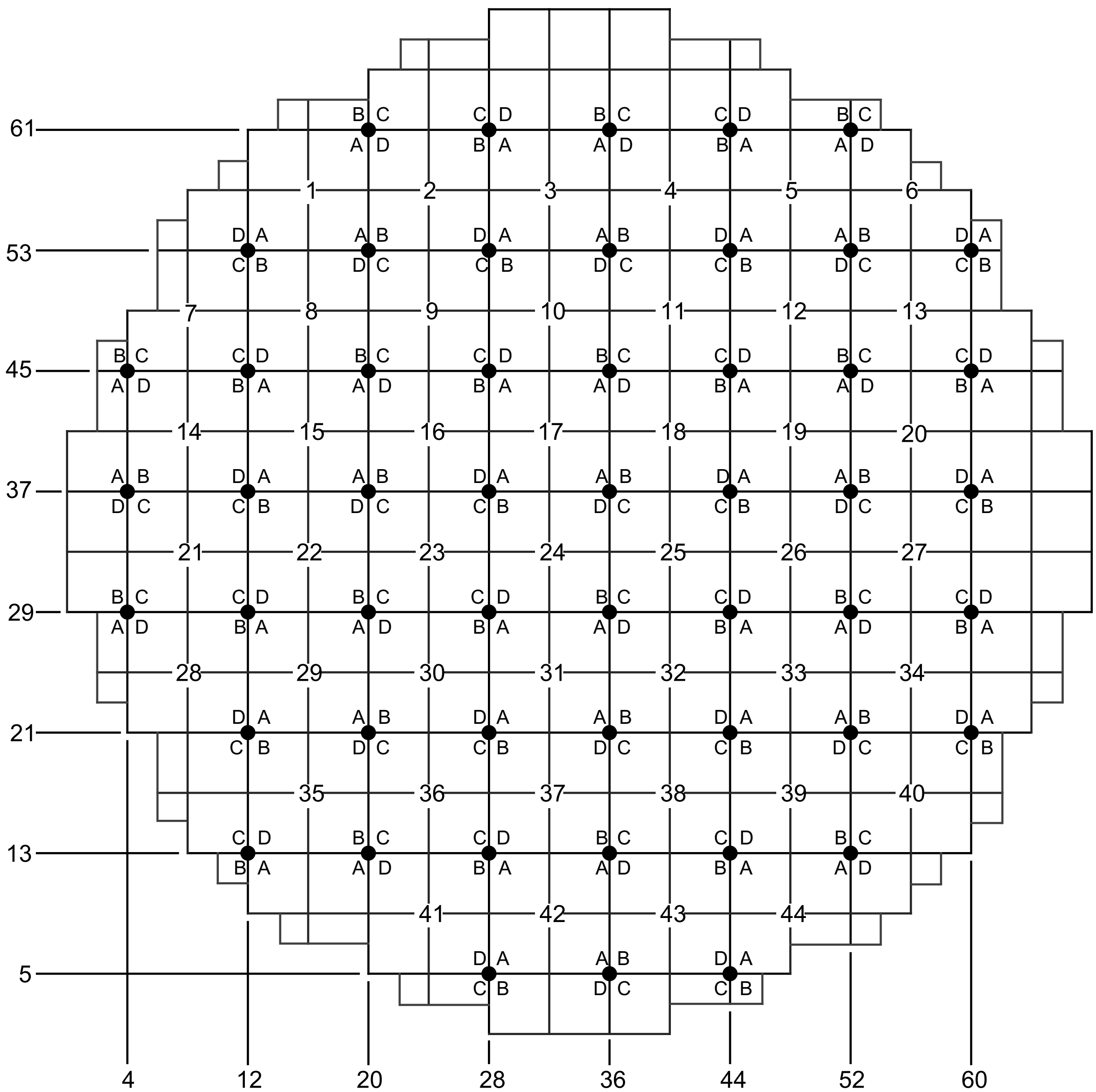
VIEW X-X FROM FIGURE 7.6-9, TYPICAL OF DIVISION I AND II SENSORS AT AZIMUTHAL LOCATIONS 16° AND 61°, DIVISION III AND IV SENSORS ARE NOT SHOWN. DRAWING NOT TO SCALE. ALL DIMENSIONS ARE IN MM.

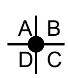
Figure 7.6-10 Suppression Pool Temperature Monitoring System Sensor and Envelope Definition

The following figures are located in Chapter 21:

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

Figure 7.6-12 Suppression Pool Temperature Monitoring System IBD (Sheets 1–6)

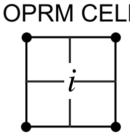




LPRMs PROVIDING INPUT TO OPRM CHANNELS A, B, C, D

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)

OPRM CELL



i : CELL NUMBER

Figure 7.6-13 LPRM Assignments to OPRM Channels

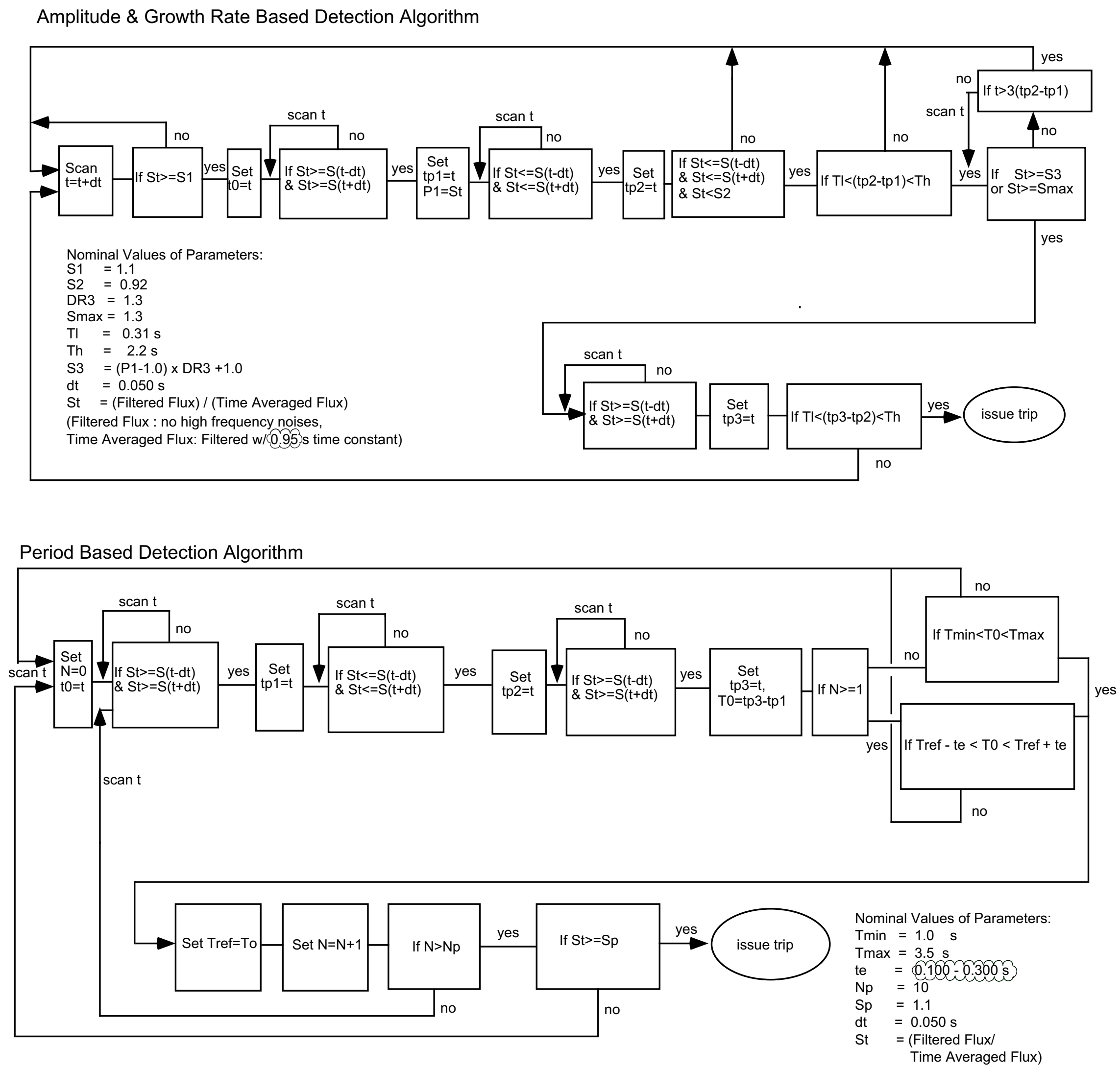


Figure 7.6-14 OPRM Logic