Chapter 6
Core and Fuel Design

Introduction and Summary

The design of the Advanced Boiling Water Reactor (ABWR) core and fuel is based on the proper combination of many design variables and operating experience. These factors contribute to the achievement of high reliability, excellent performance, and improved fuel cycle economics.

The core and fuel design methods employed for design analyses and calculations have been verified by comparison with data from operating plants, gamma scan measurements, testing facilities, and Monte Carlo neutron transport calculations. GE continually implements advanced core and fuel design technology, such as control cell core, spectral shift operation, axially varying gadolinia and enrichment zoning, fuel cladding with improved corrosion resistance, part length fuel rods, interactive channels, and wider water gaps in the ABWR core. As these technological improvements are added, the core and fuel design parameters are optimized to achieve better fuel cycle economics, while improving fuel integrity and reliability and while maintaining overall reactor safety.

The reactor lattice configuration and fuel element design for the ABWR are basically the same as employed in previous GE designed plants operating around the world. Key features of the ABWR reactor core design are summarized in the following paragraphs:

- The ABWR core mechanical design is based on conservative application of stress limits, operating experience, and experimental test results. The moderate pressure levels characteristic of a direct cycle reactor, approximately 1000 psia (6900 kPa), reduce cladding temperatures and stress levels.
- The low coolant saturation temperature, high heat transfer coefficients, and neutral water chemistry of the ABWR are significant, advantageous factors in minimizing Zircaloy clad temperature and associated temperature-dependent corrosion and hydride buildup. This results in improved cladding performance at high burnup.
- The basic thermal and mechanical criteria applied in the ABWR design have been proven by irradiation of statistically significant quantities of fuel. The design heat fluxes and linear heat generation rates are similar to values proven in fuel assembly irradiation in the large fleet of operating BWRs.
- Because of the large negative moderator density (void) coefficient of reactivity, the ABWR has a number of inherent advantages, including (1) ease of control using coolant flow as opposed to control rods for load following, (2) inherent self-flattening of the radial power distribution, (3) spatial xenon stability, and (4) ability to override xenon in order to follow load. The

inherent spatial xenon stability of the ABWR is particularly important for large-sized plants, and permits daily load following over a large range of core power levels.

- The power density (approximately 50 kW/l) and power distributions used in sizing the ABWR core includes margins providing for operational flexibility.
- The ABWR fuel assembly pitch is 0.1 inch more than the conventional BWR fuel assembly pitch so that it can accommodate more water in the bypass gaps between the fuel assemblies, which improves fuel utilization and core thermal hydraulic stability and results in milder response for pressurization transients.

Core Configuration

The reactor core of the ABWR is arranged as an upright cylinder containing a large number of fuel assemblies (872) located within the reactor vessel. The coolant flows upward through the core. The core arrangement (plan view) and the lattice configuration are shown in Figures 6-1 and 6-2, respectively. Important components of this arrangement are described in the following pages.

As can be seen from Figure 6-1, the ABWR reactor core is comprised of fuel assemblies, control rods and nuclear instrumentation. The fuel assembly and control rod mechanical designs are basically the same as used in all but the earliest GE boiling water reactors; however, evolutionary improvements have been made to these components throughout the history of the GE BWR. The current generation of these components will be described below for application to the ABWR.

GE14 Fuel Assembly Description

The BWR fuel assembly consists of a fuel bundle and a channel. The fuel bundle contains the fuel rods and the hardware necessary to support and maintain the proper spacing between the fuel rods. The channel is a Zircaloy box which surrounds the fuel bundle to direct the core coolant flow through the bundle and also serves to guide the movable control rods.

The GE14 product line is currently GE's most advanced fuel assembly design. With the introduction of GE14, GE offers the widest selection of BWR fuel designs in the industry. Utilities can choose from five different designs (GE10 to GE14) to achieve the fuel characteristics that best match their ABWR operating strategy. The GE10 bundle contains 60 fuel rods and one large central water rod in an 8x8 array. The GE11 and GE13 designs contain a 9x9 array of 66 full length fuel rods, 8 part length fuel rods which span roughly two-thirds of the active core, and two large central water rods. The GE12 and GE14 designs contain a 10x10 array of 78 full length fuel rods, 14 part length rods, and two large central water rods. Thus, GE provides 8x8, 9x9 and 10x10 fuel designs for the ABWR.

Figure 6-3 shows the GE14 design with the major components identified. The cast stainless steel lower tie plate includes a conical section which seats into the fuel support and a grid which maintains the proper fuel rod spacing at the bottom of the bundle. The cast

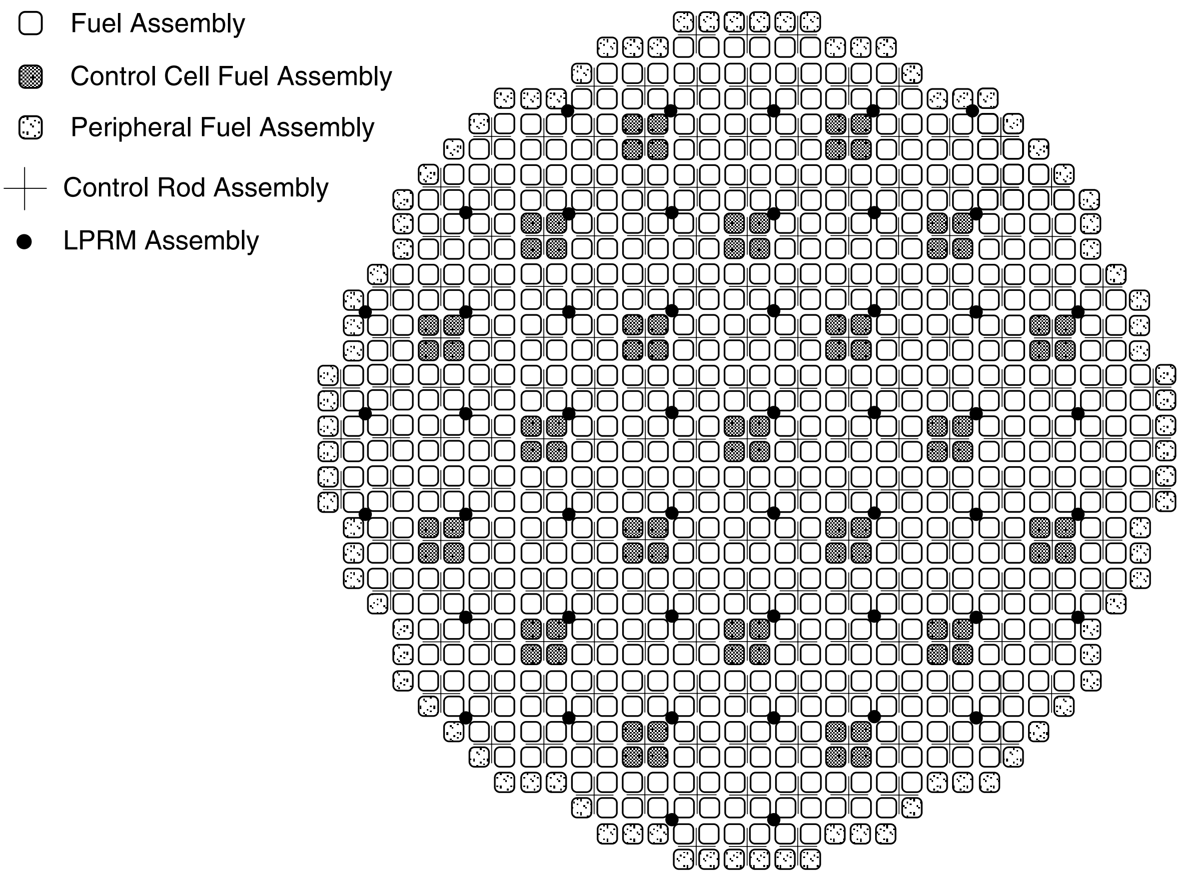


Figure 6-1. ABWR Core Configuration

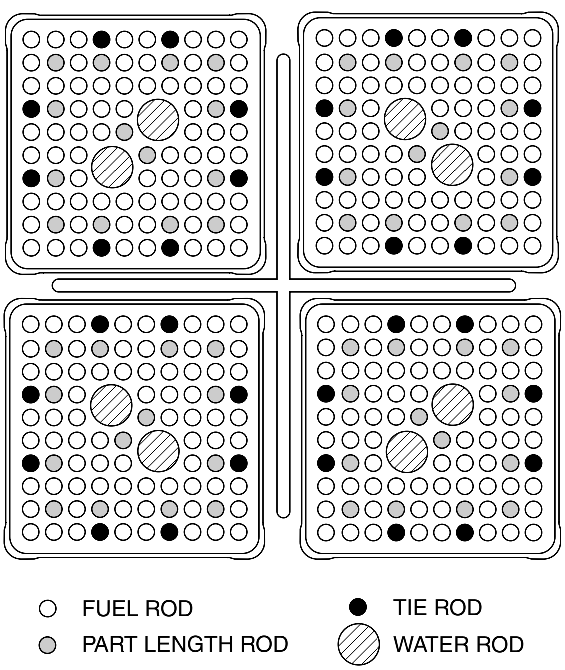


Figure 6-2. Four Bundle Fuel Module (Cell)

stainless steel upper tie plate maintains the fuel rod spacing at the top of the bundle and provides the handle that is used to lift the bundle.

The fuel bundle assembly is held together by eight tie rods located around the periphery of the fuel bundle. Each tie rod has a threaded lower end plug which screws into the lower tie plate and a threaded upper end plug which extends through a boss in the upper tie plate and is fastened with a nut. A lock tab washer is included under the tie rod nut to prevent rotation of the tie rod and nut.

The part-length rods also have lower end plugs which are threaded into the lower tie plate to prevent movement of the rods during shipping or handling with the bundle oriented horizontally. The upper end plugs of the full length fuel rods and water rods have extended shanks that protrude through bosses in the upper tie plate to accommodate the differential growth expected for high exposure operation. Expansion springs are also placed over each upper end plug shank to assure that the full length fuel rods and water rods are properly seated in the lower tie plate.

Eight high performance Zircaloy ferrule spacers are located axially to maintain the proper rod spacing along the length of the fuel bundle, to prevent flow-induced vibration, and to enhance the critical power performance. These spacers are captured in the correct axial locations by pairs of tabs welded to one of the two water rods. The water rod with tabs is placed through the spacers and then rotated to capture the spacers. Once assembled, rotation of the water rod with tabs is prevented by a square lower end plug which fits into a square hole in the lower tie plate.

The fuel assembly includes a Zircaloy-2 interactive fuel channel which channels flow vertically through the fuel bundle, provides lateral stiffness to the fuel bundle and provides a surface to support the control rods as they are inserted. To channel the fuel bundle, the channel is lowered over the upper tie plate, spacers and lower tie plate. At the bottom end, the channel fits tightly over Inconel alloy X-750 finger springs which seal the passage between the channel and lower tie plate to control leakage flow.

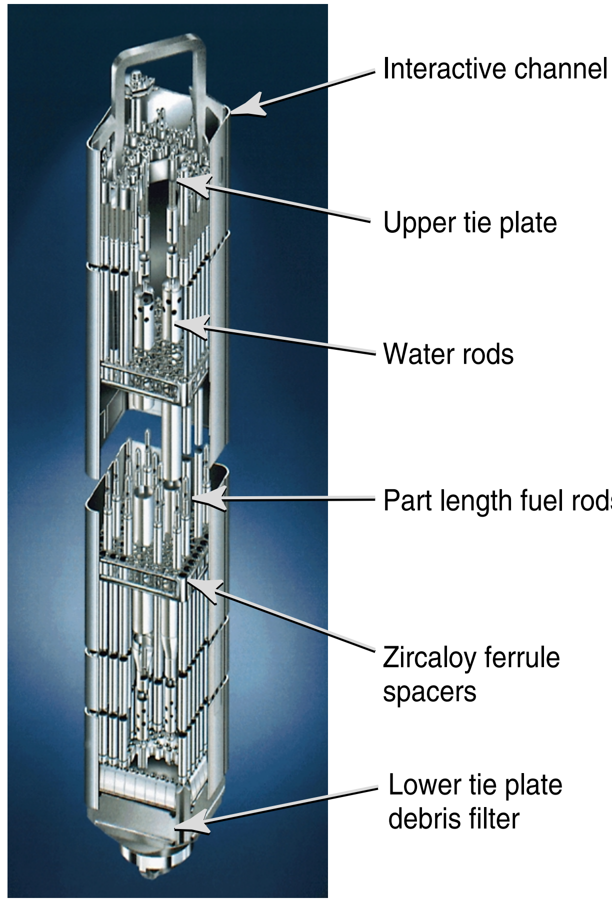


Figure 6-3. GE14 Fuel Assembly

The channel and channel fastener are attached to the fuel bundle by the channel fastener cap screw which extends through a hole in the clip (or gusset) welded to a top corner of the channel and is threaded into a post on the upper tie plate. Figure 6-4 shows the channel fastener assembly.

The fuel rod design includes annealed, fully recrystallized Zircaloy-2 cladding tubing, UO_2 fuel pellets, a retainer spring assembly, and lower and upper end plugs. The fuel rods are loaded with UO_2 or $(U,Gd)O_2$ fuel pellets as required for shutdown margin control and power shaping. A plenum spring is used to apply a preload to the fuel column to prevent fuel from shifting and being damaged inside the fuel rod during shipping and handling. This plenum spring is also shown in Figure 6-4.

The lower end plug is welded to the lower end of the cladding before loading any of the internal fuel rod components mentioned above. After loading all internal components, the fuel rod is evacuated, then backfilled with helium. The upper end plug is inserted into the top end of the fuel rod, compressing the retainer spring, and welded to the cladding.

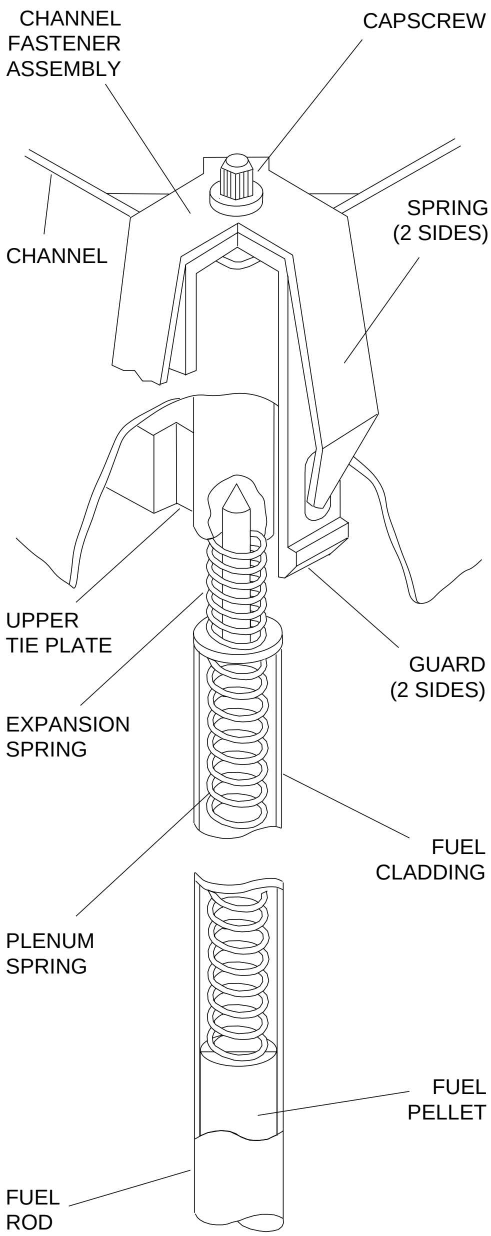


Figure 6-4. Channel Fastener Assembly

Key Fuel Design Features

The GE14 design utilizes several key design features, including part-length fuel rods, high performance spacers, low pressure drop upper tie plate, high pressure drop lower tie plate with debris filter, large central water rods, and interactive channels. These key design features are individually discussed below.

Part Length Rods

Part length fuel rods (PLRs) were introduced with the GE11 fuel design and have been used in all subsequent GE designs. For GE14, the 14 PLRs terminate just above the fifth spacer to provide increased flow area and reduce the two-phase pressure drop. This reduction in two-phase pressure drop leads to an improvement in core and channel stability and allows for an increase in the cladding diameter to maximize the fuel weight for a given overall pressure drop. In addition, the PLRs increase the moderator to fuel ratio in the top of the core to improve cold shutdown margins and fuel efficiency.

High Performance Spacers

The high performance Zircaloy ferrule spacer was developed to provide excellent critical power performance with acceptable pressure drop characteristics. This spacer concept is also used in GE10, GE11, and GE13. Eight spacers are used to maintain rod bow and flow-induced vibration margins for the reduced diameter 10x10 fuel rods of the GE14 design, while at the same time providing additional critical power capability.

Low Pressure Drop Upper Tie Plate

The upper tie plate (UTP) is designed to minimize two-phase pressure drop to improve fuel stability performance and reduce the pumping power required to drive core flow.

High Pressure Drop Lower Tie Plate with Debris Filter

As discussed previously, the use of part length rods and the low pressure drop upper tie plates to reduce two-phase pressure drop allows for an increase in single-phase pressure drop at the lower tie plate. This tradeoff provides improved stability with essentially the same overall pressure drop as previous designs. In addition, it allows for the use of very small flow holes in the lower tie plate, which act as a very effective debris filter. Figure 6-5 shows a top view of the debris filter lower tie plate. The bundle flow passes through the small holes which are only 0.125 inches in diameter, and of which there are 444. The debris filter lower tie plate design is standard with the GE14 design, and has been provided as an option for the GE11 through GE13 designs.

Large Central Water Rods

One of the basic characteristics of a BWR is that it is under-moderated at operating temperatures. In order to improve moderation and fuel efficiency, fuel rods are removed from the center of the fuel bundle and replaced with water rods to provide a zone for non-boiling water flow. The GE14 design includes two large central water rods to replace eight fuel rod locations and provide improved moderation.

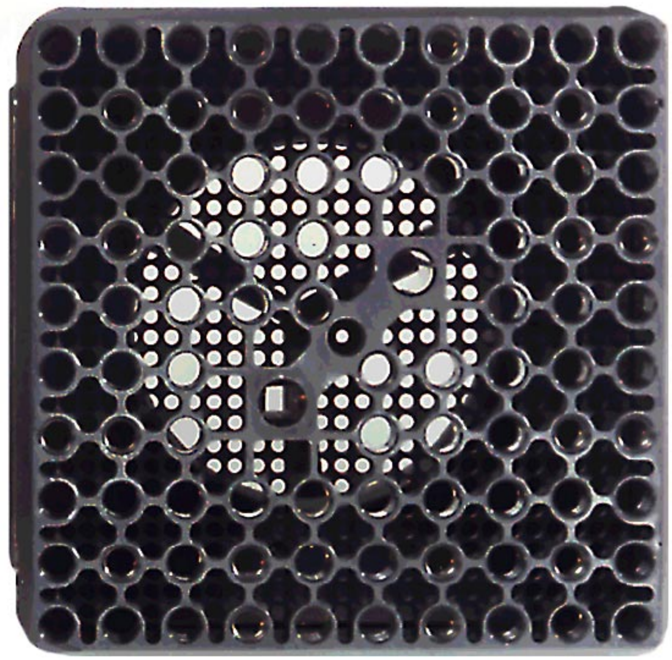


Figure 6-5. Top View of GE14 Debris Filter Lower Tie Plate

Interactive Channels

The interactive fuel channel concept used with the GE10 through GE13 fuel bundles is also included as an integral part of the GE14 design. This channel design has an optimized cross section, as illustrated in Figure 6-6, which includes thick corners where stresses are highest and thinner flat sides where stresses are low. This design minimizes the amount of Zircaloy-2 material in the channel in order to improve nuclear efficiency, increases the moderator in the bypass region for improved reactivity and hot-to-cold swing, and increases the control rod clearance.

Control Rod Descriptions

As shown in Figures 6-1 and 6-2, cruciform shaped control rods are configured for insertion between every four fuel assemblies comprising a module or “cell”. The four assemblies in a cell provide guidance for insertion and withdrawal of the control rods.

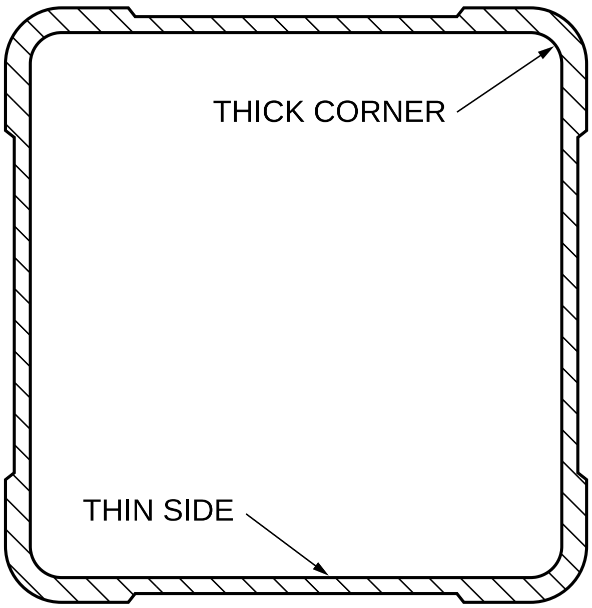


Figure 6-6. Cross-Section of Interactive Channel

The control rods perform dual functions of power distribution shaping and reactivity control. Power distribution in the core is controlled during operation of the reactor by manipulation of selected patterns of rods. The rods, which enter from the bottom of the reactor, are positioned in such a manner as to maintain the core in a critical state, and to control the radial power distribution. These groups of control elements which are inserted during power operation experience a somewhat higher duty cycle and neutron exposure than the other rods, which are used mainly for reactor shutdown.

The reactivity control function requires that all rods be available for either reactor "scram" (prompt shutdown) or reactivity regulation. Because of this, the control elements are mechanically designed to withstand the dynamic forces resulting from a scram. In the ABWR, they are connected to bottom-mounted drive mechanisms which provide electric-driven fine motion axial positioning control for reactivity regulation, as well as a hydraulically actuated rapid scram insertion function. The design of the rod-to-drive connection permits each control rod to be attached or detached from its drive during refueling without disturbing the remainder of the control functions. The bottom-mounted drives permit the entire control function to be left intact and operable for tests with the reactor vessel open.

Typically, the cruciform control rods contain stainless steel tubes in each wing of the cruciform filled with boron carbide (B_4C) powder compacted to approximately 75% of theoretical density. The tubes are seal welded with end plugs on either end. Stainless steel balls are used to separate the tubes into individual longitudinal compartments. The stainless steel balls are held in position by a slight crimp in the tube. The individual tubes act as pressure vessels to contain the helium gas released by the boron-neutron capture reaction.

The tubes are held in cruciform array by a stainless steel sheath extending the full length of the tubes. A top casting and handle, shown in Figure 6-7, aligns the tubes and provides structural rigidity at the top of the control rod. Rollers, housed by the top casting, provide guidance for control rod insertion and withdrawal. A bottom casting is also used to provide structural rigidity and contains positioning rollers and a coupler for connection to the control rod drive mechanism. The castings are welded into a single structure by means of a small cruciform post located in the center of the control rod. Control rods are cooled by the core leakage (bypass) flow.

In addition to boron carbide, hafnium absorber may be placed in the highest burnup locations of select control rods, the full length outside edge of each wing and, optionally, the tip of each wing. Hafnium is a heavy metal with excellent neutron absorbing characteristics and does not swell at high burnups.

Core Orificing

Control of the core flow distribution among the fuel assemblies is accomplished by fixed orifices. These orifices are located in the fuel support pieces and are not affected by fuel assembly removal and replacement. The core is divided into two orifice zones. The outer zone of fuel assemblies, located near the core periphery, has more restrictive orifices than the inner zone. Thus, flow to the higher power fuel assemblies is increased. The orificing of all fuel assemblies increases the thermal-hydraulic stability margin of both the core and individual fuel channels.

Other Reactor Core Components

In addition to fuel assemblies and control rods, there are also in-core monitoring components and neutron sources located in the reactor core.

SRNM Assembly

There are 10 Startup Range Neutron Monitoring (SRNM) assemblies, each consisting of a fixed position in-core regenerative fission chamber sensor

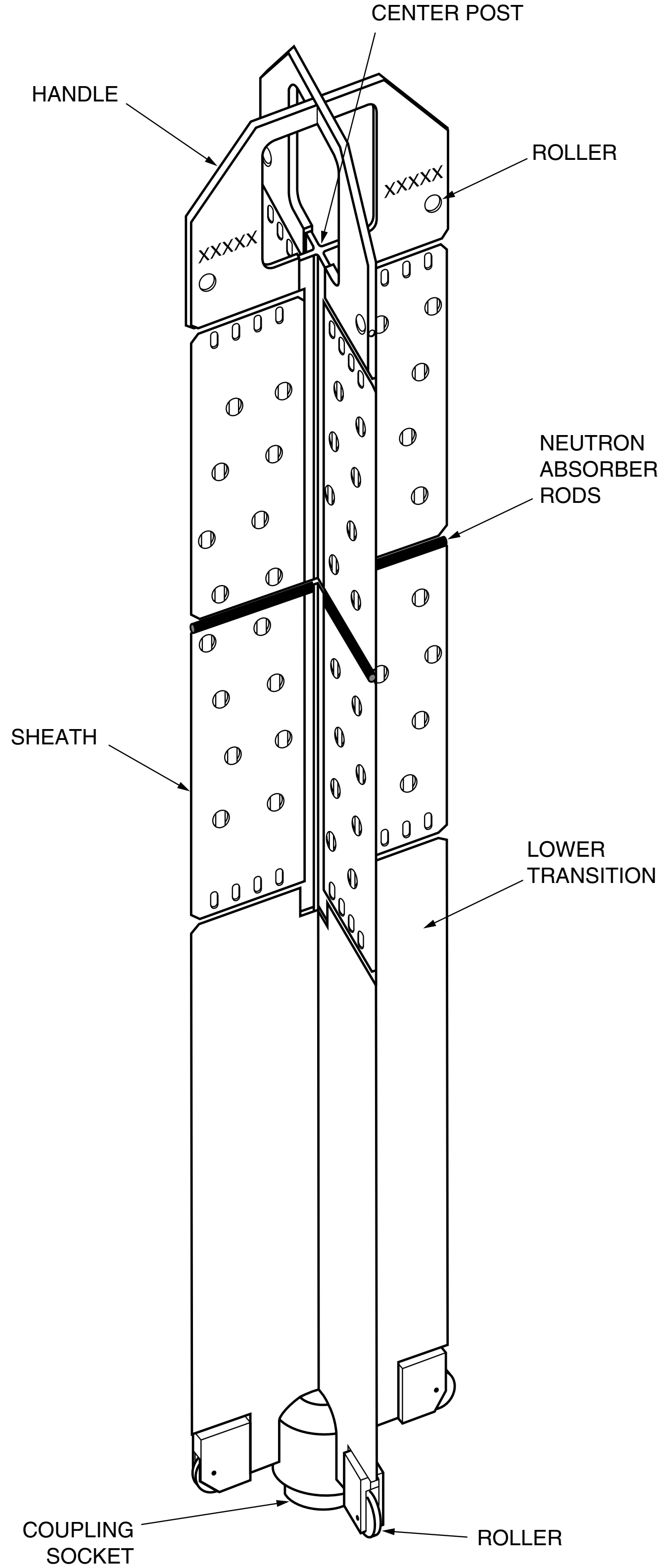


Figure 6-7. ABWR Control Rod

located slightly above the midplane of the fuel region. The sensors are contained within pressure barrier dry tubes located in the core bypass water region between fuel assemblies and distributed evenly throughout the core. The signal output exits the bottom of the dry tube under the vessel.

LPRM Assembly

There are 52 Local Power Range Monitoring (LPRM) assemblies evenly distributed throughout the reactor core. Each assembly extends vertically in the core bypass water region at every fourth intersection of the fuel assemblies and contains four fission chamber detectors evenly spaced at four axial positions adjacent to the active fuel. Detector signal cables are routed within the assembly toward the bottom of the reactor pressure vessel where the assembly penetrates the vessel pressure boundary. Below the vessel bottom, the pressure boundary is formed by an extended portion of the in-core instrument housing tube that houses the assembly.

The LPRM assembly enclosing tube also houses the automatic traversing in-core probe (ATIP) calibration tube. The ATIP sensor moves within the calibration tube to provide an axial scan of the neutron flux at that LPRM assembly location. A schematic of the ATIP, LPRM and SRNM assemblies is shown in Figure 6-8.

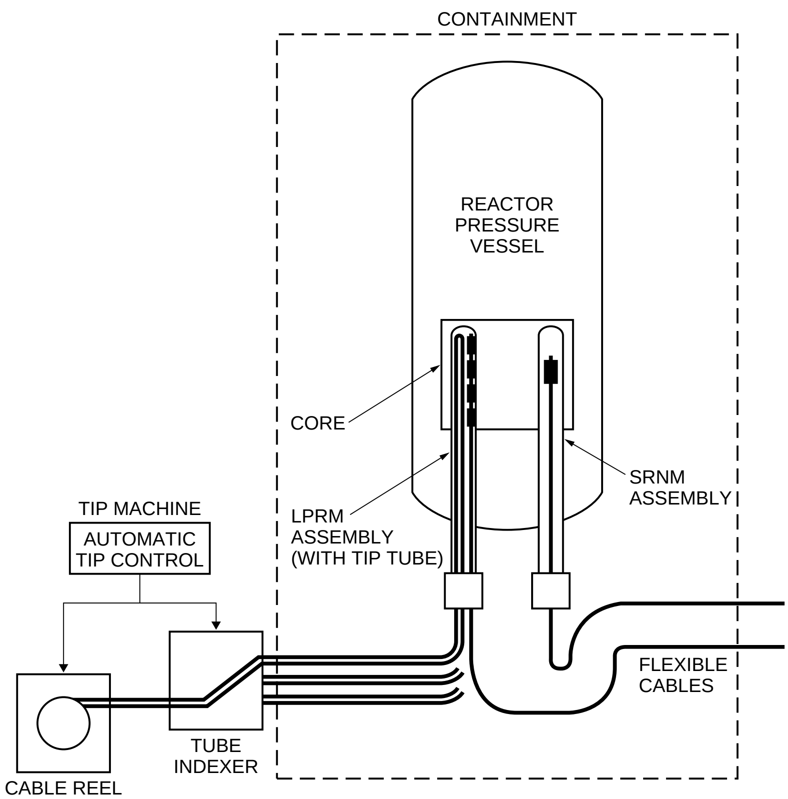


Figure 6-8. ABWR ATIP, LPRM and SRNM Schematic

Neutron Sources

Several antimony-beryllium startup sources are located within the core. They are positioned vertically in the reactor by “fit-up” in a slot (or pin) in the upper grid and a hole in the lower core support plate (Figure 6-9). The compression of a spring at the top of the housing exerts a column-type loading on the source. Though anchored firmly in place, the sources can easily be removed, but they need not be disturbed during refueling.

The active portion of each source consists of a beryllium sleeve enclosing two antimony-gamma sources. The resulting neutron emission strength is sufficient to provide indication on the source range neutron detectors for all reactivity conditions equivalent to the condition of all rods inserted prior to initial operation.

The active source material is entirely enclosed in a stainless steel cladding. The source is cooled by natural circulation of the core leakage flow in the annulus between the beryllium sleeve and the antimony-gamma sources.

Core Nuclear Design

The reactor core is designed to operate at rated power without any limitations, while delivering the total cycle length and energy desired by the utility. These design goals are achieved by designing with sufficient margin to thermal and reactivity limits to accommodate the types of uncertainties encountered in actual operation. Based on its extensive experience in BWR core design, GE has developed a consistent set of design margins to ensure meeting these objectives without compromising overall efficiency due to the use of undue conservatism.

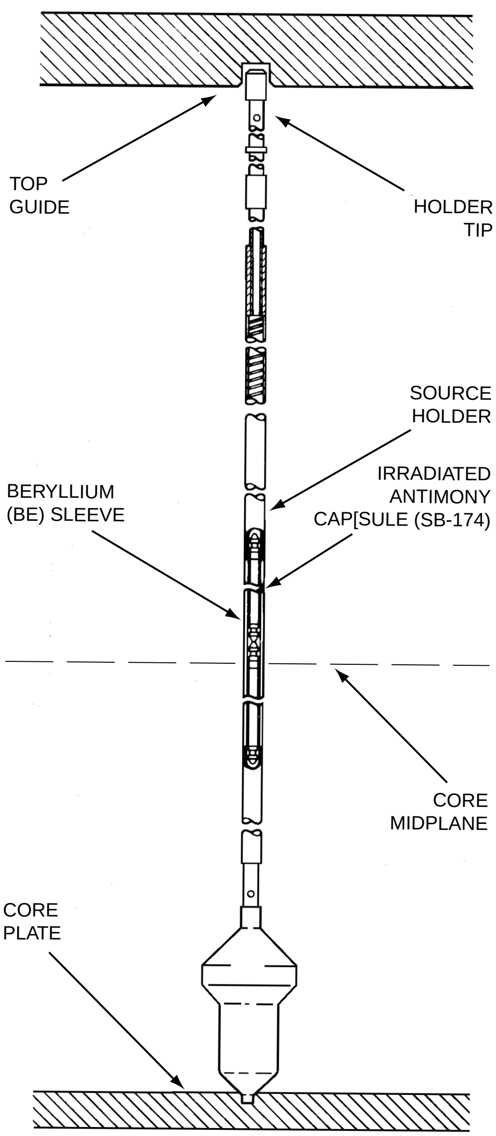


Figure 6-9. Neutron Source Schematic

Core Configuration

The ABWR core map is illustrated in Figure 6-1. There are 872 fuel assemblies, 205 control rods and 52 LPRM assemblies. Also the core periphery zone with more restrictive inlet flow orifices is shown.

Additionally, typical control cell locations are shown in Figure 6-1. ABWR can employ the Control Cell Core (CCC) operating strategy in which control rod movement to offset reactivity changes during power operations is limited to a fixed group of control rods. Each of these control rods and its four surrounding fuel assemblies comprise a control cell. All other control rods are normally withdrawn from the core while operating at power.

Low reactivity fuel assemblies are placed on the core periphery and in the control cells, to reduce neutron leakage and provide for control rod motion adjacent to low power fuel, respectively. For an initial core, the low reactivity fuel is comprised of natural uranium or low enrichment fuel. For a reload core, the low reactivity fuel is typically the high exposure fuel; fresh and low exposure fuel are scatter loaded in the remaining core fuel assembly locations.

Core Nuclear Characteristics

Reactivity Coefficients: In a boiling water reactor, two reactivity coefficients are of primary importance: the fuel Doppler coefficient and the moderator density reactivity coefficient. The moderator density reactivity coefficient may be broken into two components: that due to temperature and that due to steam voids.

- **Fuel Doppler Reactivity Coefficient:** As in all light water moderated and low enrichment reactors, the fuel Doppler reactivity coefficient is negative and prompt in its effect, opposing reactor power transients. When reactor power increases, the UO_2 temperature increases with minimum time delay and results in higher neutron absorption by resonance capture in the U-238.

- **Moderator Density Reactivity Coefficient:** During normal plant operations, the steam void component of the moderator density reactivity coefficient is of prime importance. The steam void component is large and negative at all power levels. This steam void effect results in the following operating advantages:
  - **Xenon Override Capability:** Since the steam void reactivity effect is large compared with xenon reactivity, the ABWR core has the capability of overriding the negative reactivity introduced by the buildup of xenon following a power decrease.
  - **Xenon Stability:** The steam void reactivity is the primary factor in providing the high resistance to spatial xenon oscillations in a boiling water reactor. Xenon instability is an oscillatory phenomenon of xenon concentration throughout the reactor that is theoretically possible in any type of reactor. These spatial xenon oscillations give rise to local power oscillations which can make it difficult to maintain the reactor within its thermal operating limits. Since these oscillations can be initiated by reactor power level changes, a reactor which is susceptible to xenon oscillations may be restricted in its load-following capability. The inherent resistance of the ABWR to xenon instability permits significant flexibility in load-following capability.
  - **Load Changing by Flow Control:** Since the fuel Doppler reactivity opposes a change in load, the void effect must be (and is) larger than the fuel Doppler effect in order to provide load changing capability by flow (or moderator density) control. The ABWR is capable of daily load following between 100% and 50% power by adjusting core flow, with only minor adjustments to the control rod pattern at low power.

Reactivity Control

Reactor shutdown control in BWRs is assured through the combined use of the control rods and burnable poison in the fuel. Only a few materials have nuclear cross sections that are suitable for burnable poisons. An ideal burnable poison must be essentially depleted in one operating cycle so that no residual poison exists to penalize the cycle length. It is also desirable that the positive reactivity from poison burnup match the almost linear decrease in fuel reactivity from fission product buildup and U-235 depletion. A self-shielded burnable poison consisting of digadolinia trioxide (Gd_2O_3), called gadolinia, dispersed in selected fuel rods in each fuel assembly provides the desired characteristics. The gadolinia concentration is selected such that the poison is essentially depleted during the operating cycle. Gadolinia has been used in GE BWRs since the early 1970s, and has proven to be an effective and efficient burnable poison. In addition to its use for reactivity control, gadolinia is also used to improve axial power distributions by axial zoning of the burnable poison concentration.

The core is designed so that adequate shutdown capability is available at all times. To permit margin for credible reactivity changes, the combination of control rods and burnable poison has the capability to shut down the core with the maximum worth control rod fully withdrawn. This capacity is experimentally demonstrated when reactivity alternations are made to the reactor core, such as during the initial core startup, and during each startup after a refueling outage.

Fuel Management

The flexibility of the ABWR core design permits significant variation of the intervals between refueling. The first shutdown for refueling can occur anywhere from one to two years after commencement of initial power operation. Thereafter, the cycle length can be varied up to 24 months with GE14 fuel. The desired cycle length can be obtained by adjusting both the refueling batch size and the average enrichment of the reload bundles.

The average bundle enrichments and batch sizes are a function of the desired cycle length. The initial ABWR core has an average enrichment ranging from approximately 1.7 wt% U-235 to approximately 3.2 wt% U-235 for cycle lengths ranging from one to two years. For ABWR reload cores using GE14 fuel, the average bundle enrichment is roughly 4.2 wt% U-235 with a reload batch fraction of 35% for a two year cycle.

Neutron Monitoring System

The Neutron Monitoring System (NMS) is a system of in-core neutron detectors and out-of-core electronic monitoring equipment. The system provides indication of neutron flux, which can be correlated to thermal power level for the entire range of flux conditions that can exist in the core. There are four subsystems in the NMS: the Startup Range Neutron Monitoring (SRNM) Subsystem, the Power Range Neutron Monitoring (PRNM) Subsystem [comprised of the Local Power Range Monitors (LPRM) and Average Power Range Monitors (APRM)], the Automatic Traversing In-Core Probe (ATIP) Subsystem, and the Multi-Channel Rod Block Monitoring (MRBM) Subsystem.

The NMS design has been greatly simplified for ABWR application. Key simplification features include the SRNM, period-based trip logic, and automation of the Traversing In-core Probe (TIP) System. The SRNMs replace the separate Source Range Monitor (SRM) and Intermediate Range Monitor (IRM) found in conventional BWRs. Use of these fixed in-core SRNM detectors eliminates the drive mechanism and the associated control systems for the moveable SRM and IRM detectors. IRM range switches have been eliminated by incorporating a period-based trip design in the startup power range. Hence, operability is greatly improved and accidental trips due to manual range switching are eliminated. TIP System operation for core flux mapping and calibrating the power range monitors has been fully automated in the ABWR design, thereby substantially enhancing operability.

Startup Range Neutron Monitoring (SRNM) Subsystem

The SRNM Subsystem monitors the neutron flux from the source range to approximately 15% of the rated power. The SRNM Subsystem provides neutron flux related trip inputs (flux level and period) to the Reactor Protection System (RPS), including a non-coincident trip function for refueling operations and a coincident trip function for other modes of operation. The SRNM Subsystem has 10 channels where each channel includes one detector installed at a fixed position within the core.

Power Range Neutron Monitoring (PRNM) Subsystem

The PRNM Subsystem provides flux information for monitoring the average power level of the reactor core. It also provides information for monitoring the local power level. The PRNM Subsystem monitors local thermal neutron flux up to 125% of rated power, and overlaps with part of the SRNM range.

The PRNM Subsystem consists of two subsystems:

- Local Power Range Monitoring (LPRM) Subsystem
- Average Power Range Monitoring (APRM) Subsystem

The LPRM Subsystem continuously monitors local core neutron flux. It consists of 52 detector assemblies with 4 detectors per assembly. The 208 LPRM detectors are separated and divided into four groups to provide four independent APRM signals. The APRM Subsystem averages the readings of the assigned LPRM detectors and provides measurement of reactor core power. Individual LPRM signals are also transmitted through dedicated interface units to various systems such as the RCIS, and the plant process computer.

An Oscillation Power Range Monitor (OPRM) is also part of the APRM. Each OPRM receives identical LPRM signals from the corresponding APRM as inputs, and forms many OPRM cells to monitor the neutron flux behavior of all regions of the core. The LPRM signals assigned to each cell are summed and averaged to provide an OPRM signal for this cell. The OPRM trip protection algorithm detects thermal hydraulic instability and provides trip output to the RPS if the trip setpoint is exceeded.

Automatic Traversing In-Core Probe (ATIP) Subsystem

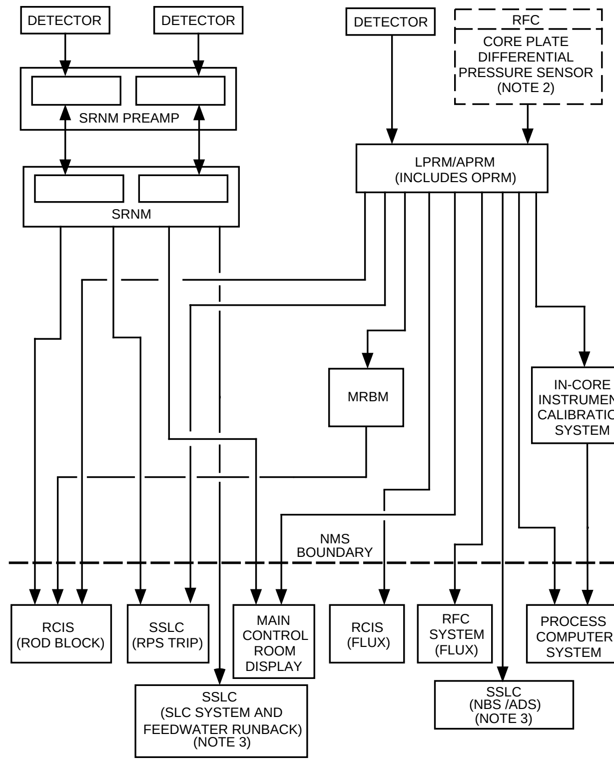
This is a single non-safety processor system included in the NMS used to provide steady state local power information for LPRM calibration and three dimensional reactor power determination.

The ATIP controller contains the purge control system, flux amplifiers and automatic/manual TIP sequencing controls for the three TIP machines located in the Reactor Building. The ATIP Subsystem performs an axial scan of the neutron flux in the core at the LPRM assembly locations. The subsystem can be controlled manually by the operator, or it can be under micro-processor-based automated control. The ATIP Subsystem typically consists of neutron-sensitive ion chambers, flexible drive cables, guide tubes, indexing machines, drive machines, and an automatic control system.

Multi-Channel Rod Block Monitor (MRBM) Subsystem

The MRBM Subsystem is designed to stop the withdrawal of control rods and prevent fuel damage when the rods are incorrectly being continuously withdrawn, whether due to malfunction or operator error. The MRBM averages the LPRM signals surrounding each control rod being withdrawn. It compares the averaged LPRM signal to a preset rod block setpoint, and, if the averaged values exceed this setpoint, the MRBM Subsystem issues a control rod block demand to the RCIS. The rod block setpoint is a core flow biased variable setpoint.

Those portions of the Neutron Monitoring System that input signals to the RPS qualify as a nuclear safety system. The SRNM and the APRM Subsystems, which monitor neutron flux via in-core detectors, provide scram logic inputs to the RPS to initiate a scram in time to prevent excessive fuel clad damage as a result of overpower transients. The APRM Subsystem also generates a simulated thermal power signal. Both upscale neutron flux and upscale simulated thermal power are conditions which provide scram logic signals. A block diagram of a typical NMS division is shown in Figure 6-10.



NOTES:

1. DIAGRAM REPRESENTS ONE OF FOUR NMS DIVISIONS (MRBM IS A DUAL CHANNEL SYSTEM. THERE IS ONLY ONE IN-CORE INSTRUMENT CALIBRATION SYSTEM).
2. USED FOR RAPID CORE FLOW DECREASE TRIP.
3. SRNM AND APRM ATWS PERMISSIVE SIGNALS TO SSLC.
4. INTERCONNECTIONS MAY BE FIBER-OPTIC OR METALLIC.

Figure 6-10. Basic Configuration of a Typical Neutron Monitoring System Division

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