

IP3  
FSAR UPDATE

CHAPTER 3

REACTOR

3.1 DESIGN BASIS

3.1.1 Performance Objectives

The reactor thermal power analyzed is 3216 MWt.

The fuel rod cladding was designed to maintain its integrity for the anticipated fuel assembly life. The effects of gas release, fuel dimensional changes, and corrosion-induced and irradiation-induced changes in the mechanical properties of cladding were considered in the design of the fuel assemblies.

Rod Control Clusters are employed to provide sufficient reactivity control to terminate any credible power transient prior to reaching the design minimum departure from nucleate boiling ratio (DNBR) of the applicable limit. This is accomplished by ensuring sufficient control cluster worth to shut the reactor down by at least 1.3% in the hot condition with the most reactive control cluster stuck in the fully withdrawn position.

Redundant equipment is provided to add soluble poison to the reactor coolant in the form of boric acid to maintain shutdown margin when the reactor is cooled to ambient temperatures.

In addition, the control rod worth in conjunction with the boric acid injection from the refueling water storage tank (RWST) is sufficient to prevent an unacceptable return to power level as a result of the maximum credible steam line break (one safety valve stuck fully open) even assuming that the most reactive control rod is fully withdrawn.

With the BIT functionally eliminated, the return to power following a credible steamline break accident has been evaluated showing that the event is bounded by the hypothetical steamline break. The departure from nucleate boiling (DNB) design basis is met with no consequential fuel failures predicted, and assuring that the return to power remains within the limits established for the protection of the health and safety of the public, with margin.

Plant specific analyses performed by Westinghouse for Indian point Unit 3, have shown that the Boron Injection Tank (BIT) may be bypassed, eliminated, or the concentration of its contents reduced, while continuing to meet applicable safety criteria.

The functional elimination of the BIT replaces the concentrated boric acid contained therein, with water from the Refueling Water Storage Tank (RWST); this obviates the need to maintain the BIT and its associated piping at elevated temperatures.

The lowering of the minimum required boric acid concentration in the BIT:

- 1) reduces the potential for degradation of carbon steel components and supports as a result of leakage;
- 2) eliminates the need to maintain recirculation of boric acid through BIT;
- 3) eliminates the need to maintain the BIT heaters and heat tracing on the associated SIS piping and recirculation lines; and

internals support ledge in the case of horizontal loads. The internals also provide a form fitting baffle surrounding the fuel assemblies which confines the upward flow of coolant in the core area to the fuel bearing region.

## Reactor Internals

### Design Description

The reactor internals were designed to support and orient the reactor core fuel assemblies and control rod assemblies, absorb the control rod dynamic loads and transmit these and other loads to the reactor vessel flange, provide a passageway for the reactor coolant, and support incore instrumentation. The reactor internals are shown in Figure 3.2-23.

The internals were designed to withstand the forces due to weight, preload of fuel assemblies, control rod dynamic loading, vibration, and earthquake acceleration. The internals were analyzed in a manner similar to that employed for Connecticut Yankee, San Onofre, Zorita, Saxton and Yankee. Under the loading conditions specified, which included conservative effects of design earthquake loading, the structure satisfied stress values prescribed in Section III, ASME Nuclear Vessel Code.

The reactor internals were fabricated primarily from type 304 stainless steel.

The reactor internals are equipped with bottom-mounted incore instrumentation supports. These supports were designed to sustain the applicable loads outlined above.

The components of the reactor internals are divided into three parts consisting of the lower core support structure (including the entire core barrel and thermal shield), the upper core support structure and the in-core instrumentation support structure.

### Lower Core Support Structure

The major containment and support member of the reactor internals is the lower core support structure, shown in Figure 3.2-23. This support structure assembly consists of the core barrel, the core baffle, and lower core plate and support columns, the thermal shield, the intermediate diffuser plate and the bottom support plate which is welded to the core barrel. All the major material for this structure is type 304 stainless steel. The core support structure is supported at its upper flange from a ledge in the reactor vessel head flange and its lower end is restrained in its transverse movement by a radial support system attached to the vessel wall. Within the core barrel are axial baffle and former plates which are attached to the core barrel wall and form the enclosure periphery of the assembled core. The lower core plate is positioned at the bottom level of the core below the baffle plates and provided support and orientation for the fuel assemblies.

The lower core plate is a 2-inch thick member through which the necessary flow distributor holes for each fuel assembly were machined. Fuel assembly locating pins (two for each assembly) are also inserted into this plate. Columns were placed between this plate and the bottom support plate of the core barrel in order to provide stiffness and to transmit the core load to the bottom support plate. Intermediate between the support plate and lower core support plate was positioned a perforated plate to diffuse uniformly the coolant flowing into the core.

IP3  
FSAR UPDATE

The one-piece thermal shield is fixed to the core barrel at the top with rigid bolted connections. The bottom of the thermal shield is connected to the core barrel by means of axial flexures. This bottom support allows for differential axial growth of the shield/core barrel but restricts radial or horizontal movement of the bottom of the shield. Rectangular tubing in which material samples can be inserted and irradiated during reactor operation are welded to the thermal shield and extend to the top of the thermal shield. These samples are held in the rectangular tubing by a preloaded spring device at the top and bottom.

The lower core support structure and principally the core barrel serve to provide passageways and control for the coolant flow. Inlet coolant flow from the vessel inlet nozzles proceeds down the annulus between the core barrel and the vessel wall, flows on both sides of the thermal shield, and then into a plenum at the bottom of the vessel. It then turns and flows up through the lower support plate, passes through the intermediate diffuser plate and then through the lower core plate. The flow holes in the diffuser plate and the lower core plate are arranged to give a very uniform entrance flow distribution to the core. After passing through the core and coolant enters the area of the upper support structure and then flows generally radially to the core barrel outlet nozzles and directly through the vessel outlet nozzles.

A small amount of water also flows between the baffle plates and core barrel to provide additional cooling of the barrel. Similarly, a small amount of the entering flow is directed into the vessel head plenum to provide cooling of the head. Both these flows eventually are directed into the upper support structure plenum and exit through the vessel outlet nozzles.

Vertically downward loads from weight, fuel assembly preload, control rod dynamic loading and earthquake acceleration are carried by the lower core plate partially into the lower core plate support flange on the core barrel shell, and partially through the lower support columns to the lower core support and thence through the core barrel shell to the core barrel flange supported by the vessel head flange. Transverse loads from earthquake acceleration, coolant cross flow, and vibration are carried by the core barrel shell to be distributed to the lower radial support to the vessel wall, and to the core barrel flange. Transverse acceleration of the fuel assemblies is transmitted to the core barrel shell by direct connection of the lower core plate to the barrel wall and by a radial support type connection of the upper core plate to slab sided pins pressed into the core barrel.

The main radial support system of the core barrel is accomplished by “key” and “keyway” joints to the reactor vessel wall. At equally spaced points around the circumference, an Inconel block is welded to the vessel ID. Another Inconel block is bolted to each of these blocks, and has a “keyway” geometry. Opposite each of these is a “key” which is attached to the internals. At assembly, as the internals are lowered into the vessel, the keys engage the keyways in the axial direction. With this design, the internals are provided with a support at the furthest extremity, and may be viewed as a beam fixed at the top and simply supported at the bottom.

Radial and axial expansions of the core barrel are accommodated, but transverse movement of the core barrel is restricted by this design. With this system, cycle stresses in the internal structures are within the ASME Section III limits. This eliminates any possibility of failure of the core support.

In the event of downward vertical displacement of the internals, energy absorbing devices limit the displacement by contacting the vessel bottom head. The load is transferred through the energy devices of the internals.

IP3  
FSAR UPDATE

The energy absorbers, which are cylindrical in shape, are contoured on their bottom surface to the reactor vessel bottom head geometry. Their number and design were determined so as to limit the forces imposed to less than yield. Assuming a downward vertical displacement the potential energy of the system is absorbed mostly by the strain energy of the energy absorbing devices.

The free fall in the hot condition is on the order of  $\frac{1}{2}$  inch, and there is an additional strain displacement in the energy absorbing devices of approximately  $\frac{3}{4}$  inch. Alignment features in the internals prevent cocking of the internals structure during this postulated drop. The control rods are designed to provide assurance of control rod insertion capabilities under this assumed drop of internals condition. The drop distance of about  $1\frac{1}{4}$  inch is not enough to cause the tips of the shutdown group of RCC assemblies to come out of the guide tubes in the fuel assemblies.

#### Upper Core Support Assembly

The upper core support assembly, shown in Figure 3.2-28, consists of the top support plate, deep beam sections, and upper core plate between which are contained 48 support columns and 61 guide tube assemblies. The support columns establish the spacing between the top support plate, deep beam sections, and the upper core plate and are fastened at top and bottom to these plates and beams. The support columns transmit the mechanical loadings between the two plates and serve the supplementary function of supporting thermocouple guide tubes. The guide tube assemblies, shown on Figure 3.2-29, sheath and guide the control rod drive shafts and control rods and provide no other mechanical functions. They are fastened to the top support plate and are guided by pins in the upper core plate for proper orientation and support. Additional guidance for the control rod drive shafts is provided by the control rod shroud tube which is attached to the upper support plate and guide tube.

The upper core support assembly, which is removed as a unit during refueling operation, is positioned in its proper orientation with respect to the lower support structure by flat-sided pins pressed into the core barrel which in turn engage in slots in the upper core plate. At an elevation in the core barrel where the upper core plate is positioned, the flat-sided pins are located at angular positions of  $0^\circ$ ,  $90^\circ$ ,  $180^\circ$ , and  $270^\circ$ . Four slots are milled into the core plate at the same positions. As the upper support structure is lowered into the main internals, the slots in the plate engage the flat-sided pins in the axial direction. Lateral displacement of the plate and of the upper support assembly is restricted by this design. Fuel assembly location pins protrude from the bottom of the upper core plate and engage the fuel assemblies as the upper assembly is lowered into place. Proper alignment of the lower core support structure, the upper core support assembly, the fuel assemblies and control rods is thereby assured by this system of locating pins and guidance arrangement. The upper core support assembly is restrained from any axial movements by a large circumferential spring which rests between the upper barrel flange and the upper core support assembly and is compressed by the reactor vessel head flange.

Vertical loads from weight, earthquake acceleration, hydraulic loads and fuel assembly preload are transmitted through the upper core plate via the support columns to the deep beams and top support plate and then the reactor vessel head. Transverse loads from coolant cross flow, earthquake acceleration, and possible vibrations are distributed by the support columns to the

IP3  
FSAR UPDATE

top support plate and upper core plate. The top support plate is particularly stiff to minimize deflection.

#### Incore Instrumentation Support Structures

The incore instrumentation support structures consist of an upper system to convey and support thermocouples penetrating the vessel through the head and a lower system to convey and support flux thimbles penetrating the vessel through the bottom.

The upper system utilizes the reactor vessel head penetrations. Instrumentation port columns are slip-connected to in-line columns that are in turn fastened to the upper support plate. These port columns protrude through the head penetrations. The thermocouples are carried through these port columns and the upper support plate at positions above their readout locations. The thermocouple conduits are supported from the columns of the upper core support system. The thermocouple conduits are sealed stainless steel tubes.

In addition to the upper in-core instrumentation, there are reactor vessel bottom port columns which carry the retractable, cold worked stainless steel flux thimbles that are pushed upward into the reactor core. Conduits extend from the bottom of the reactor vessel down through the concrete shield area and up to a thimble seal line. The minimum bend radii are about 144 inches and the trailing ends of the thimbles (at the seal line) are extracted approximately 15 feet during refueling of the reactor in order to avoid interference within the core. The thimbles are closed at the leading ends and serve as the pressure barrier between the pressurized water and the containment atmosphere.

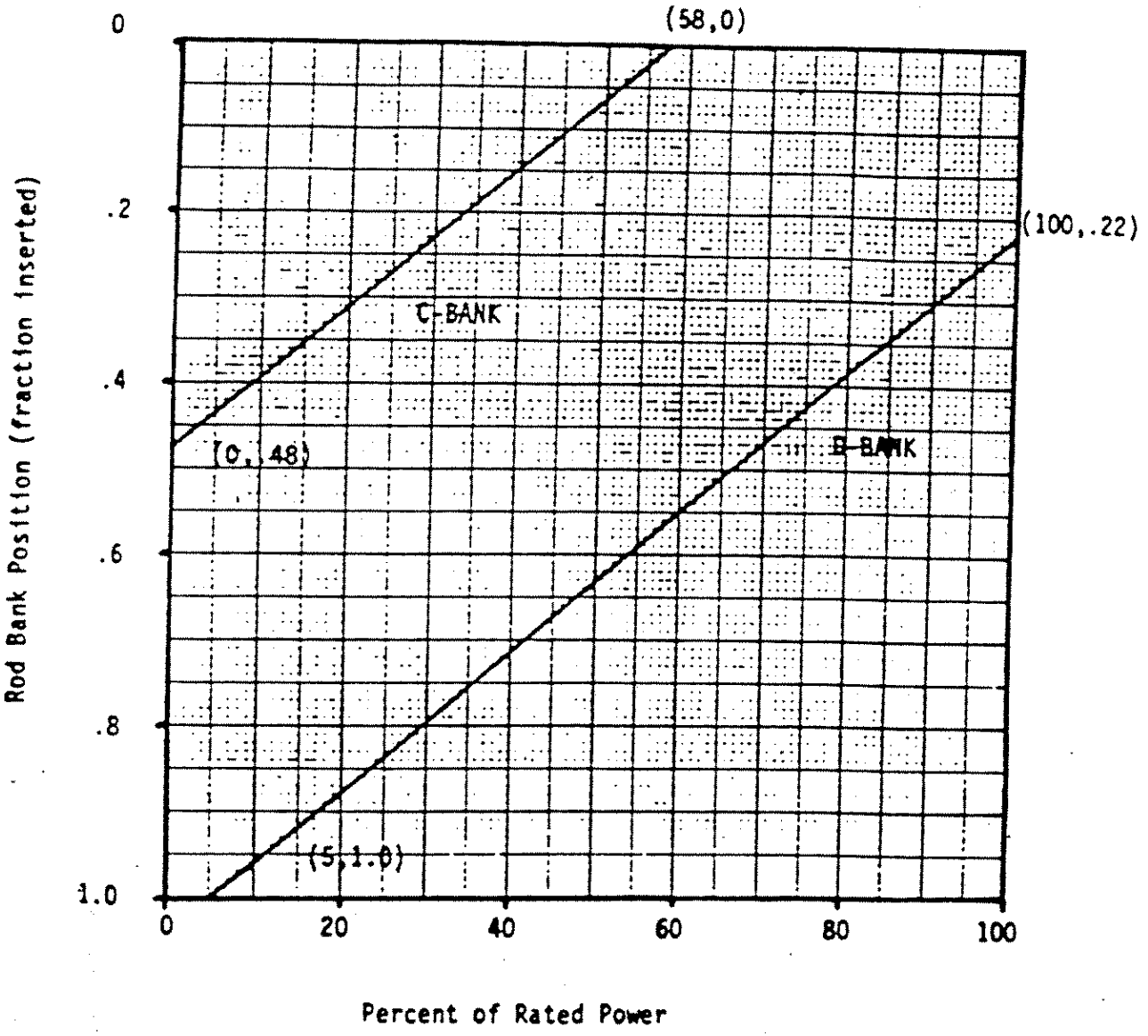
Mechanical seals between the retractable thimbles and the conduits are provided at the seal line. During normal operation, the retractable thimbles are stationary and move only during refueling or for maintenance, at which time a space of approximately 15 feet above the seal line is cleared for the retraction operation. Section 7.4 contains more information on the layout of the incore instrumentation system.

The incore instrumentation support structure was designed for adequate support of instrumentation during reactor operation and is rugged enough to resist damage or distortion under the conditions imposed by handling during the refueling sequence.

#### Evaluation of Core Barrel and Thermal Shield

The internals design was based on analysis, test and operational information. Troubles in previous Westinghouse PWR's were evaluated and information derived was considered in this design. For example, the Westinghouse design uses a one-piece thermal shield which is attached rigidly to the core barrel at one end and flexured at the other. The early designs that malfunctioned were multi-piece thermal shields that rested on vessel lugs and were not rigidly attached at the top.

Early core barrel designs that have malfunctioned in service, now abandoned, employed threaded connections such as tie rods, joining the bottom support to the bottom of the core barrel, and a bolted connection that tied the core barrel to the upper barrel. The malfunctioning of core barrel designs in earlier service was believed to have been caused by the thermal shield which was oscillating, thus creating forces on the core barrel. Other forces were induced by unbalanced flow in the lower plenum of the reactor. In the Indian Point 3 RCC design there are



NOTE: Banks A and B are fully withdrawn at zero power

INDIAN POINT 3 FSAR UPDATE	
INSERTION LIMITS 100 STEP OVERLAP FOUR LOOP OPERATION (CYCLE 1)	
REV. 1, JULY 1990	FIGURE NO. 3.2-38