General Electric Advanced Technology Manual

Chapter 6.1

Reactor Vessels

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6.1 REACTOR VESSELS

Learning Objectives:

After studying this section, you should be able to:

1. Describe the internal components and their arrangement that may or may not provide 2/3 core coverage capability following a LOCA.

6.1.1 Introduction

The reactor vessels utilized for a particular product line are dependent on the vintage of the plant, core cooling regulations, type of recirculation system, and technology used during its period of design. The reactor vessel houses the reactor core, serves as part of the reactor coolant boundary, supports and aligns the fuel and control rods, provides a flow path for the circulation of coolant past the fuel, removes moisture from the steam exiting the reactor vessel, limits the downward control rod motion following a postulated failure of a control rod drive housing, and in all cases except the BWR/2 product line provides an internal refloodable volume following a loss of coolant accident.

6.1.2 BWR/2 Reactor Vessel

The BWR/2 reactor vessel, Figure 6.1-1, is an insulated pressure vessel mounted vertically within the drywell and is comprised of a cylindrical shell with an integral hemispherical bottom head. The top head is also hemispherical but is removable to facilitate refueling operations. The base material of the vessel is high strength alloy carbon steel. All internal surfaces including the shell, heads, flanges and attachments are clad with Type 304 stainless steel to a thickness of 0.25 inches. Small nozzles which are not practicable to clad internally with stainless overlay are solid nickel-chromium-iron alloy.
The vessel head is attached to the vessel shell by sixty four six inch diameter studs that are threaded into bushings in the vessel flange. Spherical washers and closure nuts are match marked in sets of two and are used in sets. To secure the head to the vessel shell, the studs are elongated by hydraulic stud tensioners which permit the nuts to be turned while the stud is under tension.

Leakage of radioactive coolant and steam between the mating surfaces of the vessel and closure head flanges to atmosphere is contained by two self-energizing O-ring gaskets. These silver plated and polished Ni-Cr-Fe (Inconel) O-rings are approximately 0.50 inches in diameter. The O-rings are designed to have no detectable leakage through the inner or outer member during any reactor operating condition.

6.1.2.1 Vessel Internals

The major reactor vessel internal components included in this discussion are the core support assembly, core shroud, diffuser, core plate, upper core grid, core spray system sparger, feedwater sparger, steam separators and dryers.

Core Support Assembly

The core support assembly consists of a stainless steel forged ring that is welded to an Inconel segment. The Inconel segment is welded to the lower shell of the vessel. The core support assembly supports the core shroud and separates the recirculation system suction from its discharge.

Core Shroud

The core shroud is supported by the core support assembly. The core shroud along with the core support assembly forms a 17 inch water annulus inside the reactor vessel wall. In addition, a flow barrier is provided by the lower portion of the shroud and the support assembly. This conical skirt, welded to the reactor vessel wall, effectively separates the recirculation inlet core flow from the downcomer annulus flow.

Diffuser

The vessel diffuser is a cylindrical shell hanging downward from a shelf provided by a ring girder. The diffuser contains hundreds of 1.25 inch diameter holes and is approximately eight feet in height. The diffuser serves a twofold purpose; it prevents direct contact of the recirculation flow to the control rod guide tubes and provides a uniform flow of coolant below the fuel orifice region.

Core Plate

The core plate is provided to laterally guide and align the control rod guide tube and fuel support castings. Twelve peripheral fuel assemblies, located outside the control rod pattern are supported vertically by the core plate. These peripheral fuel assemblies rest in a fuel support piece that is welded to the core plate. The core plate prevents recirculation flow from bypassing the fuel assemblies by directing the flow into the control rod guide tube.

Upper Core Grid

The upper core grid or top guide is mounted and supported by twelve brackets inside the shroud. Eight bolts are provided to laterally position and level the top guide. Four hold down bolts attach the top guide to the ledge of the core shroud.

Core Spray Sparger

Two independent core spray loops are installed in the vessel above the upper core grid (top guide) and within the core shroud. The loops are connected to the Core Spray System which is used for core cooling under loss of coolant accident conditions.

Feedwater Sparger

The feedwater spargers are mounted to the reactor vessel wall in the upper part of the downcomer or annulus region. The spargers, each supplied by one of the two feedwater nozzles, complete a half circle of the vessel interior and discharges water radially inward. A number of 1-inch holes in each sparger permits the cooler feedwater to mix with downcomer recirculation flow before coming in contact with the vessel.

Steam Separator

The steam separator assembly consists of the shroud head and an array of standpipes with steam separators located above each standpipe. The shroud head mates with the core shroud and is bolted to it. The shroud head is a dished unit and forms the cover of the core discharge plenum region. A metal to metal contact seals the separator assembly and the core shroud flange. Operation of the steam separators is identical to that of the separators covered in the systems manual.

Steam Dryer

The steam dryers are required to dry a mass flow of wet steam at 1015 psia and 10 percent moisture by weight to a mass flow of dry steam at 1015 psia and 0.10 percent moisture by weight. The mass flow of steam ranges from zero to 6,933,000 pounds per hour. The dryer assembly is supported by four internal vessel pads. Vertical guides inside the vessel provide alignment during installation, four hold down bolts hold the unit in position.

The dryer assembly is mounted in the vessel above the steam separator assembly and forms the top and sides of the wet steam plenum. Steam that has passed through the separators enters the chevron-type dryer units. A series of troughs and tubes remove the remaining moisture which flows into the downcomer annulus.

6.1.3 BWR/3 and BWR/4 Reactor Vessels

The introduction of the BWR/3 product line (Figure 6.1-2) produced major changes in the reactor vessel design. One of the more important changes was the elimination of the five recirculation loop concept in favor of two loops with jet pumps mounted internal to the

reactor vessel. The elimination of five loops removed the recirculation system discharge nozzle penetrations in the vessel bottom head region and reduces the probability of a large break loss of coolant accident. The installation of the jet pumps provides a standpipe effect so the core can be reflooded following a loss of coolant accident and allows better communication between the annulus region and the core region without the need of the recirculation loops.

The BWR/3 product line vessel also included modifications to the feedwater spargers, steam dryers, vessel head, and the cladding overlay. The feedwater spargers increased in number from two to four and contain converging nozzles for better efficiency and extended sparger life. The dryer assembly retained the same operating principle but, added more drying units and was no longer bolted down. The vessel head gained two new penetrations (head spray and spare), in addition to holddown pads to prevent the steam dryer from lifting during system operation. The vessel upper head and nozzle penetration are not clad because it is not needed and the cladding tended to propagate cracks into the base metal on nozzle penetrations.

6.1.3.1 BWR/4 Advanced Vessel Design

Two BWR/4 product line vessels favor the later BWR/5 and BWR/6 design in that they contain separate and independent penetrations for the Low Pressure Coolant Injection (LPCI) mode of the Residual Heat Removal System. The LPCI injection lines penetrate the vessel at four different locations and continue until they penetrate the core shroud.

6.1.4 BWR/5 and BWR/6 Reactor Vessel

The BWR/5 product line (Figure 6.1-3) produced changes in the vessel upper head, steam separator and dryer assemblies, instrumentation quadrant taps, and LPCI injection penetrations. The upper vessel head penetrations was reduced from three to only two, one spare and one multipurpose to perform the functions previously performed by two separate penetrations. The steam separator assembly acquired more separating units as did the dryer assembly. The dryer assembly also underwent holddown changes to eliminate the problem of ensuring it was disconnected from the core shroud prior to lifting. The LPCI injection penetrations were reduced from four to three.

6.1.5 Summary

The reactor vessels utilized for a particular product line are dependent on the vintage of the plant, core cooling regulations, type of recirculation system, and technology used during its period of design. The reactor vessel houses the reactor core, serves as part of the reactor coolant boundary, supports and aligns the fuel and control rods, provides a flow path for the circulation of coolant past the fuel, removes moisture from the steam exiting the reactor vessel, limits the downward control rod motion following a postulated

failure of a control rod drive housing, and in all cases except the BWR/2 product line provides an internal refloodable volume following a loss of coolant accident.

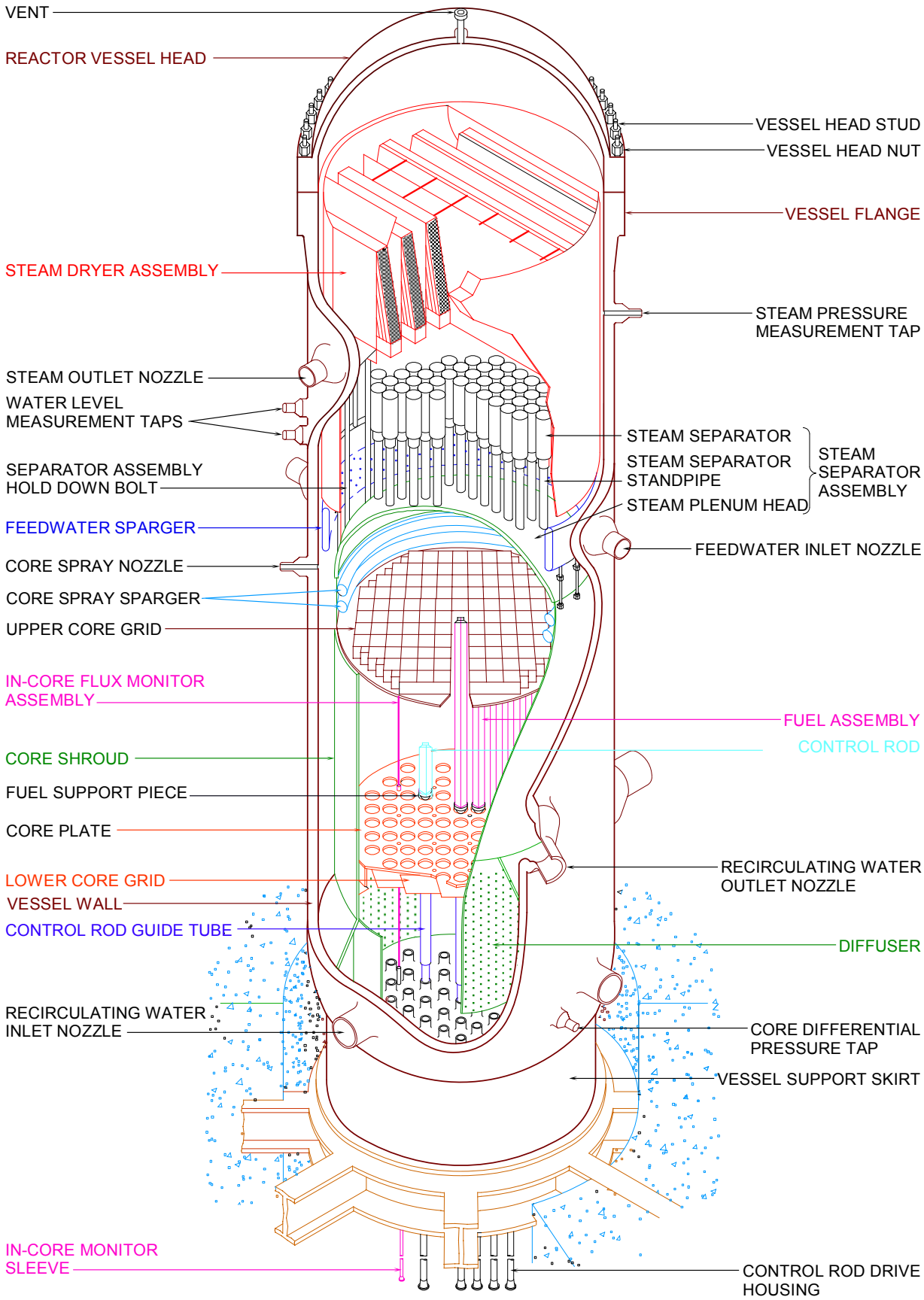

Figure 6.1-1 BWR/2 Reactor Vessel

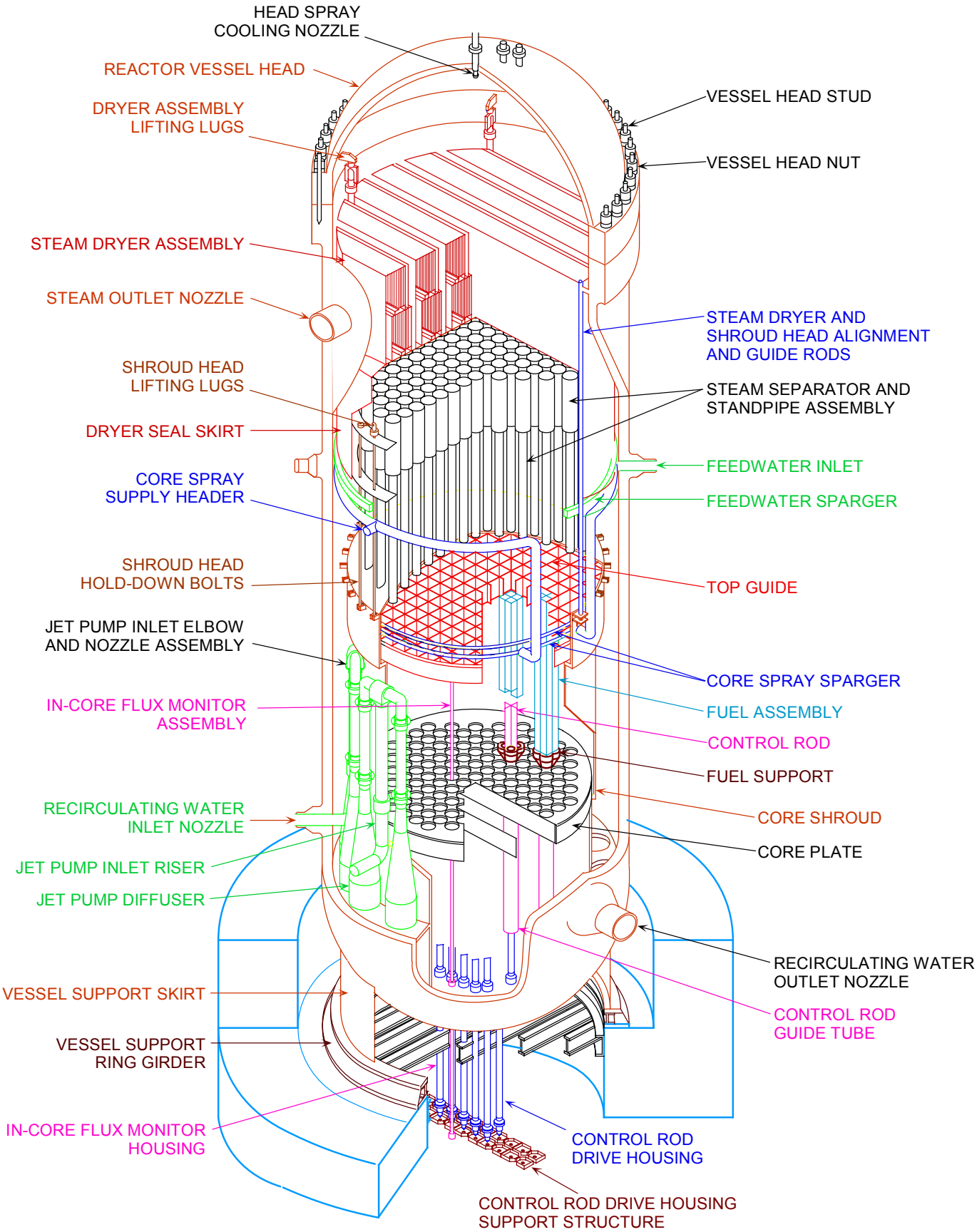

Figure 6.1-2 Reactor Vessel (BWR/3 or BWR/4)

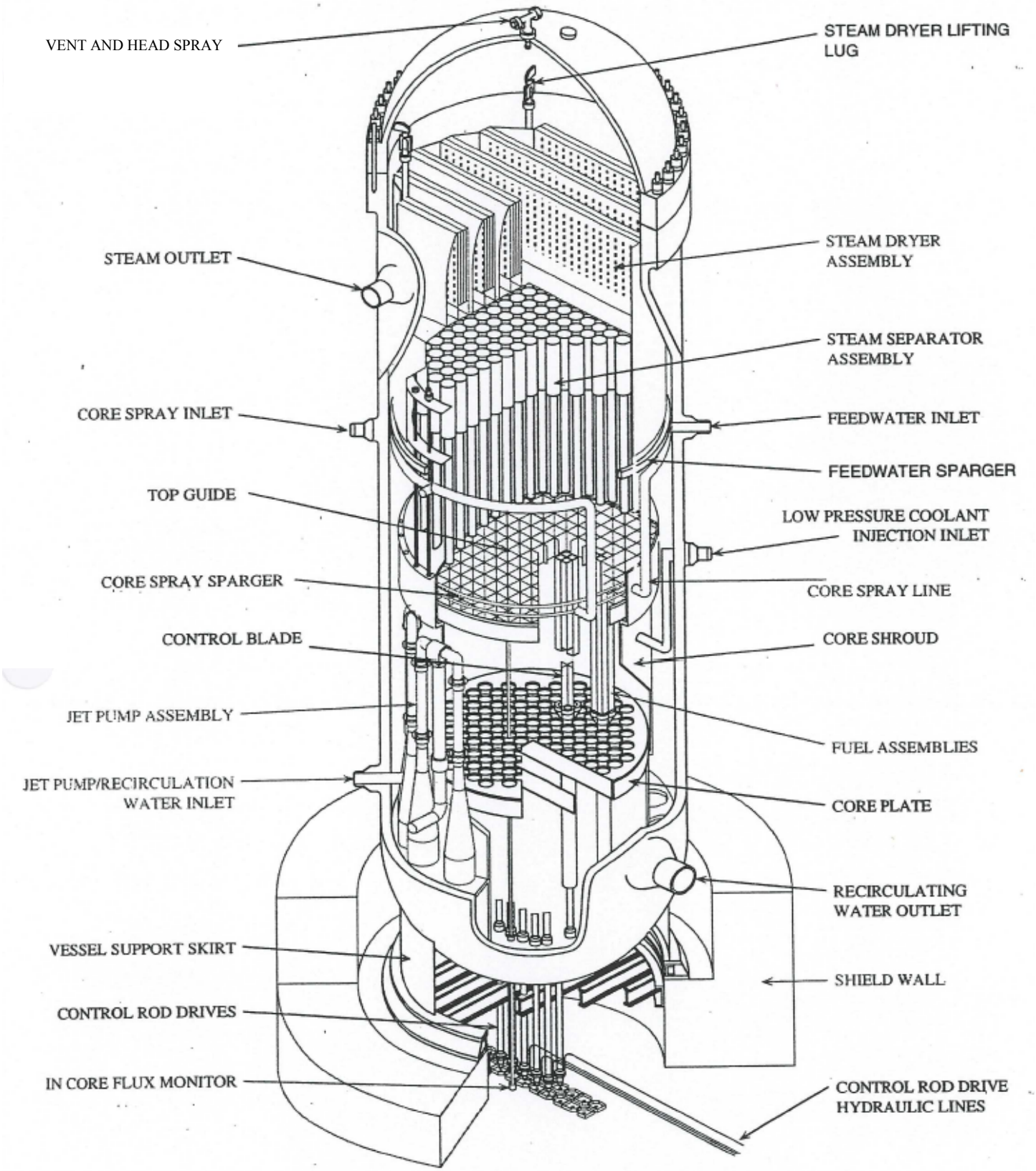

Figure 6.1-3 Reactor Vessel (BWR/5 or BWR/6)