Binding Energy per nucleon

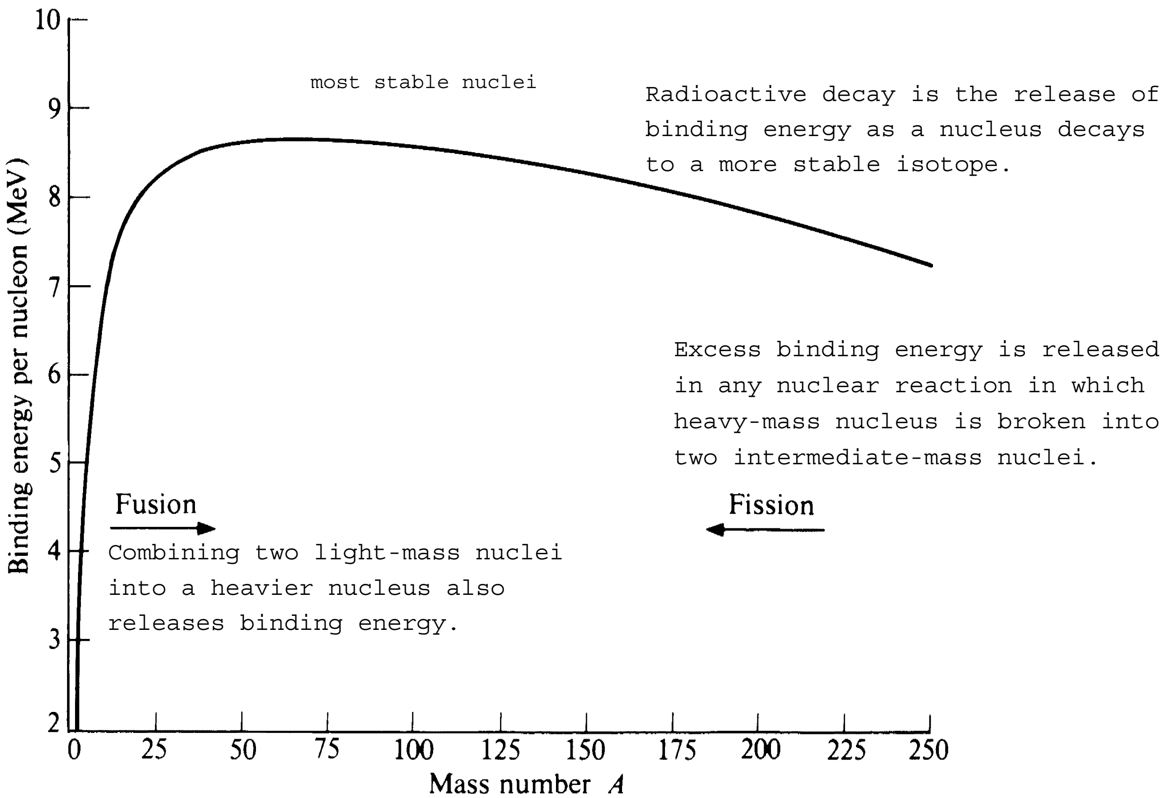


FIGURE 2.7
Variation of the binding energy per nucleon with the atomic mass. (*From Steam: Its Generation and Use, 1972.*)

Fission Probability

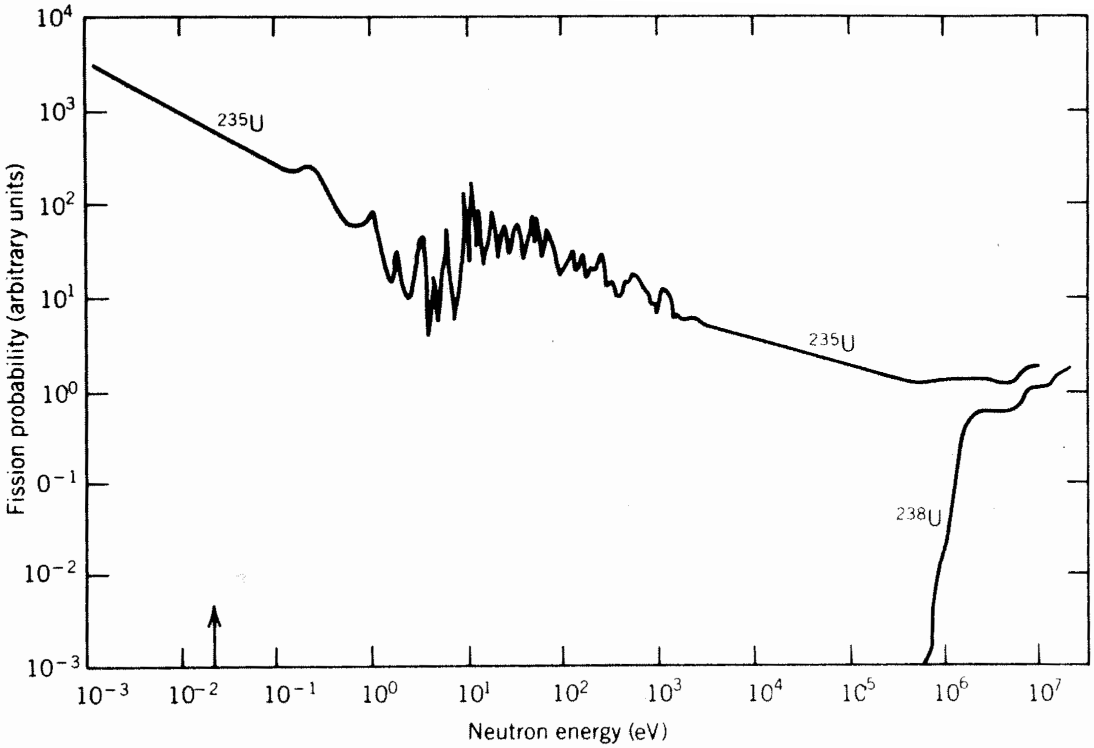
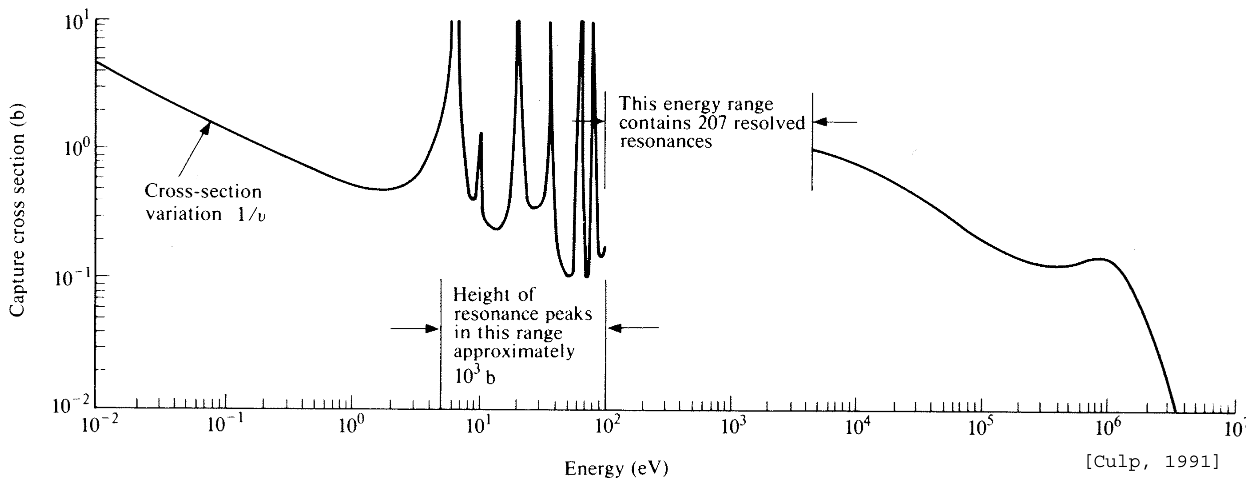


Figure 4.4 The fission probability for ^{235}U and ^{238}U as a function of neutron energy. The arrow at 0.025 eV indicates the energy of thermalized neutrons. For ^{238}U, the fission probability becomes appreciable only above 1 MeV neutron energy. [K&R, 1993]

Neutron Cross Section



[Culp, 1991]

FIGURE 3.2
The microscopic neutron-absorption cross section for U-238. (*From Steam: Its Generation and Use, 1972.*)

Types of Neutron Reactors

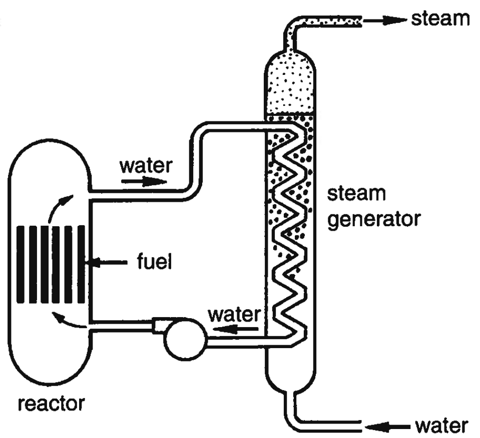


Figure 11.2. Pressurized water reactor (PWR).

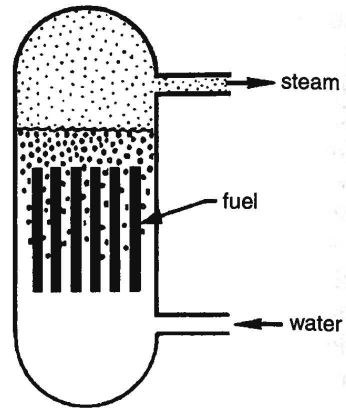


Figure 11.3. Boiling water reactor (BWR).

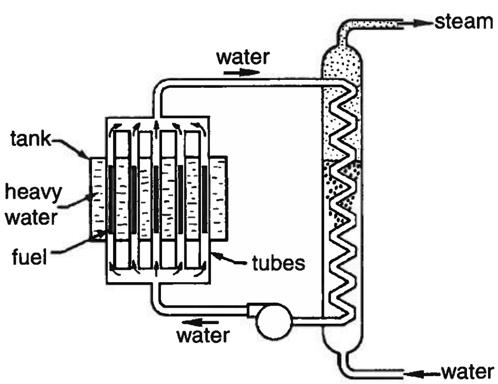


Figure 11.4. Heavy water reactor (HWR).

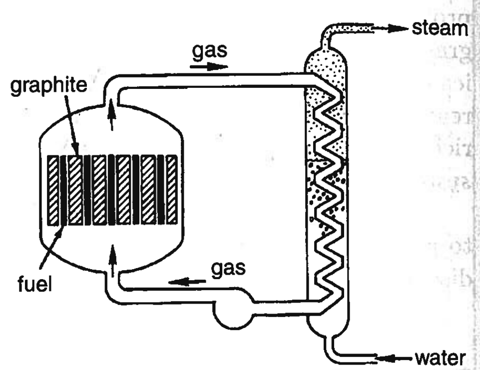


Figure 11.5. Gas cooled reactor (GCR).

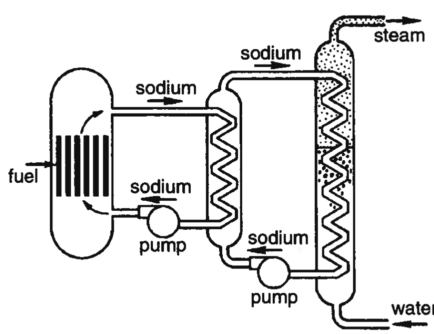


Figure 11.6. Liquid metal fast breeder reactor (LMFBR).

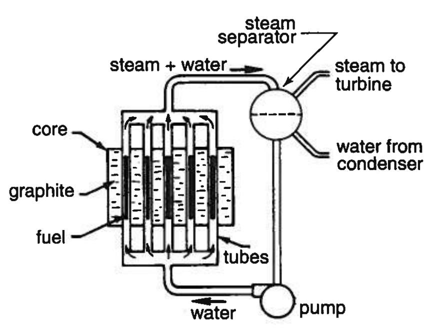


Figure 11.7. Graphite-moderated water-cooled reactor (RMBK).

Fundamentals of Nuclear Science and Engineering, 2nd ed., Shultis and Faw, CRC Press, 2008.

U.S. Nuclear Power Reactors

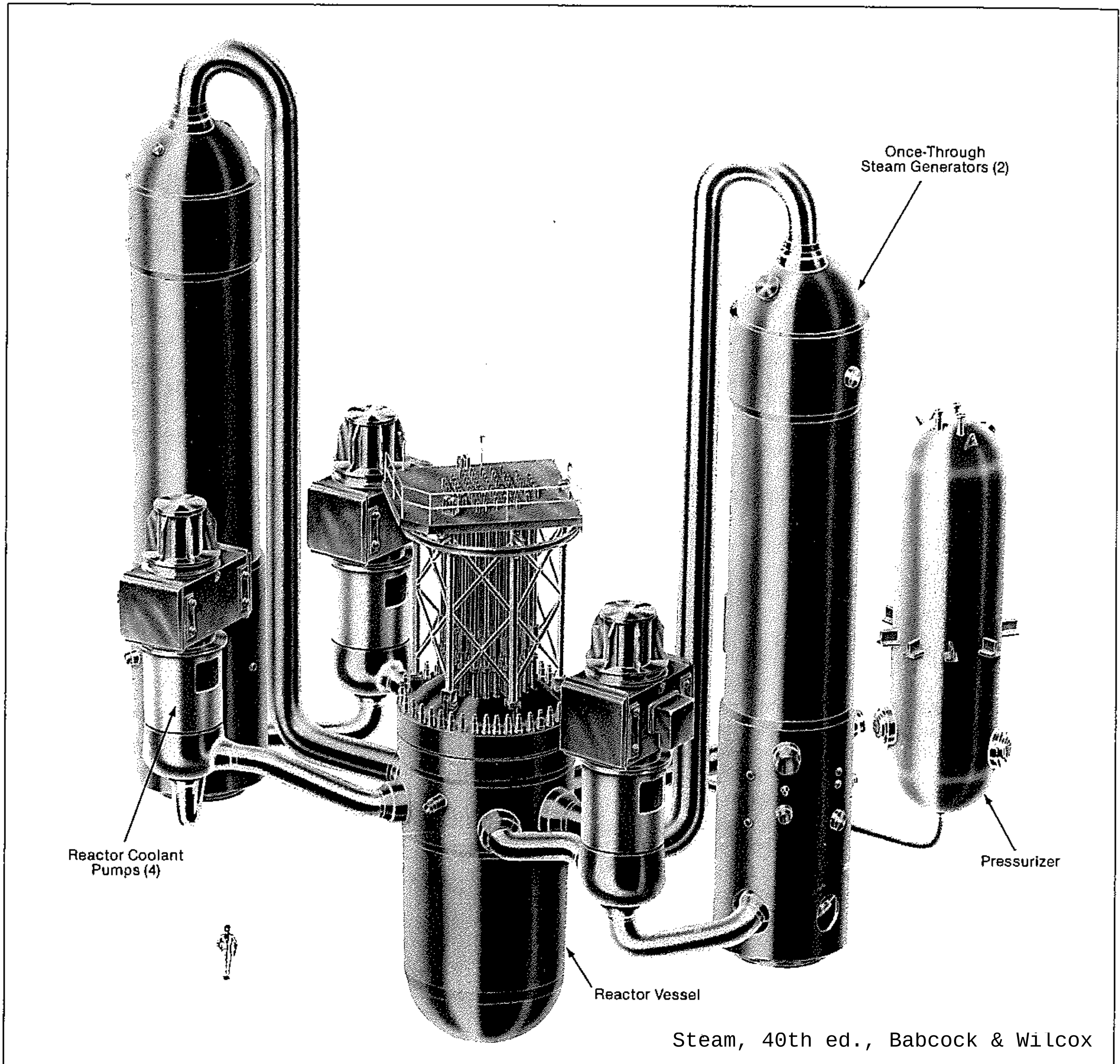


Fig. 3 B&W nuclear steam supply system.

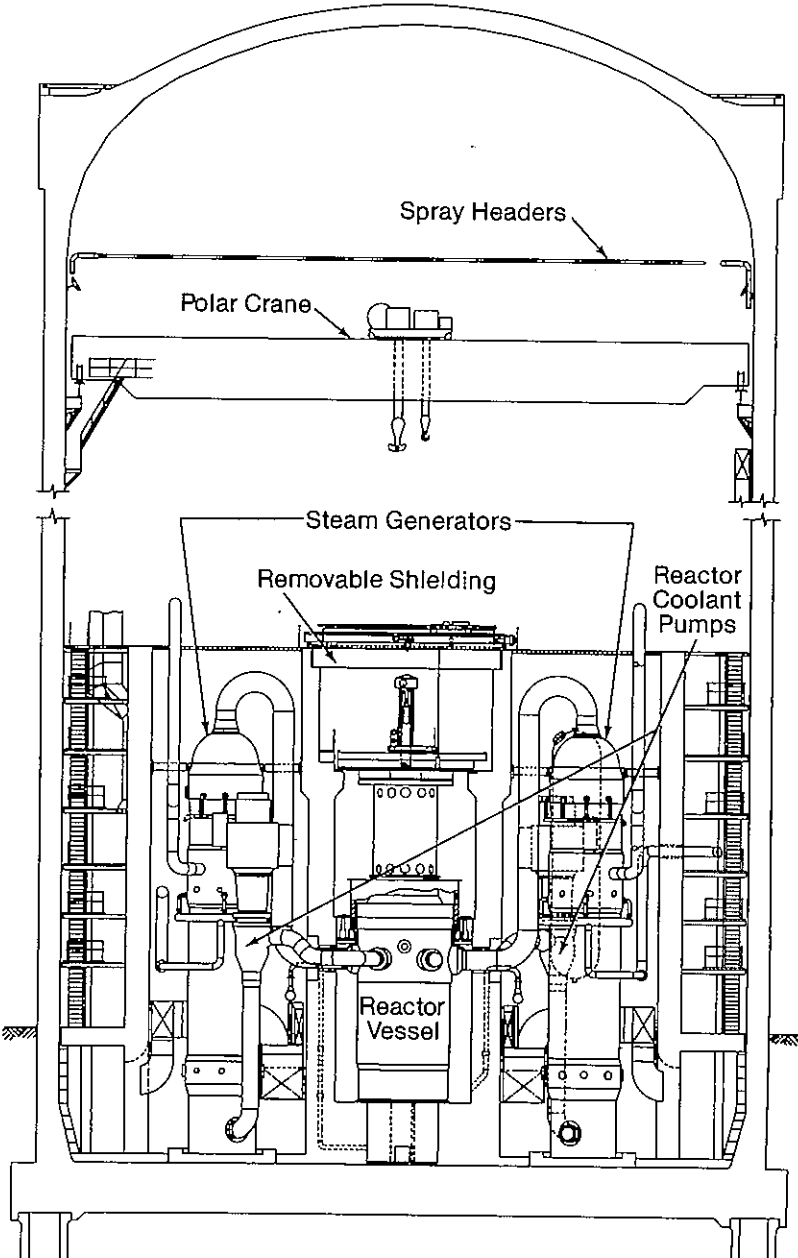


Fig. 2 PWR containment building, sectional view.

Steam, 40th ed., Babcock & Wilcox

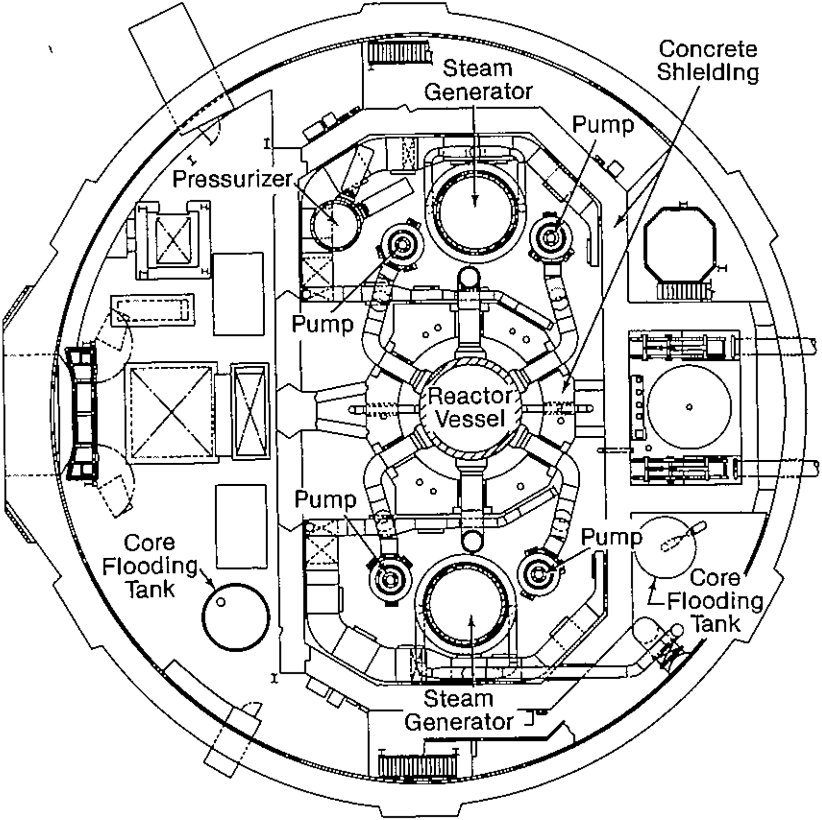


Fig. 4 Reactor containment building, ground floor plan view.

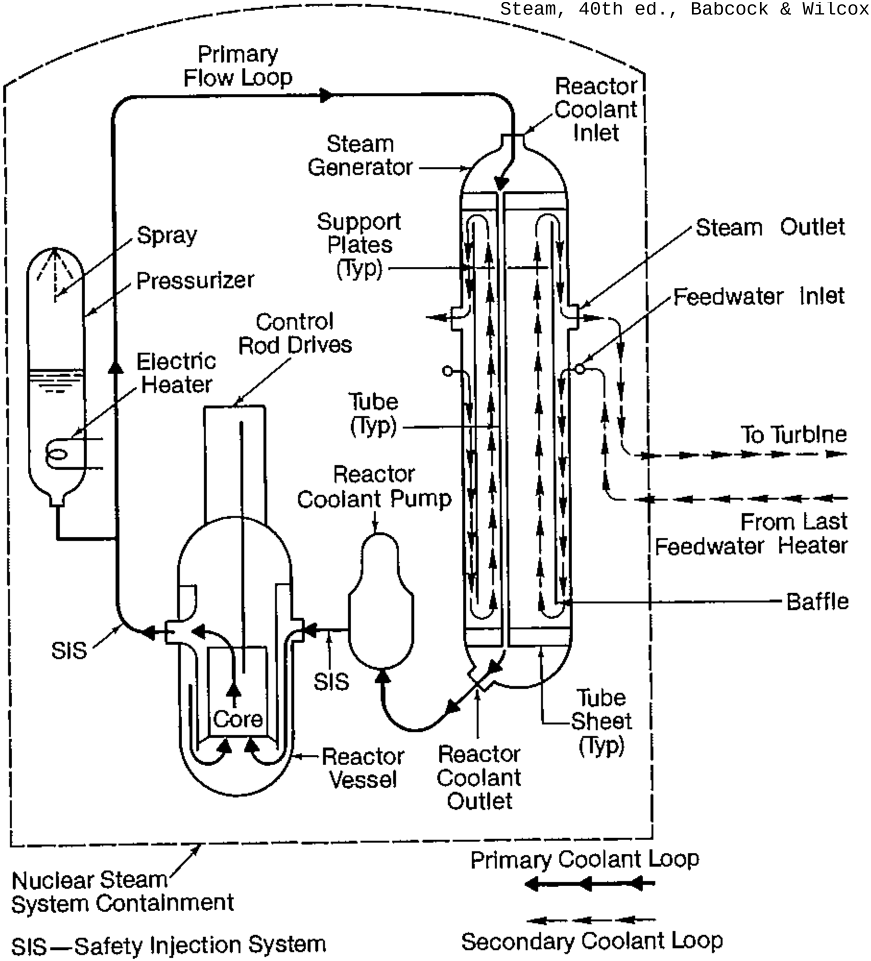
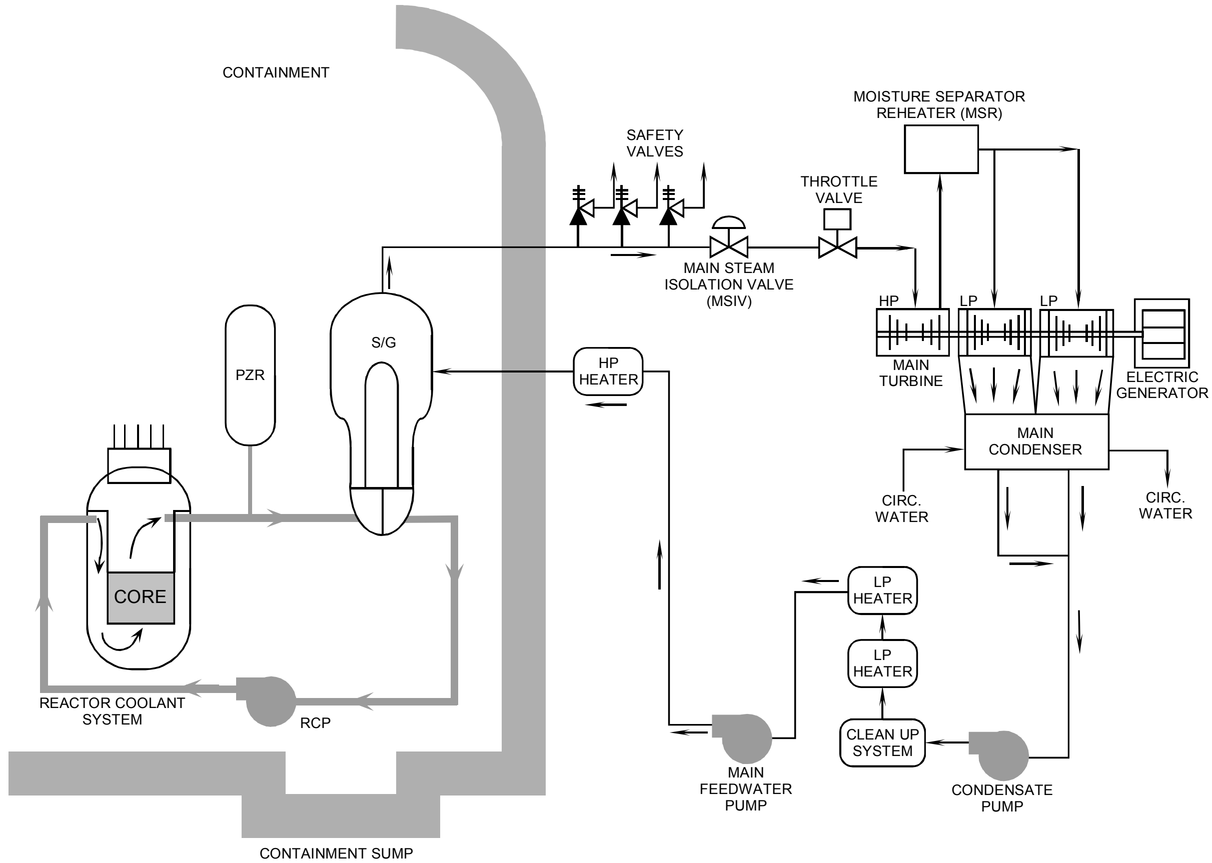


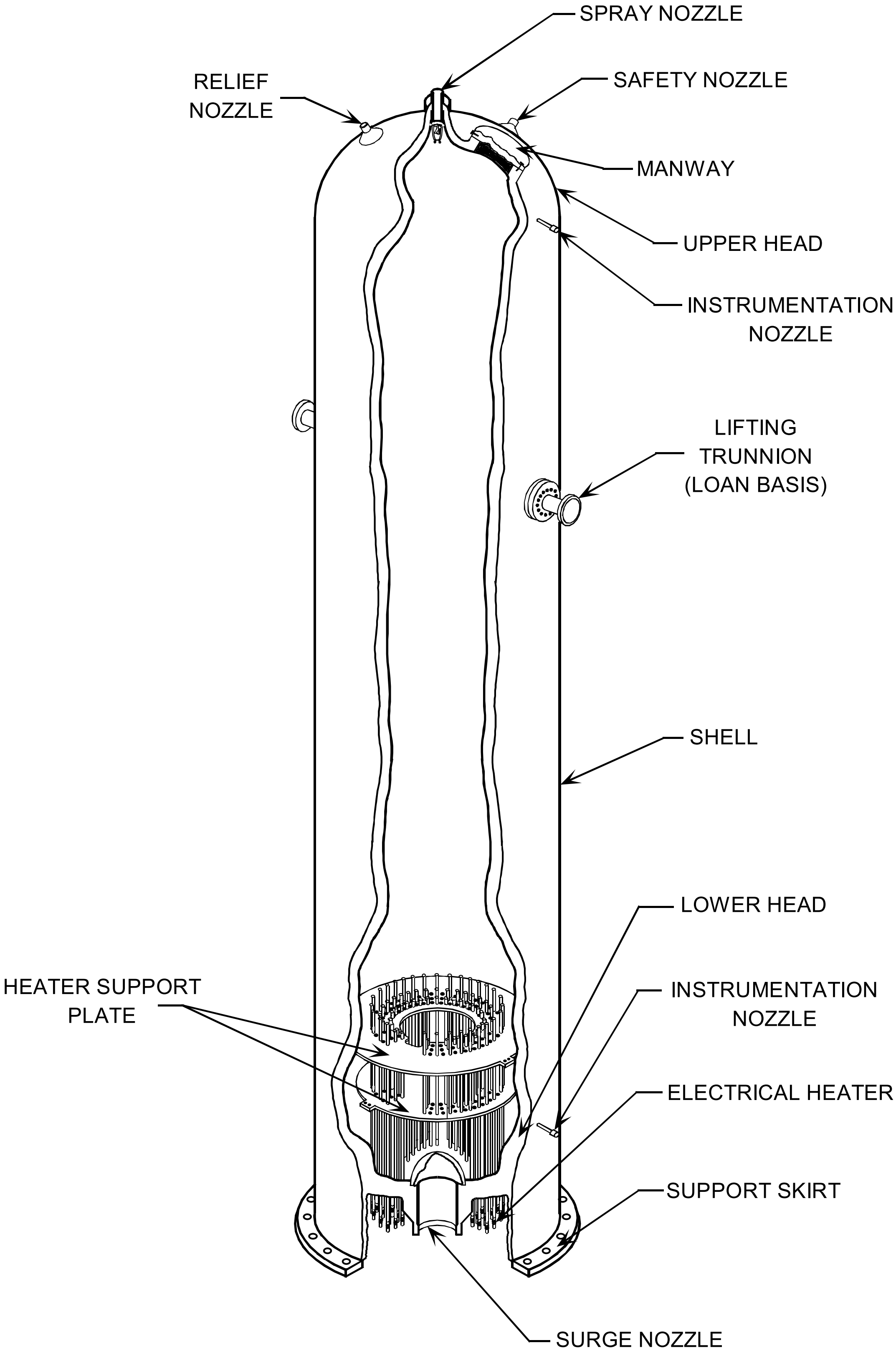
Fig. 5 Simplified schematic of primary and secondary loops.



The major secondary systems of a pressurized water reactor are the main steam system and the condensate/feedwater system. Since the primary and secondary systems are physically separated from each other (by the steam generator tubes), the secondary system will contain little or no radioactive material.

The main steam system starts at the outlet of the steam generator. The steam is routed to the high pressure main turbine. After passing through the high pressure turbine, the steam is piped to the moisture separator/reheaters (MSRs). In the MSRs, the steam is dried with moisture separators and reheated using other steam as a heat source. From the MSRs, the steam goes to the low pressure turbines. After passing through the low pressure turbines, the steam goes to the main condenser, which is operated at a vacuum to allow for the greatest removal of energy by the low pressure turbines. The steam is condensed into water by the flow of circulating water through the condenser tubes.

At this point, the condensate/feedwater system starts. The condensed steam collects in the hotwell area of the main condenser. The condensate pumps take a suction on the hotwell to increase the pressure of the water. The condensate then passes through a cleanup system to remove any impurities in the water. This is necessary because the steam generator acts as a concentrator. If the impurities are not removed, they will be left in the steam generator after the steam forming process, and this could reduce the heat transfer capability of the steam generator and/or damage the steam generator tubes. The condensate then passes through some low pressure feedwater heaters. The temperature of the condensate is increased in the heaters by using steam from the low pressure turbine (extraction steam). The condensate flow then enters the suction of the main feedwater pumps, which increases the pressure of the water high enough to enter the steam generator. The feedwater now passes through a set of high pressure feedwater heaters, which are heated by extraction steam from the high pressure turbine (heating the feedwater helps to increase the efficiency of the plant). The flow rate of the feedwater is controlled as it enters the steam generators.



Cutaway View of a Pressurizer

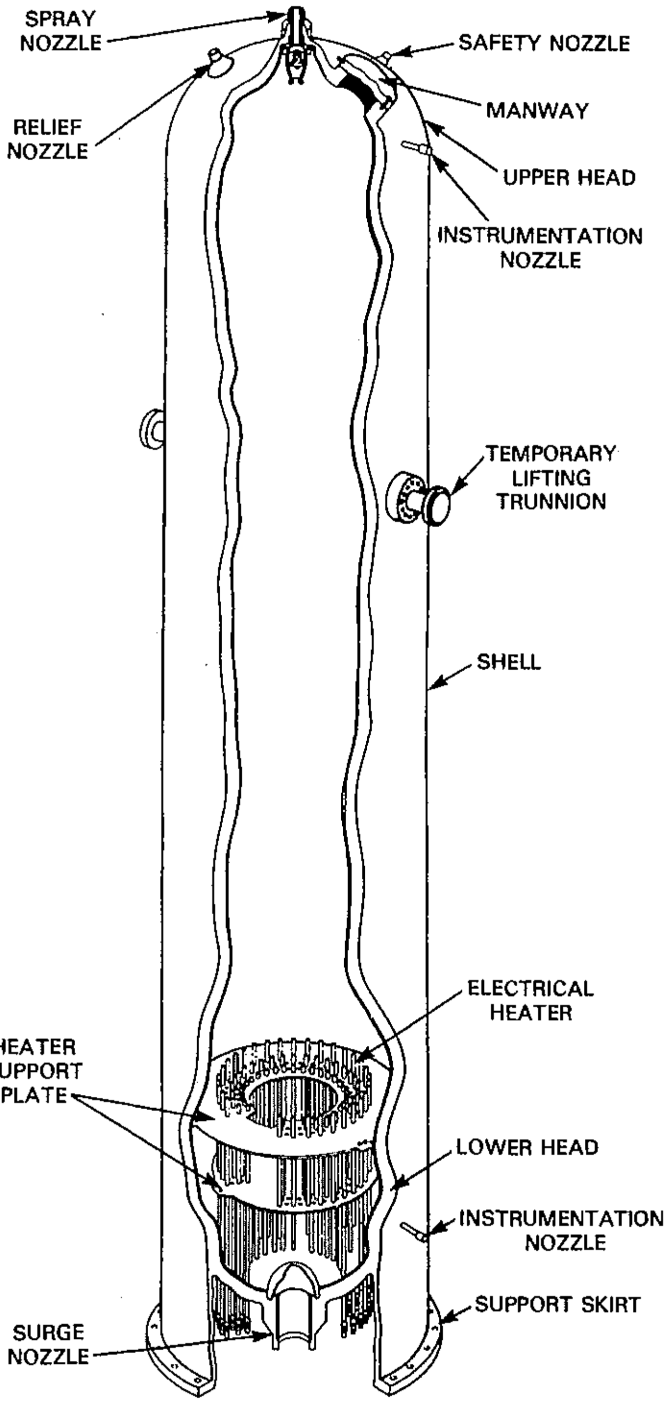
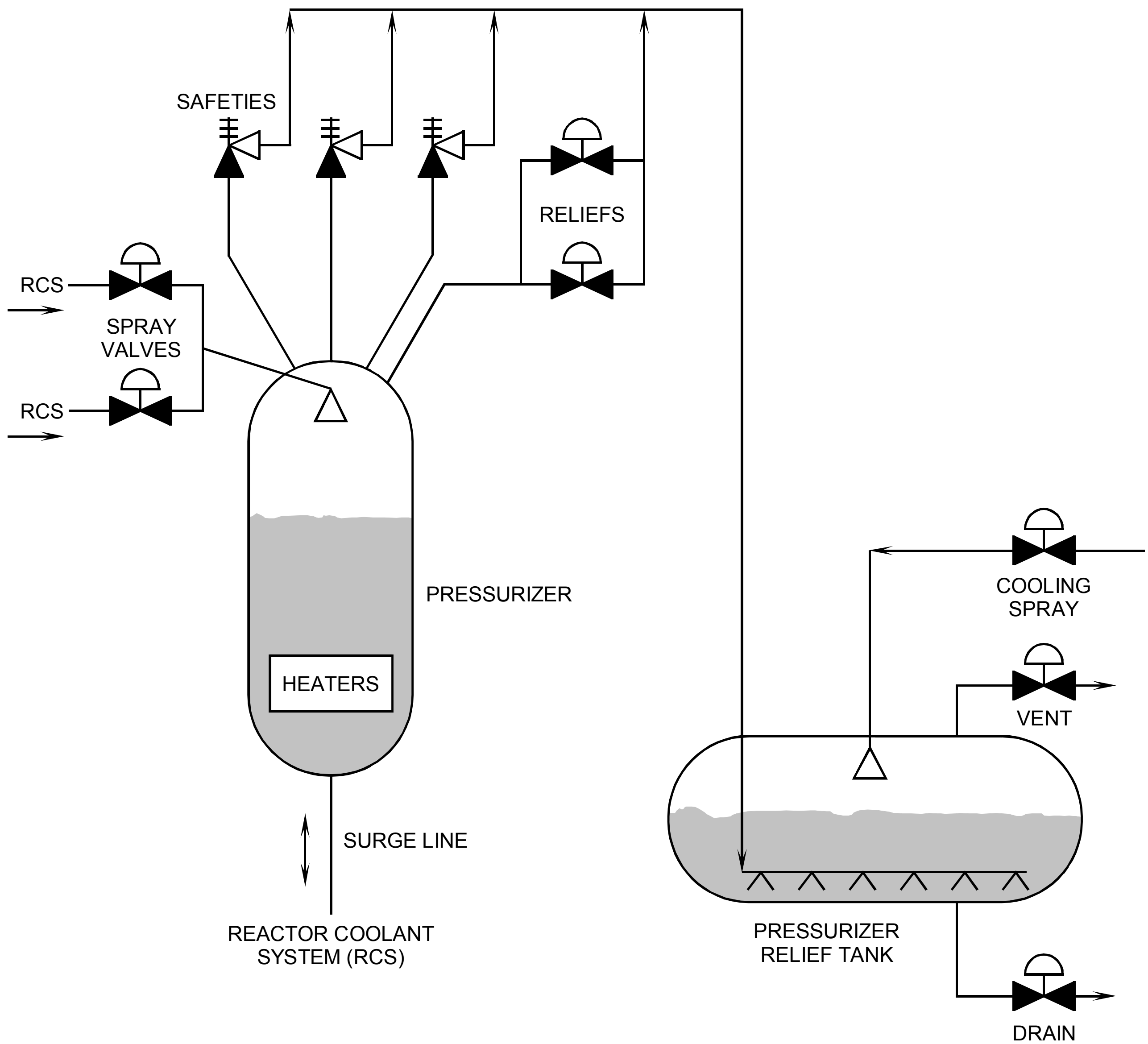


Fig. 23-12. Pressurizer for a large PWR design. (From Westinghouse. Used with permission.)



Pressurizer and Pressurizer Relief Tank

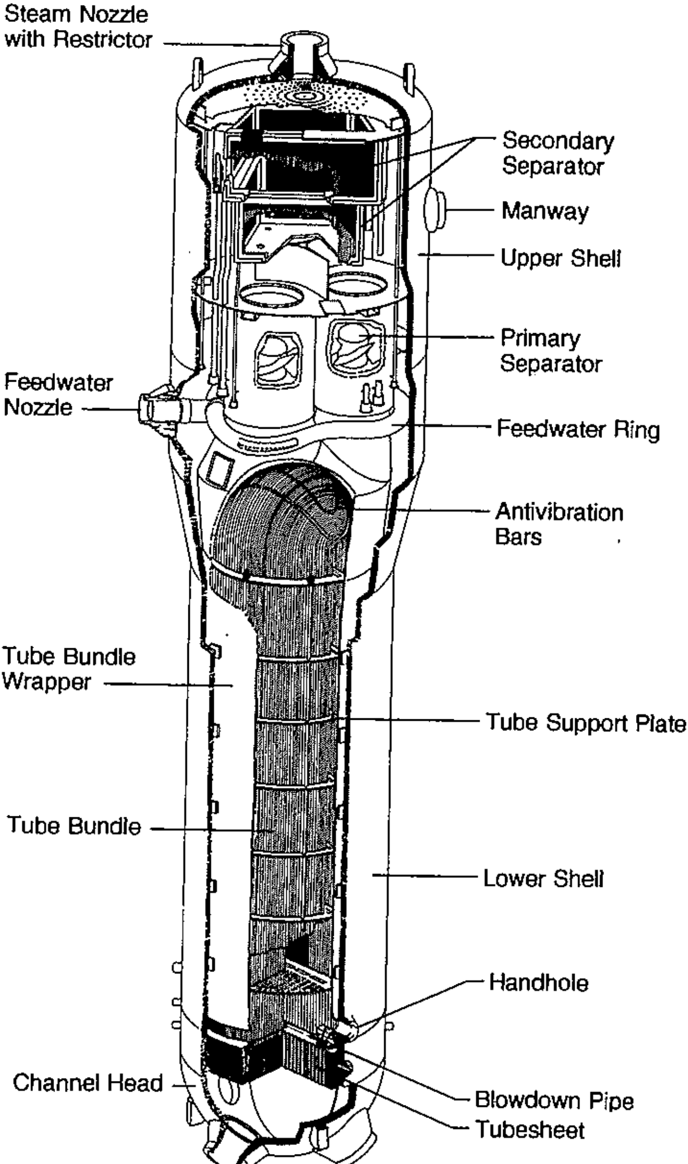


Fig. 23-11. Steam generator for a large PWR. (From Westinghouse. Used with permission.)

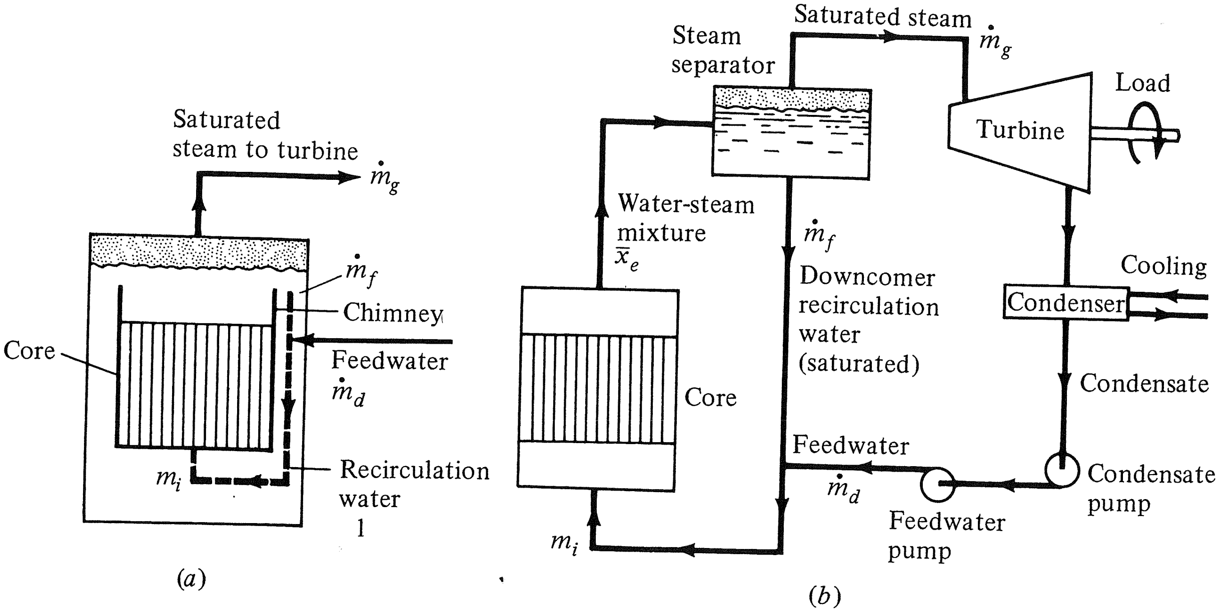


Figure 10-15 Schematic of a BWR system: (*a*) internal and (*b*) external recirculation.

10-8 BWR LOAD FOLLOWING CONTROL

The *recirculation control* method is based on a direct cycle but with variable recirculation flow in the downcomer. It is shown schematically in Fig. 10-17. Equation (10-17) is rewritten with the help of Eqs. (10-8*a*) and (10-9) as

$$Q_t = \bar{x}_e \dot{m}_i (h_g - h_d) \tag{10-18}$$

h_g, the saturated steam enthalpy at the system pressure, and h_d, the feedwater enthalpy, are both weak functions of load. Thus the plant load Q_t is therefore proportional to the product of $\bar{x}_e$ and $\dot{m}_i$, the flow in the downcomer.

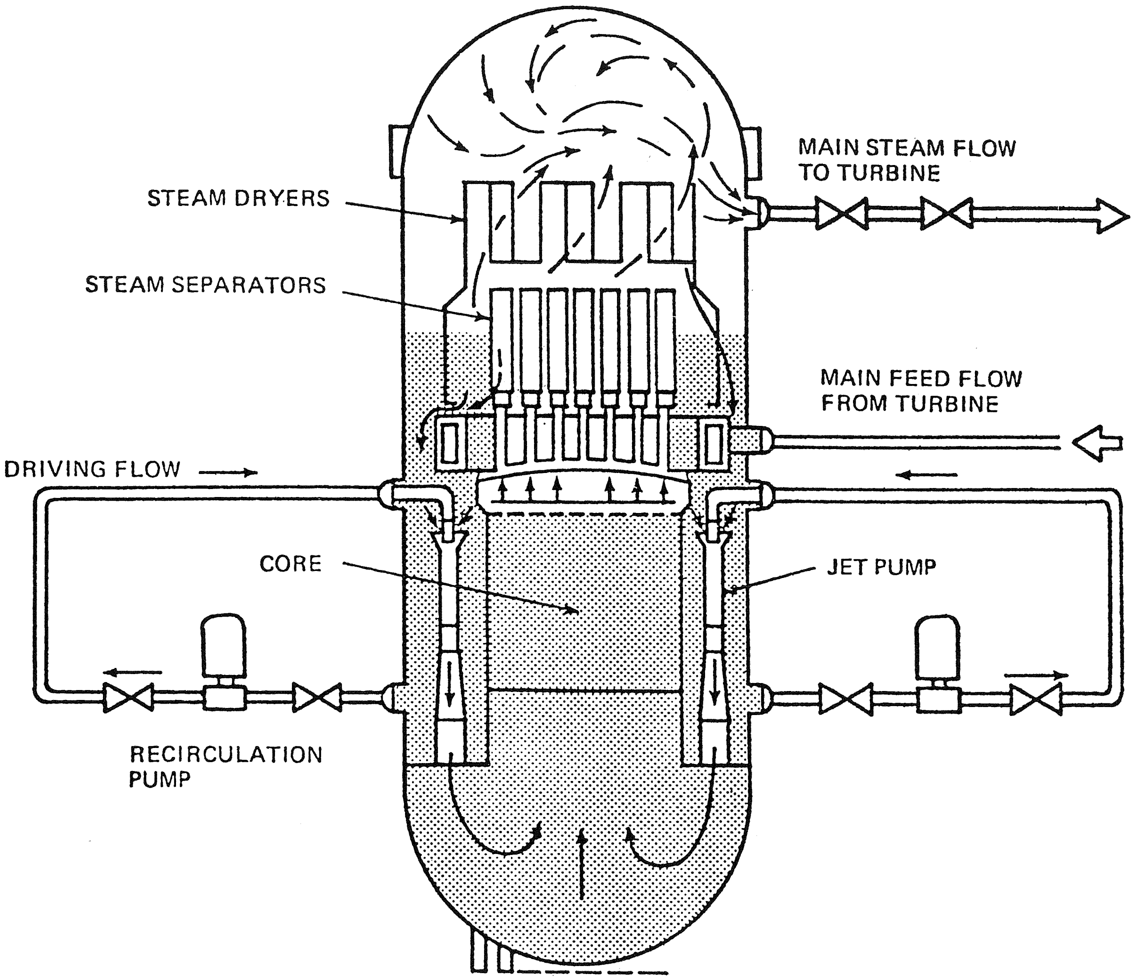
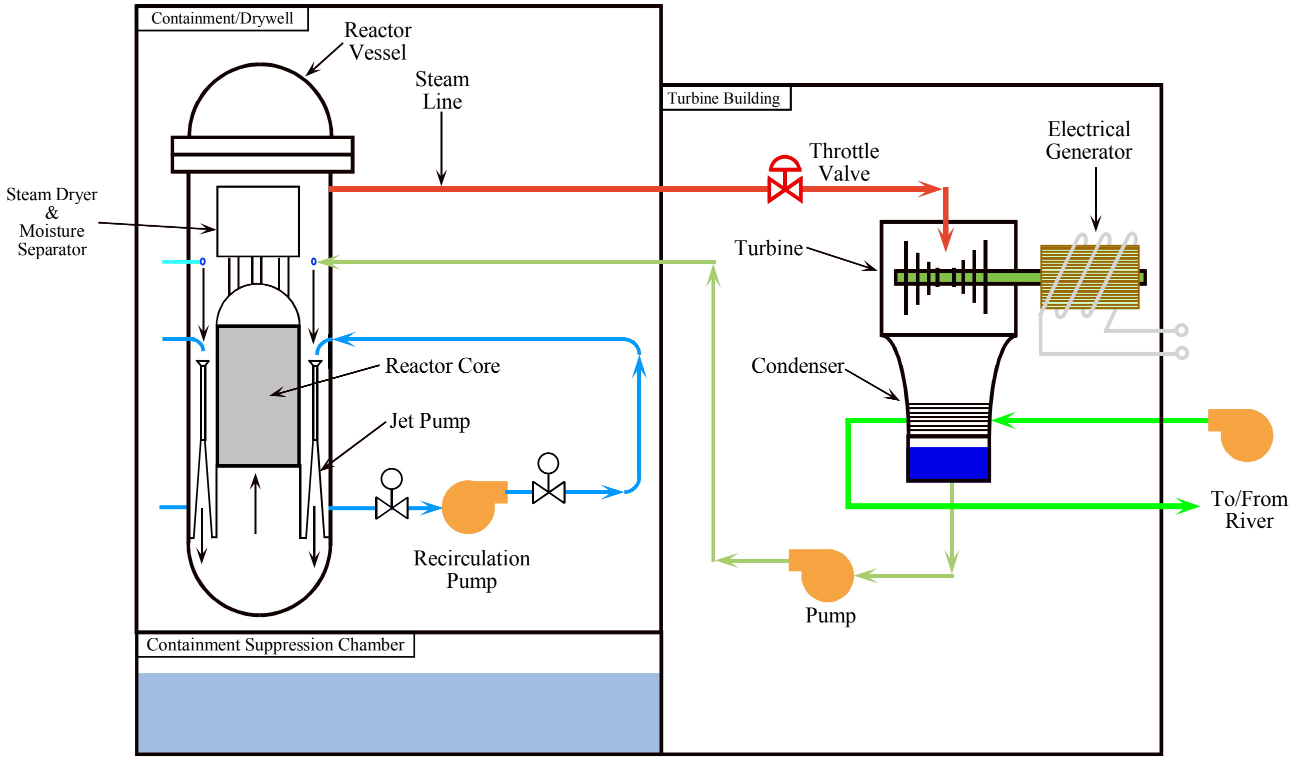
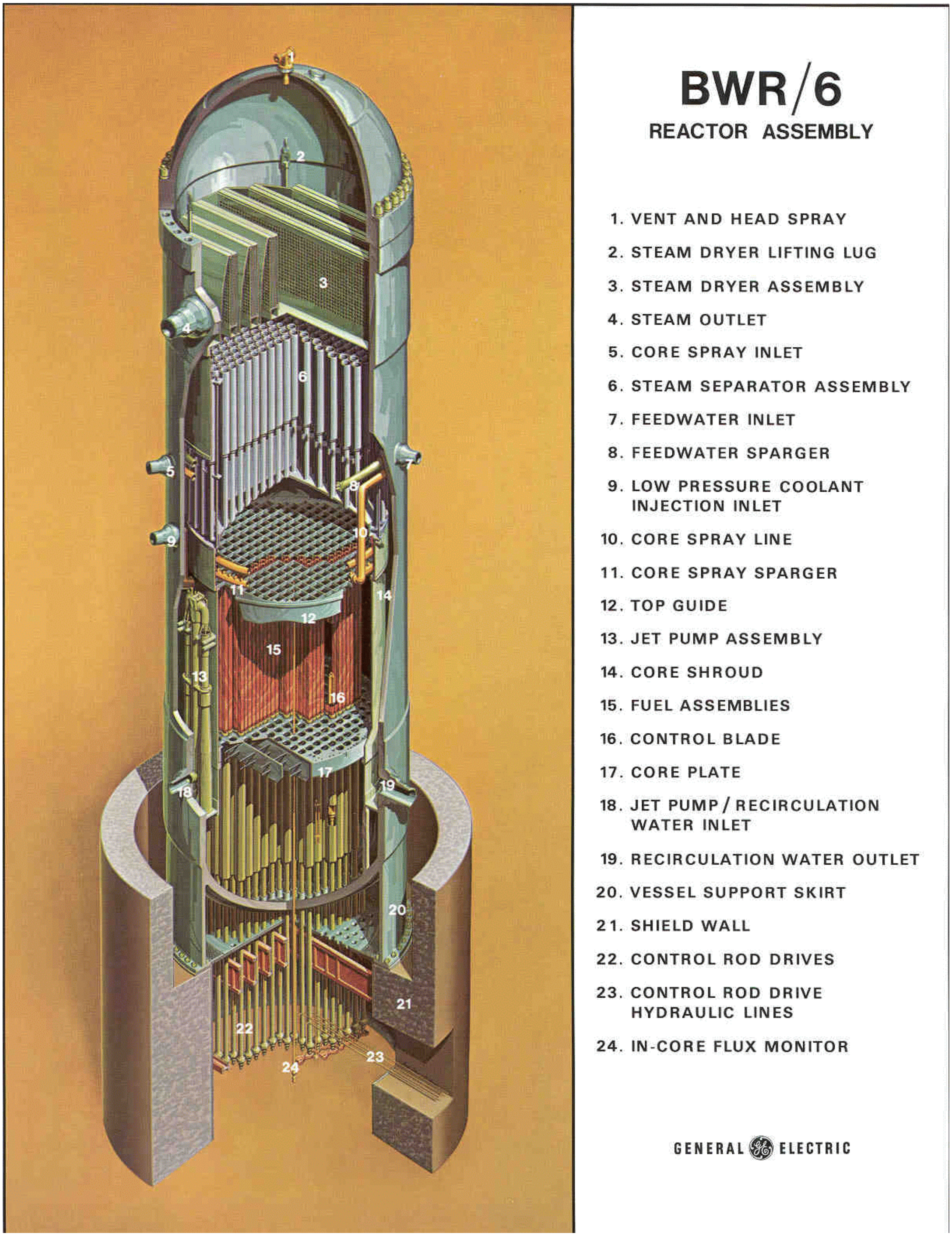


Figure 10-17 BWR reactor vessel internal flow paths.



Boiling Water Reactor Plant

Inside the boiling water reactor (BWR) vessel, a steam water mixture is produced when very pure water (reactor coolant) moves upward through the core absorbing heat. The major difference in the operation of a BWR from other nuclear systems is the steam void formation in the core. The steam-water mixture leaves the top of the core and enters the two stages of moisture separation, where water droplets are removed before the steam is allowed to enter the steam line. The steam line, in turn, directs the steam to the main turbine causing it to turn the turbine and the attached electrical generator. The unused steam is exhausted to the condenser where it is condensed into water. The resulting water is pumped out of the condenser with a series of pumps and back to the reactor vessel. The recirculation pumps and jet pumps allow the operator to vary coolant flow through the core and change reactor power.



BWR 6 Reactor Vessel

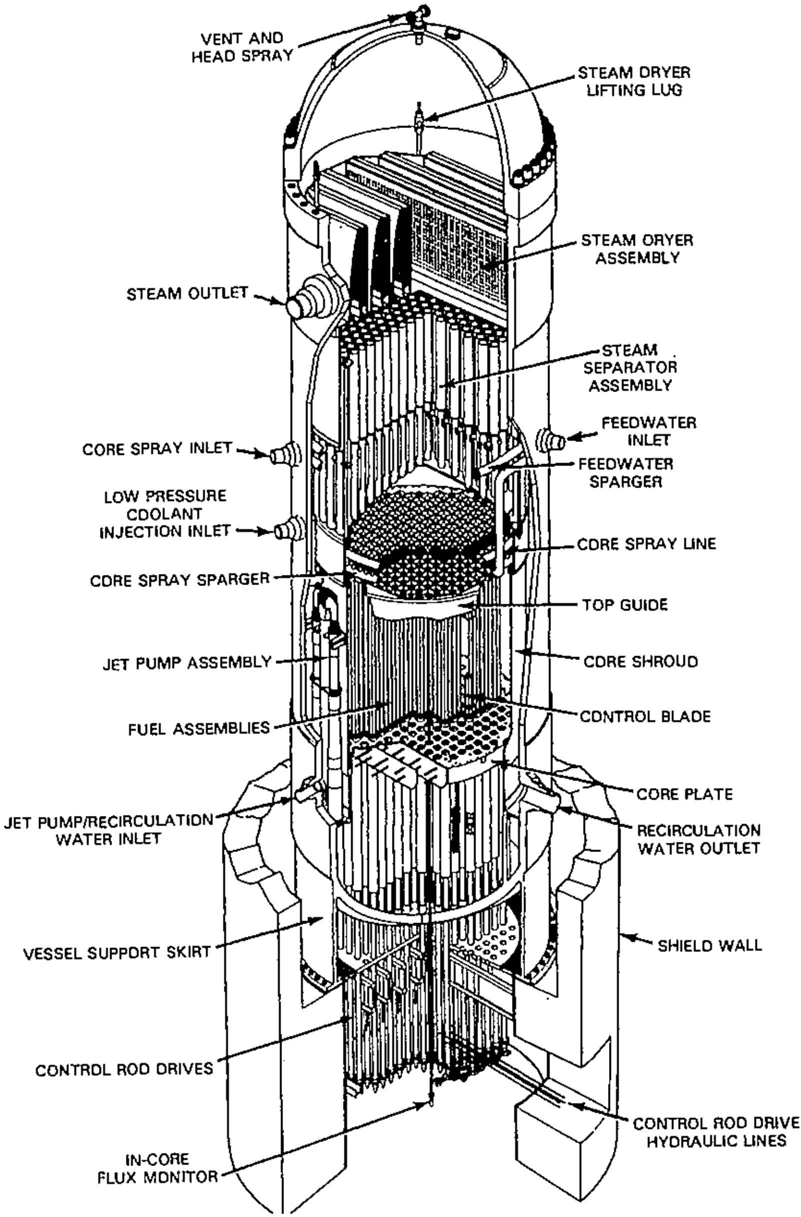


Fig. 23-15. Pressure vessel for a BWR. (From General Electric Company. Used with permission.)