NUCL 402 Engineering of Nuclear Power Systems

Lecture 2: PWR and BWR

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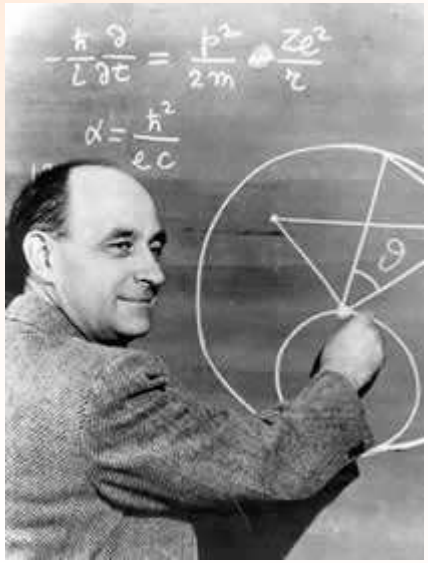
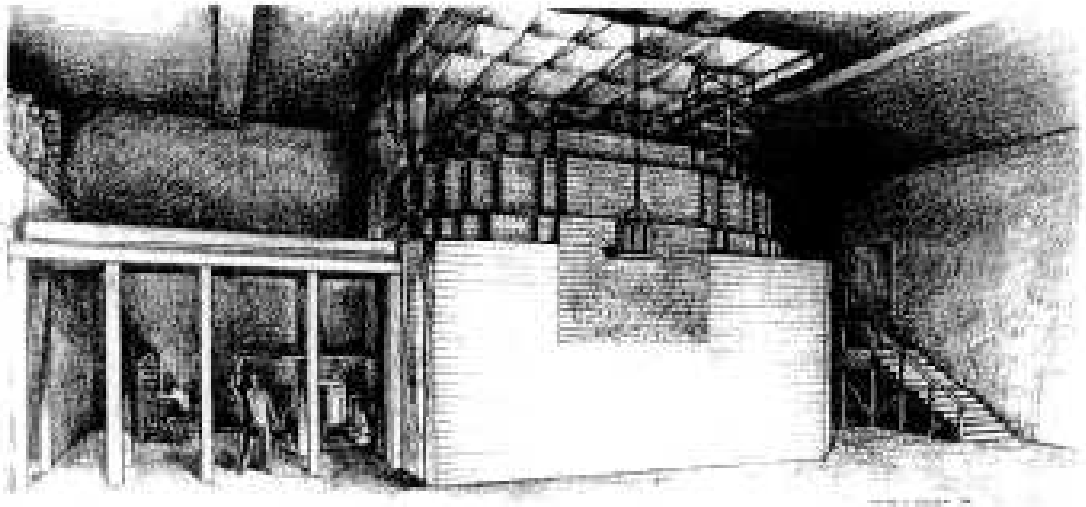
Power Reactor History

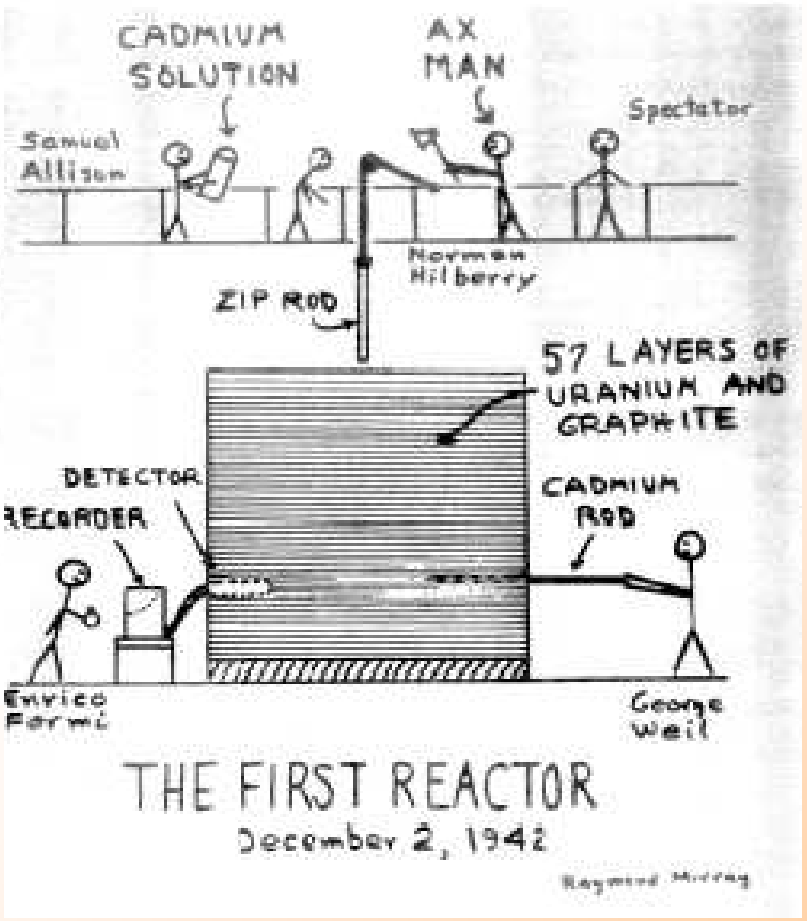
•**1942** December 2 -- Enrico Fermi's team produces the world's first sustained nuclear chain reaction.
•**1943** March 20 -- Chicago Pile 2 achieves criticality.
•**1944** May 15 -- Walter Zinn starts Chicago Pile 3, the world's first heavy-water-moderated nuclear reactor,
•**1946** August 1 -- Pres. Harry Truman signs the Atomic Energy Act.
•**1952** EBR-1 first demonstration of nuclear-generated electricity .



Chicago Pile 1 (CP-1)



Drawing depicting CP-1. (Courtesy of Argonne National Laboratory)



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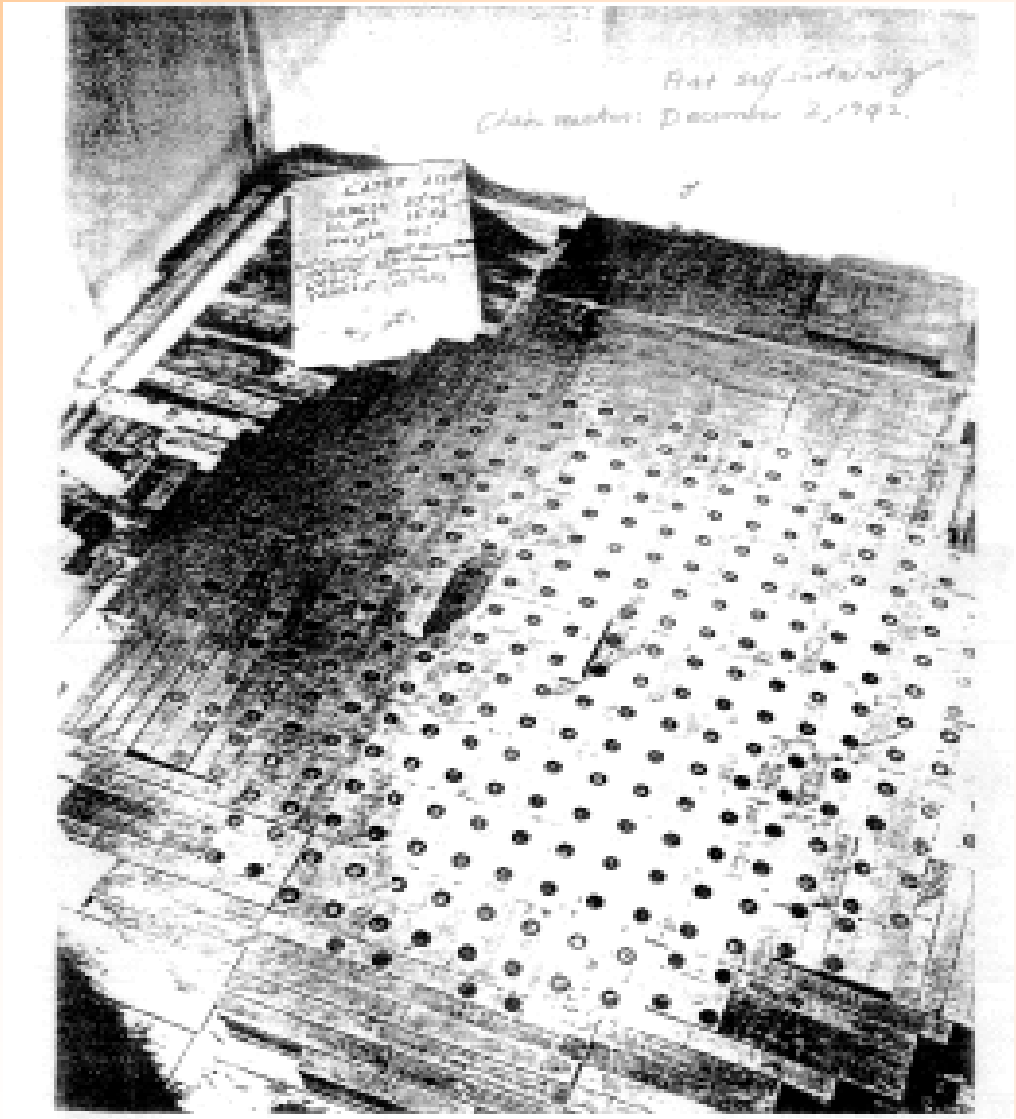
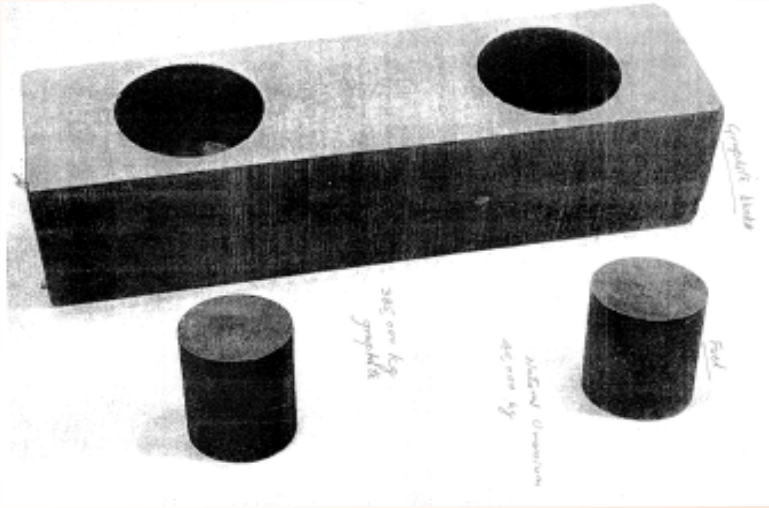
CP-1



CP-1 during construction, showing the pattern of graphite blocks and uranium pellets. (Courtesy of Argonne National Laboratory)



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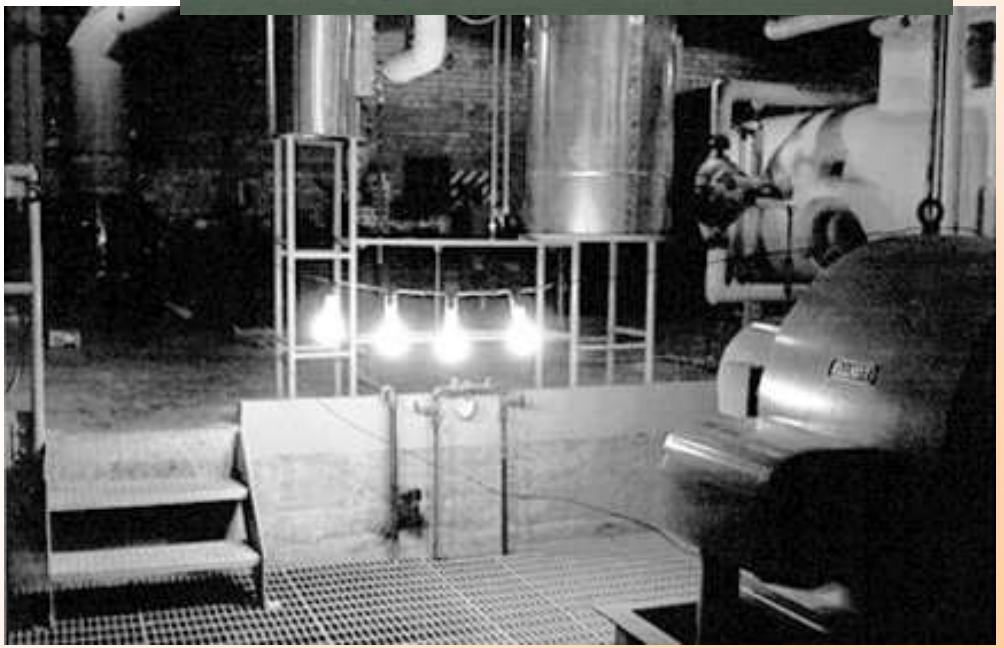
Experimental Breeder Reactor -1 (EBR -1)

- Located at the National Reactor Testing Station in Idaho, was completed and was operated by Argonne National Laboratory.
- In the first demonstration of nuclear-generated electricity in the United States, 4 light bulbs were powered.

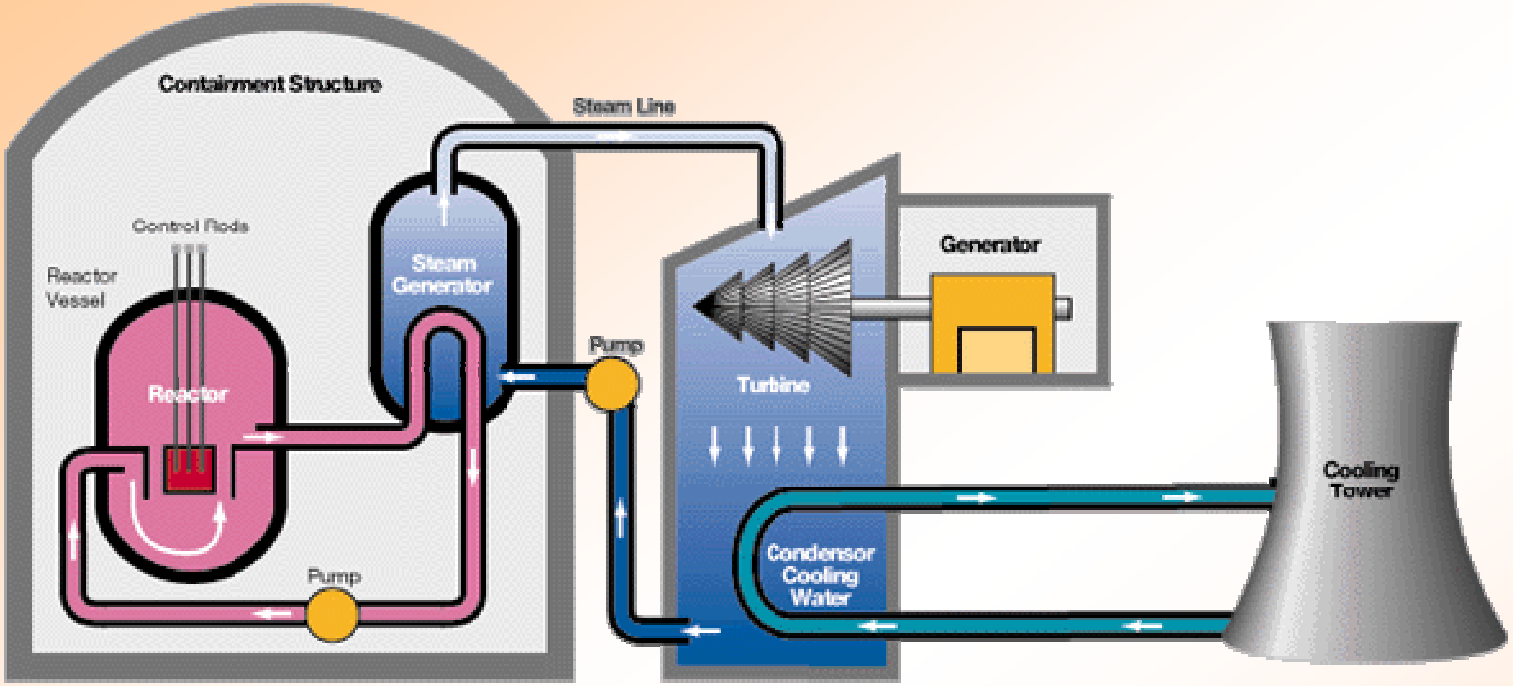


During the 1960's, a number of smaller prototype reactors were designed and operated by utilities and/or government agencies.

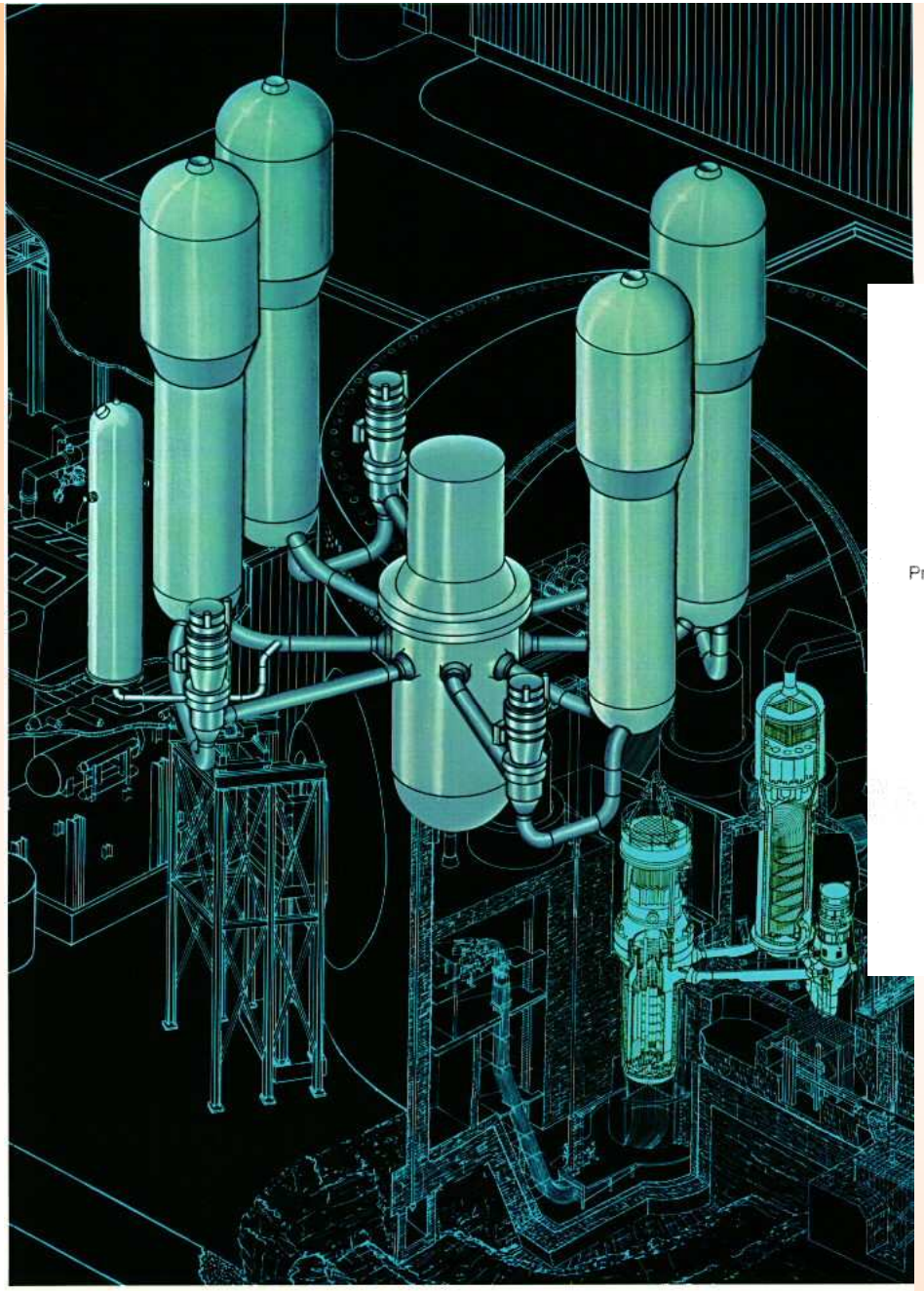
Year	Unit	MWe	Utility	Reactor Type	Shutdown
1957	Shippingport	60	Duquesne Light	PWR / LWBR	1982
1960	Dresden 1	200	Commonwealth Edison	BWR	1978
1961	Yankee Rowe	160	Yankee Atomic	PWR	1991
1962	Big Rock Point	60	Consumers Power	BWR	1997
1963	Indian Point 1	250	Consolidated Edison	PWR	1974
1963	Humboldt Bay 3	60	PG&E	BWR	1976
1963	Hallam	75		LMGMR	1964
1964	BONUS	70		BWR	1968
1966	Fermi 1	60	Detroit Edison	LMFBR	1978
1966	Hanford-N	860	AEC/WPPSS	LGR	1988
1966	Pathfinder	60	Northern States Power	BWR	1967
1967	Peach Bottom 1	40	Philadelphia Electric	HTGR	1974
1969	LaCrosse	50	Dairyland Power	BWR	1987

Pressurized Water Reactor (PWR)

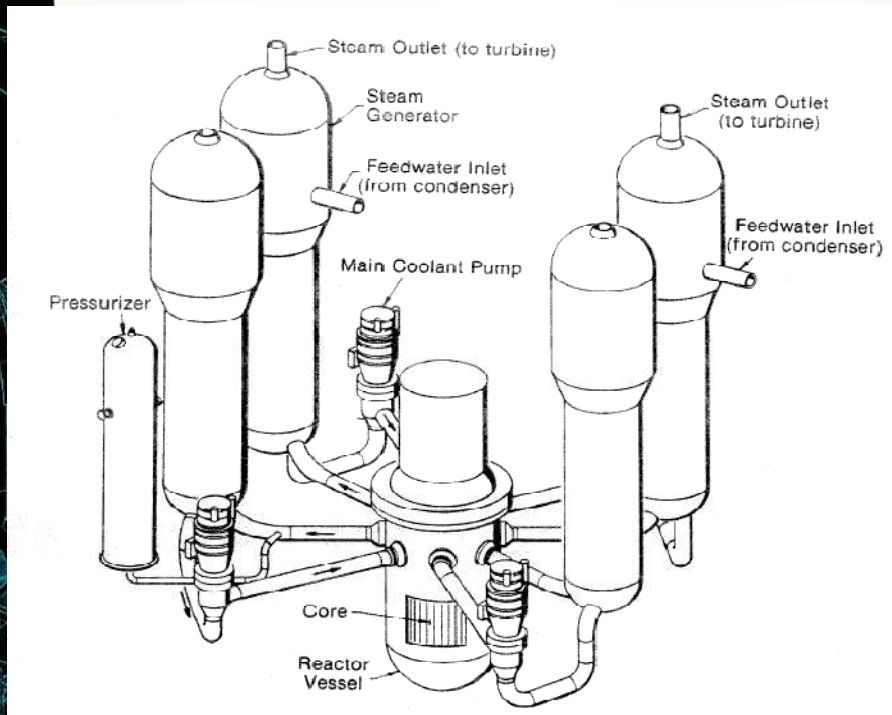
These reactors were originally designed by Westinghouse Bettis Atomic Power Laboratory for military ship applications, then by the Westinghouse Nuclear Power Division for commercial applications. The first commercial PWR plant in the United States was Shippingport, which operated for Duquesne Light until 1982. In addition to Westinghouse, Asea Brown Boveri-Combustion Engineering (ABB-CE), Framatome, Kraftwerk Union, Siemens, and Mitsubishi have typically built this type of reactor throughout the world. Babcock & Wilcox (B&W) built a PWR design power plant but used vertical once-through steam generators, rather than the U-tube design used by the rest of the suppliers. Industry consolidation has occurred so that Framastom-ANP and Westinghouse are two key remaining manufacturers.



- ✓ Reactor Coolant System-2, 3, or 4 Cooling "Loops" connected to the Reactor, each containing a Reactor Coolant Pump, and Steam Generator
- ✓ Secondary Cooling System-include the Main Steam System and the Condensate-Feedwater Systems
- ✓ Condenser Cooling Water pumped through the condenser by Circulating Water Pumps, cean, sea, lake, river, or Cooling Tower



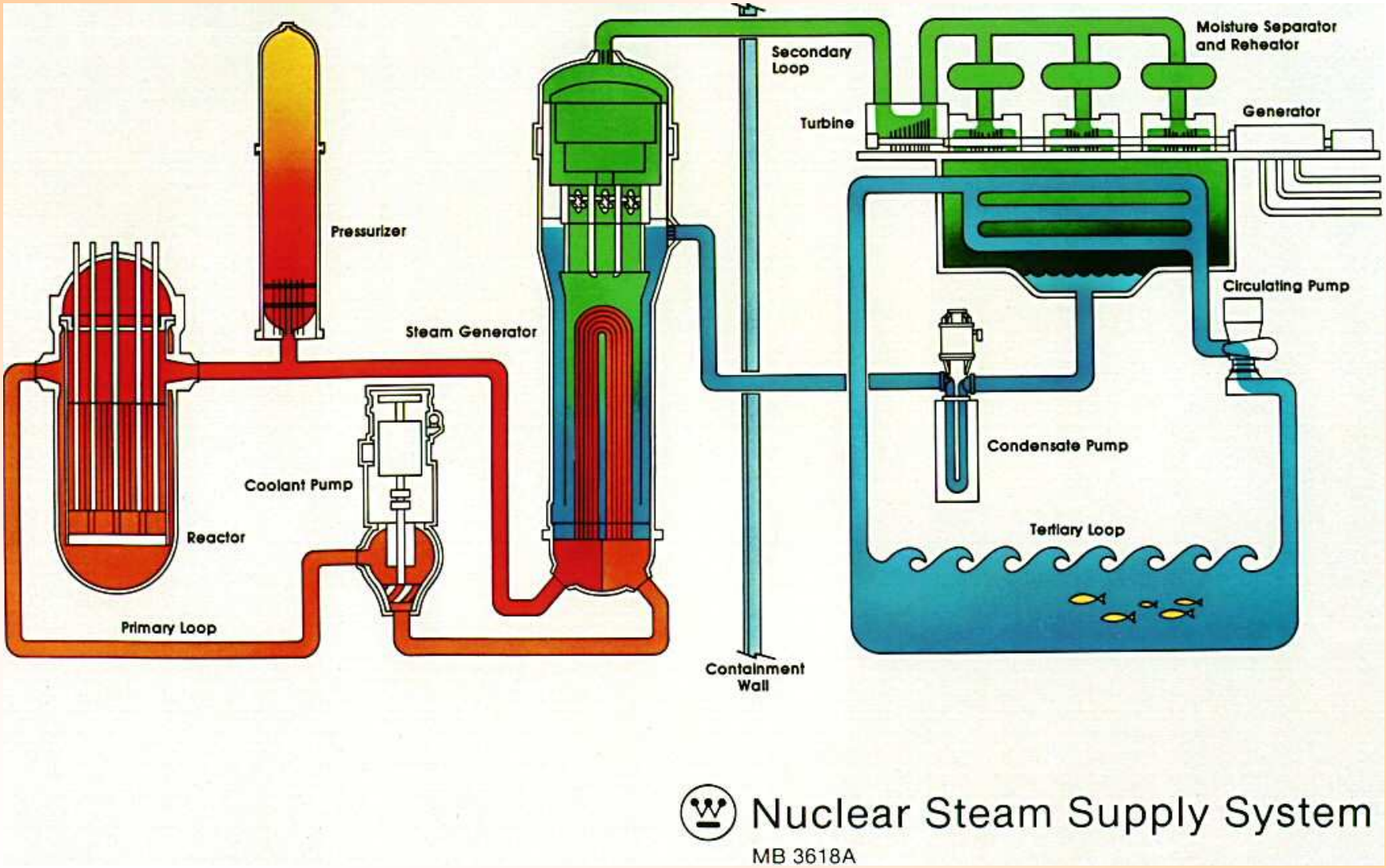
Westinghouse NUCLEAR STEAM SUPPLY SYSTEM



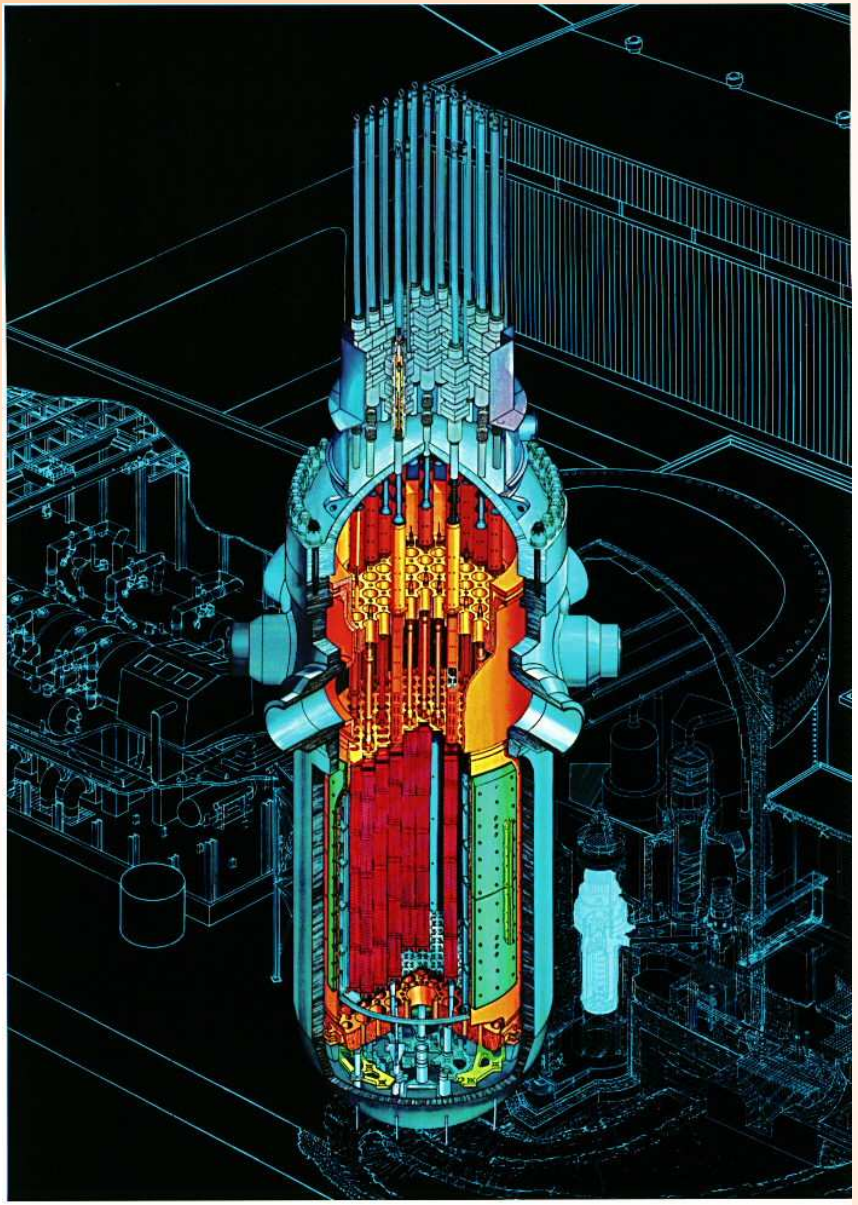
PWR

Manufacturer	MWt	MWe	Loops	Pressurizer	Reactor Coolant Pumps per Loop
Westinghouse	450-3000	167-1000	1-4	1	1
Framatome	2700-3600	900-1300	3-4	1	1
Babcock & Wilcox	2400-3000	800-1000	2	1	2
Combustion Engineering	2400-3600	800-1300	2	1	2
ABB	3000	1000	4	1	1
Mitsubishi	3000	1000	4	1	1

Each loop has one steam generator


Moisture Separator
and Reheator
Secondary
Loop
Turbine
Generator
Pressurizer
Steam Generator
Circulating Pump
Coolant Pump
Condensate Pump
Reactor
Tertiary Loop
Primary Loop
Containment
Wall
Nuclear Steam Supply System
MB 3618A

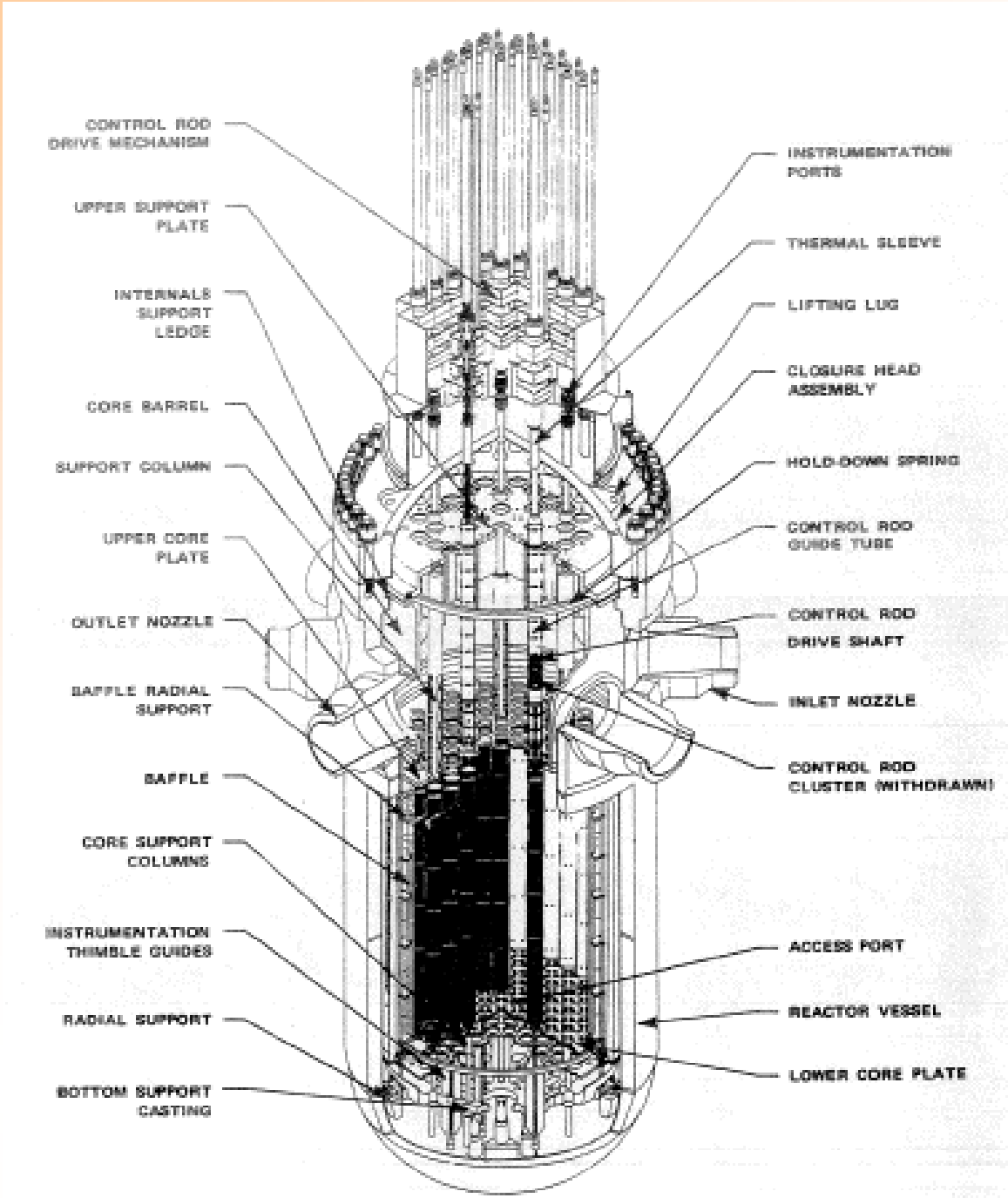
Pressure Vessel



Westinghouse NUCLEAR REACTOR

Function:

- To provide structural support for the fuel
- To maintain a pressure boundary for the reactor coolant
- To transfer heat from the fuel to the water
- To not allow bulk boiling



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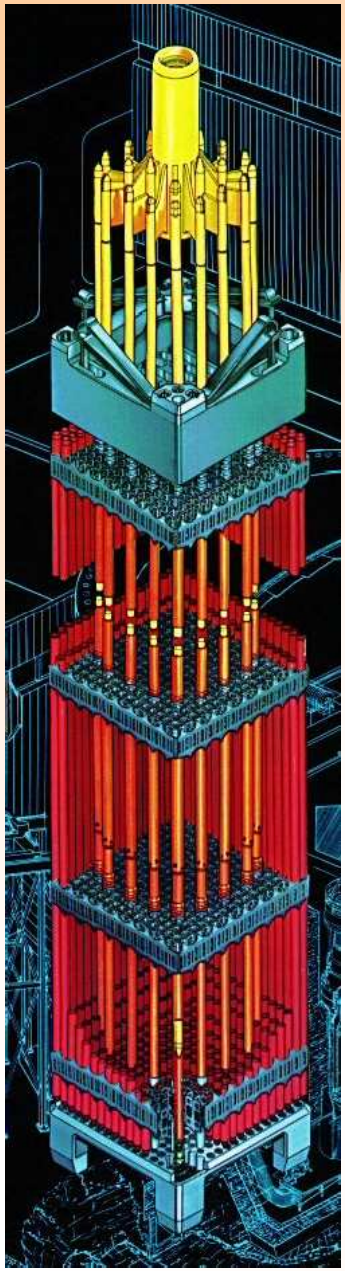
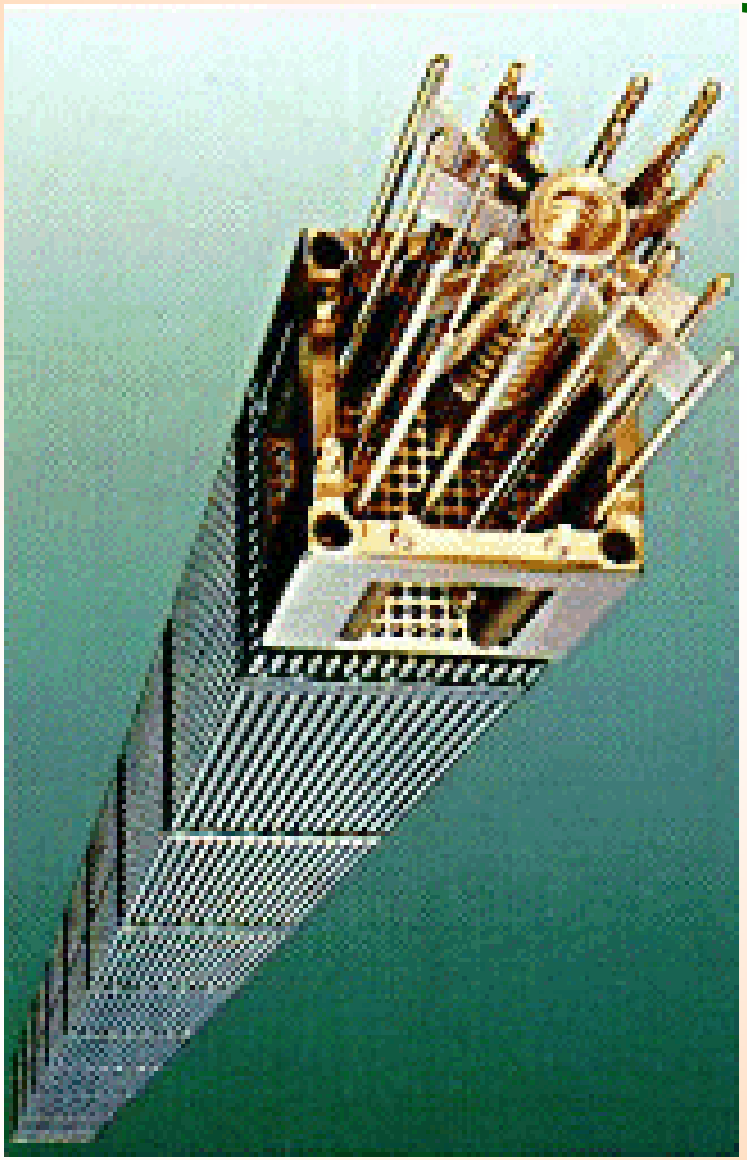
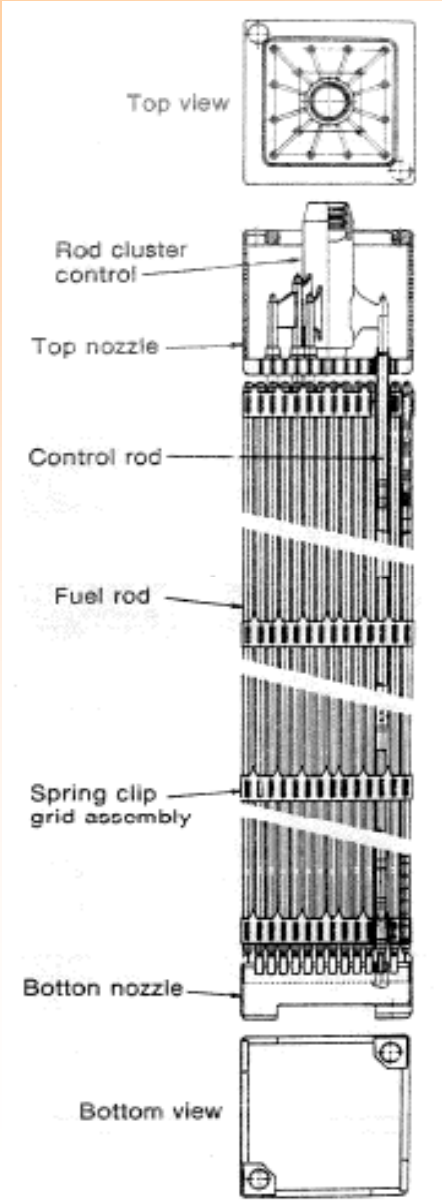
Fuel Assembly



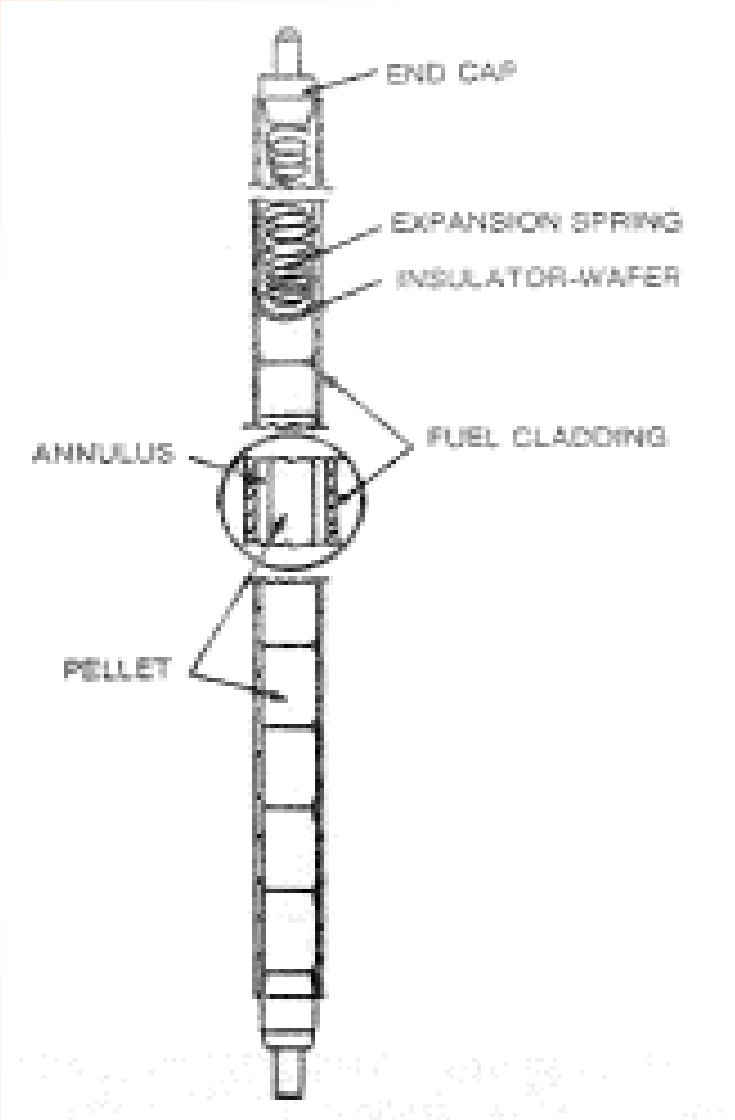


- ✓ Rod control cluster assemblies of 16-20 rods that can be inserted into selected fuel assemblies,

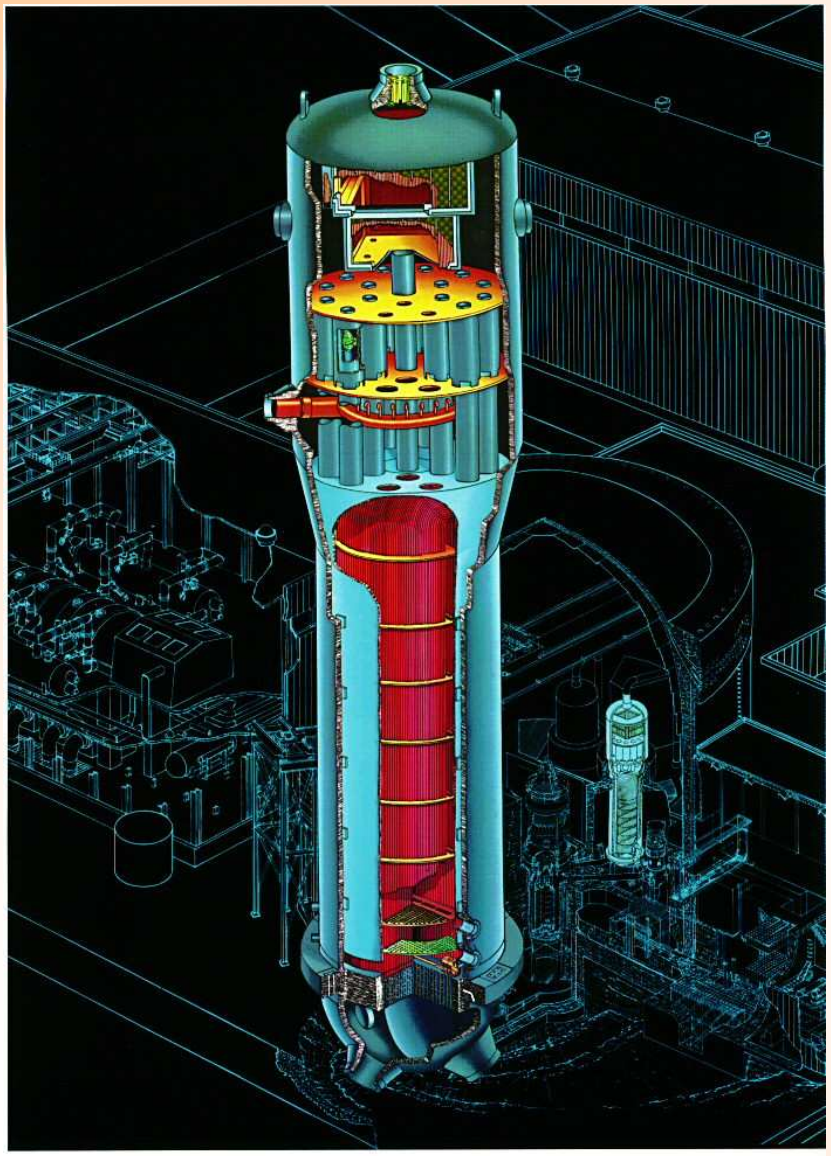
PWR Fuel Assembly



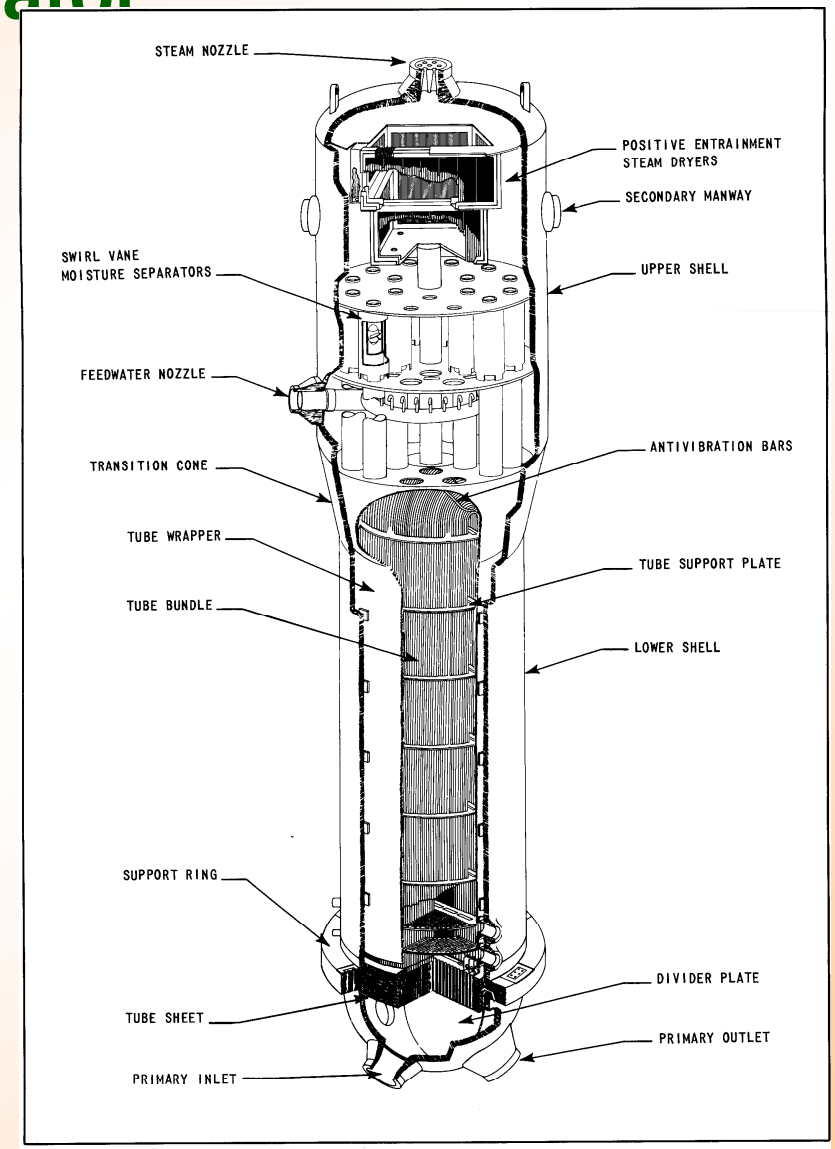
LWR Fuel Rod



Steam Generator



Westinghouse STEAM GENERATOR



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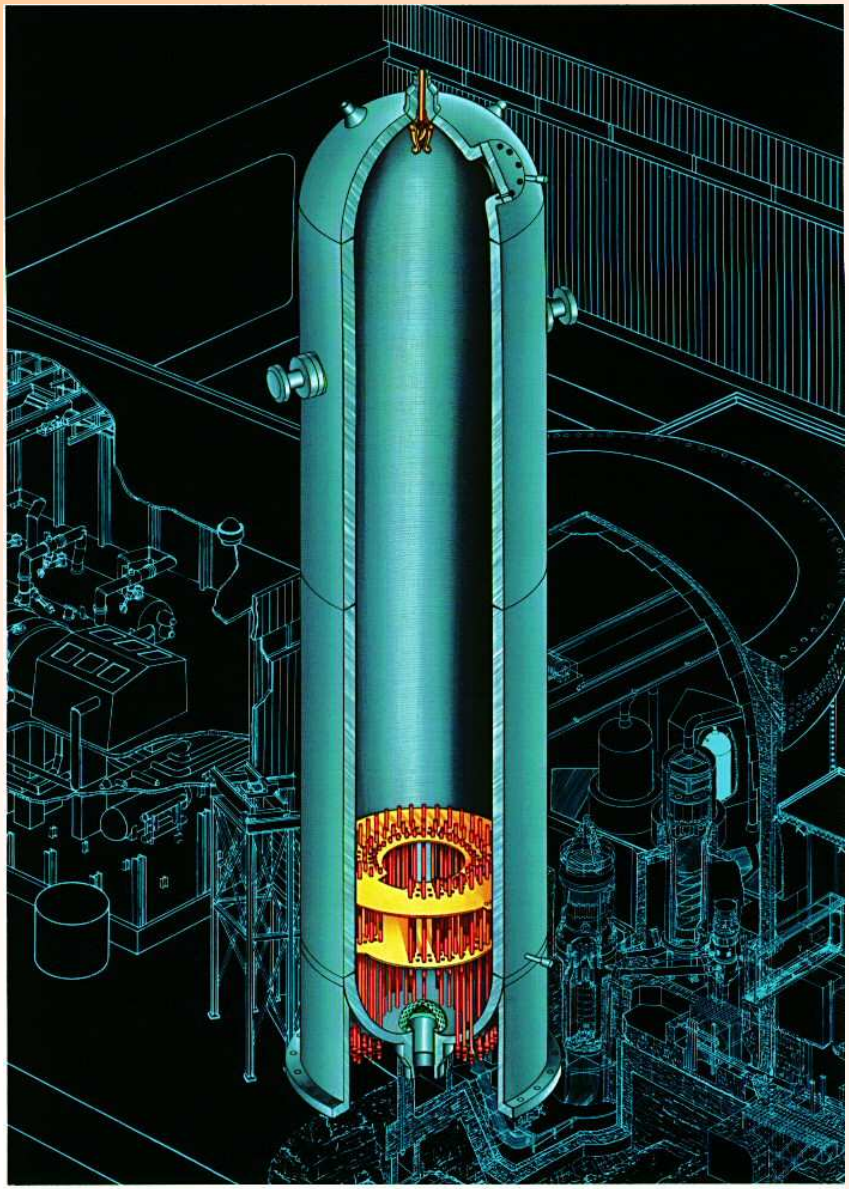
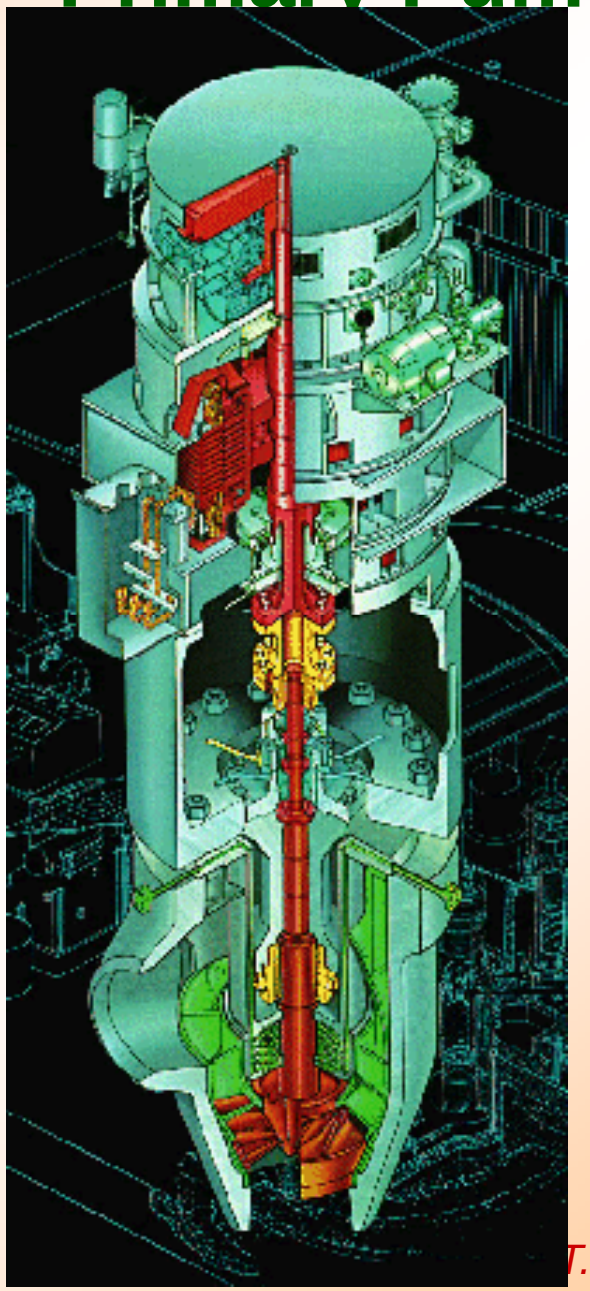
Pressurize



Westinghouse PRESSURIZER

Primary Pump



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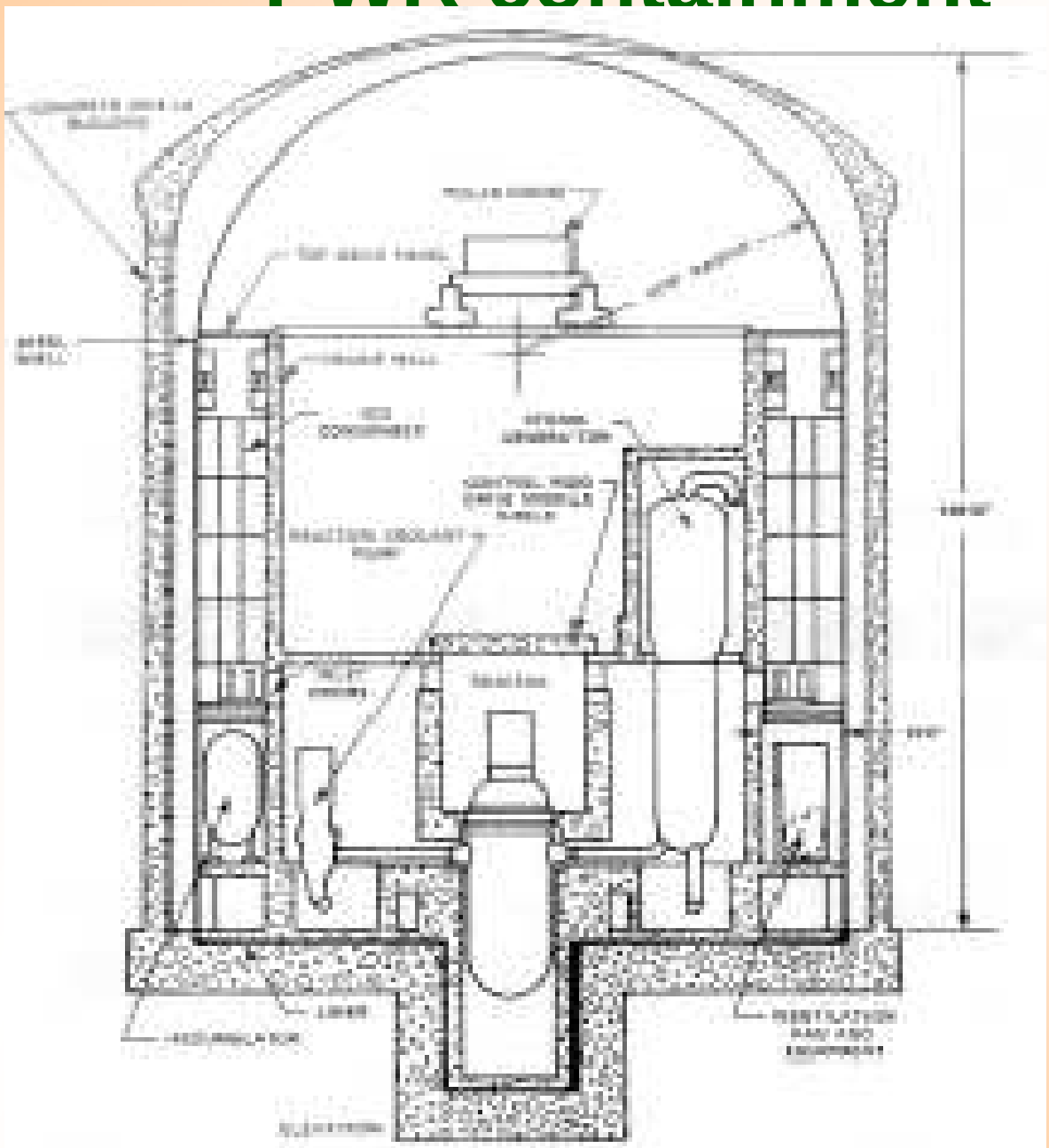
PWR containment



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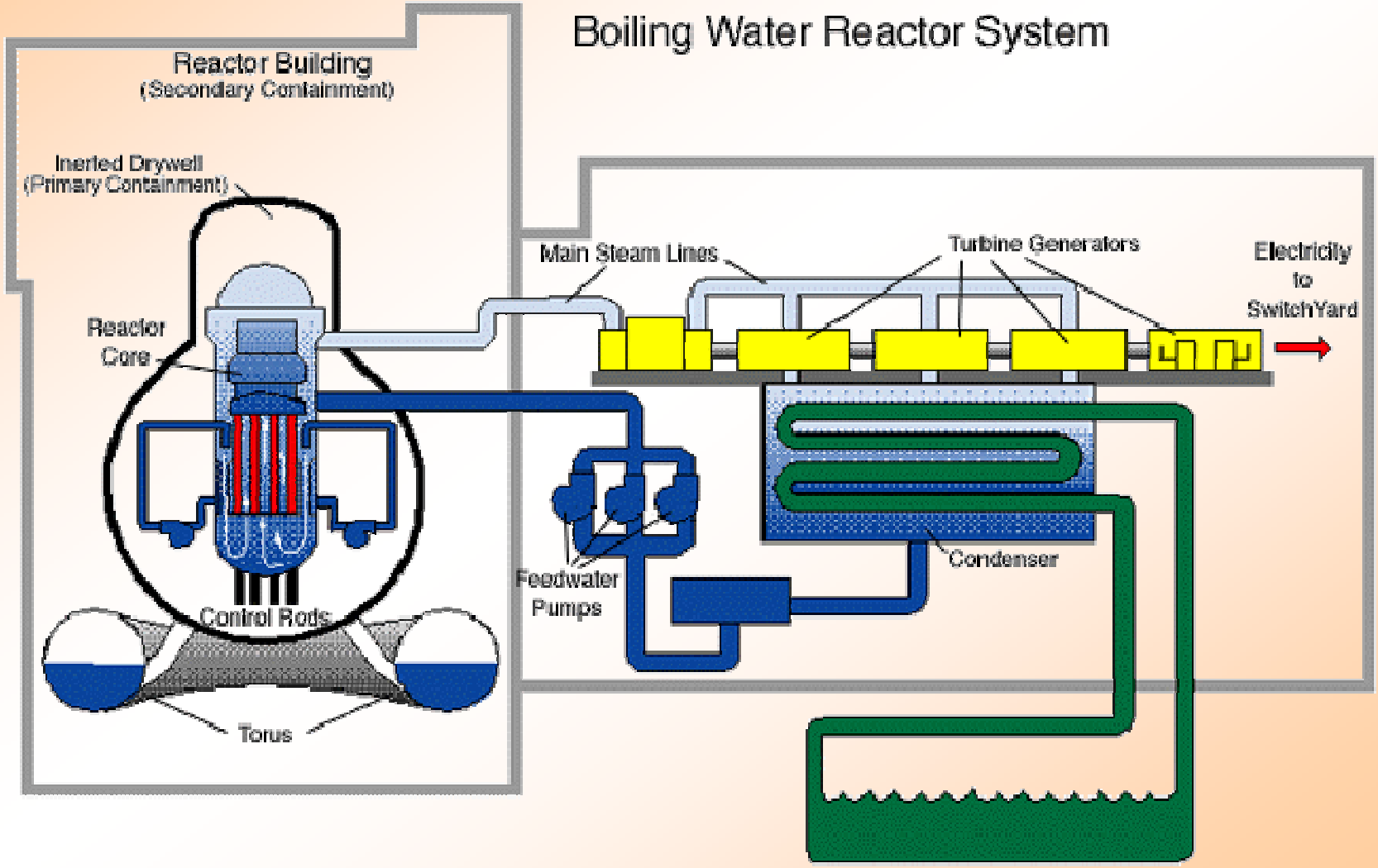
BWR



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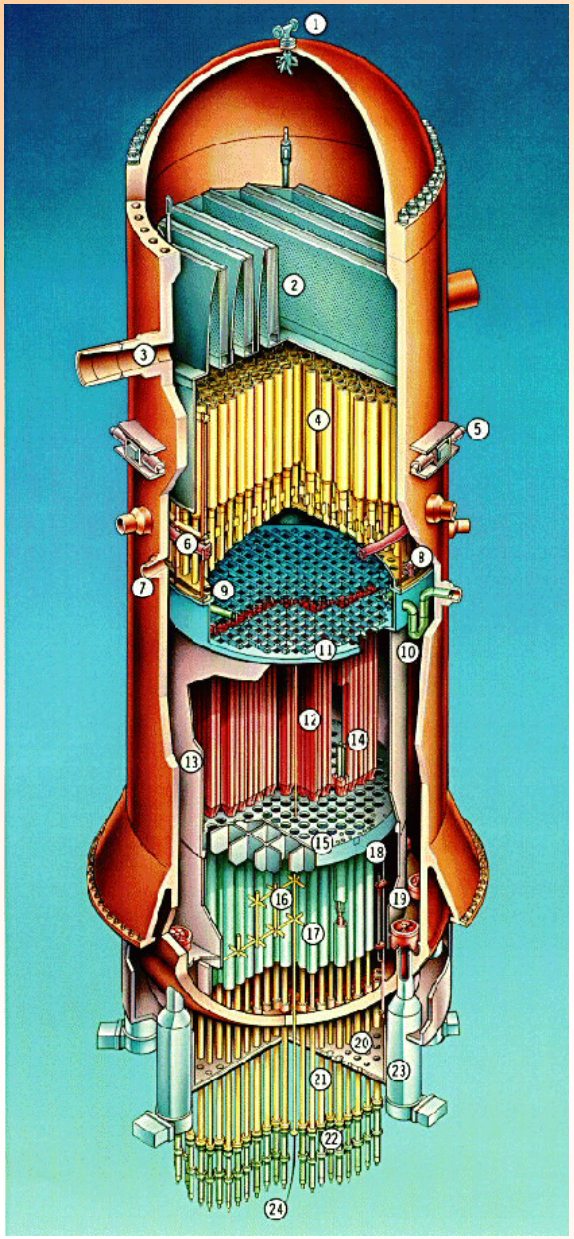
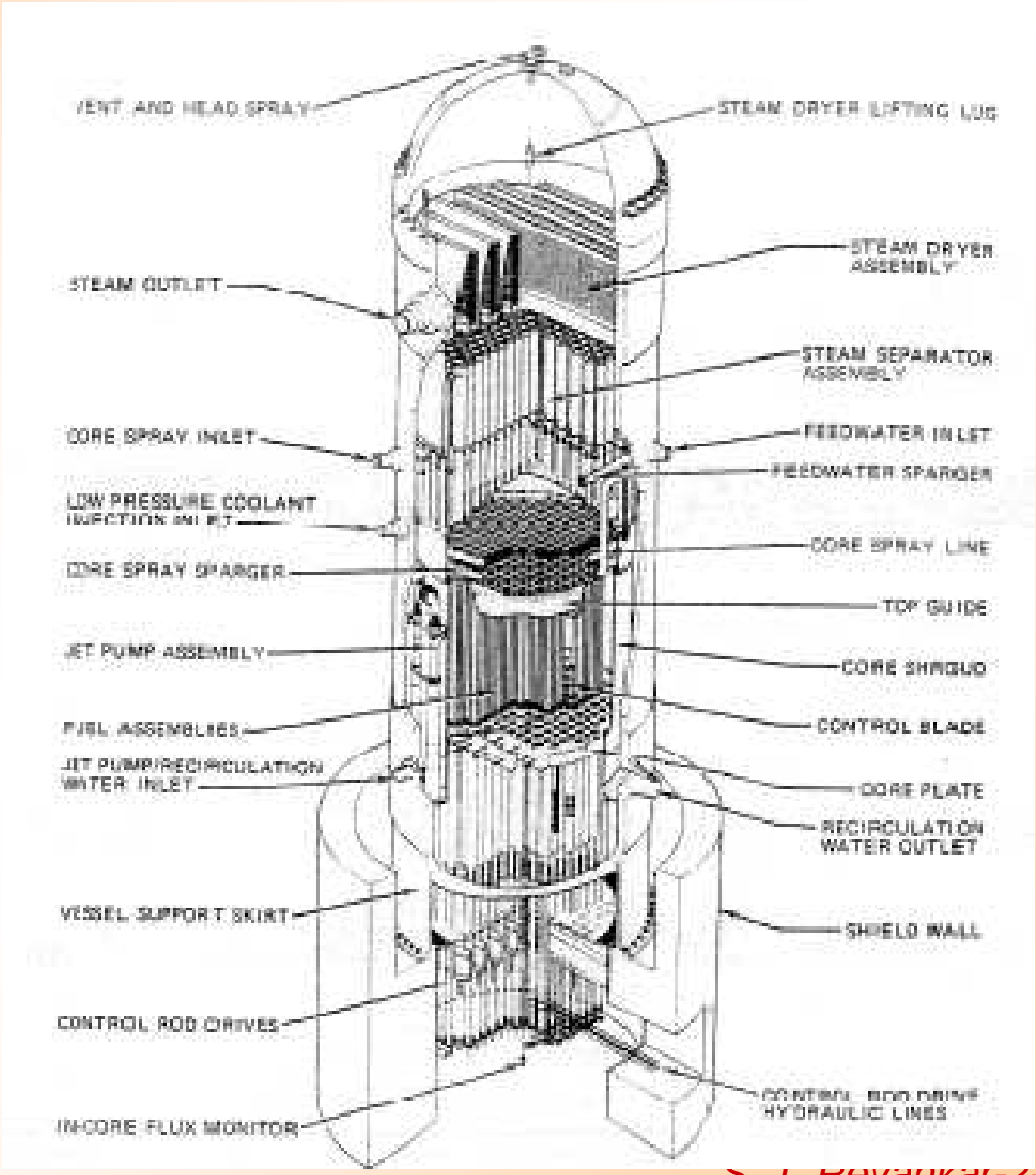
BWR Pressure Vessel





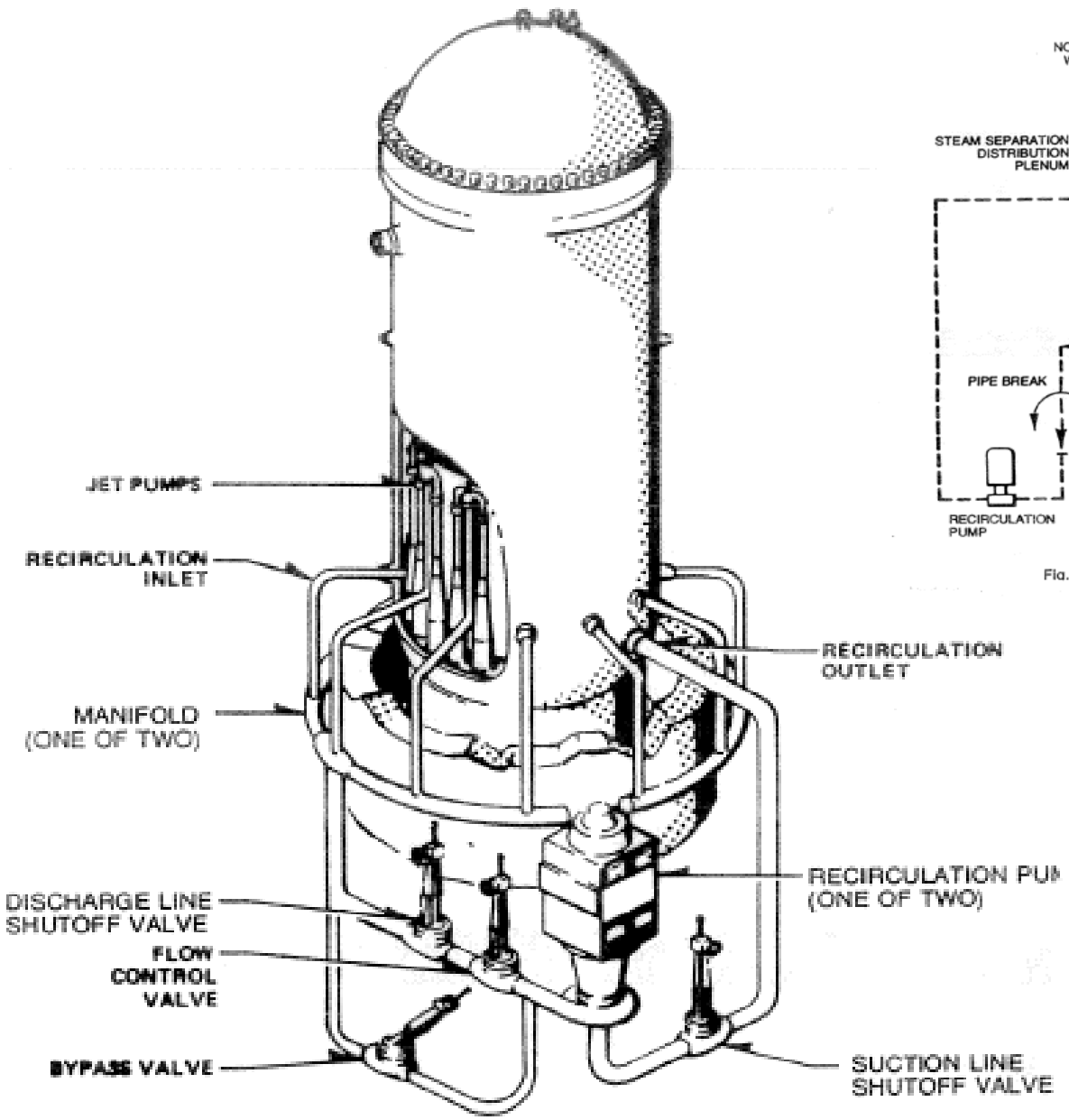


Fig. 2-4. The BWR vessel arrangement for jet pump recirculation system.

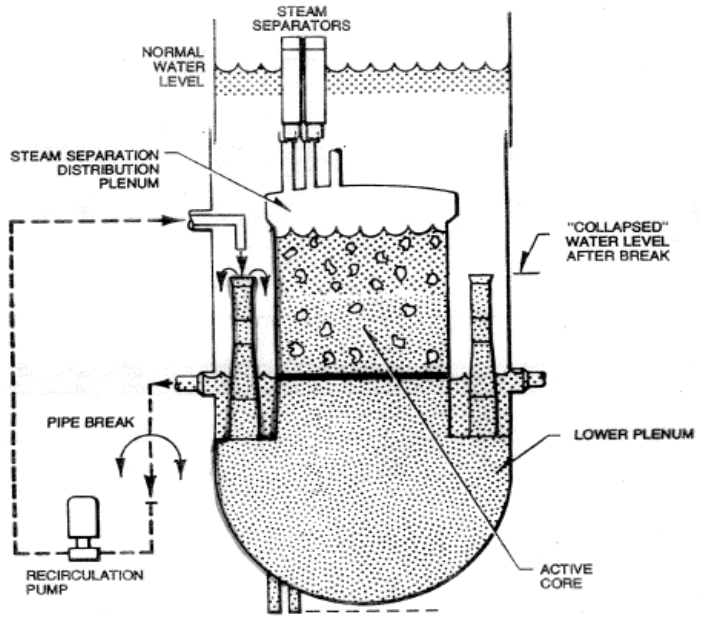


Fig. 2-7. Core submersion capability of jet pump system.

✓ **Jet pumps**

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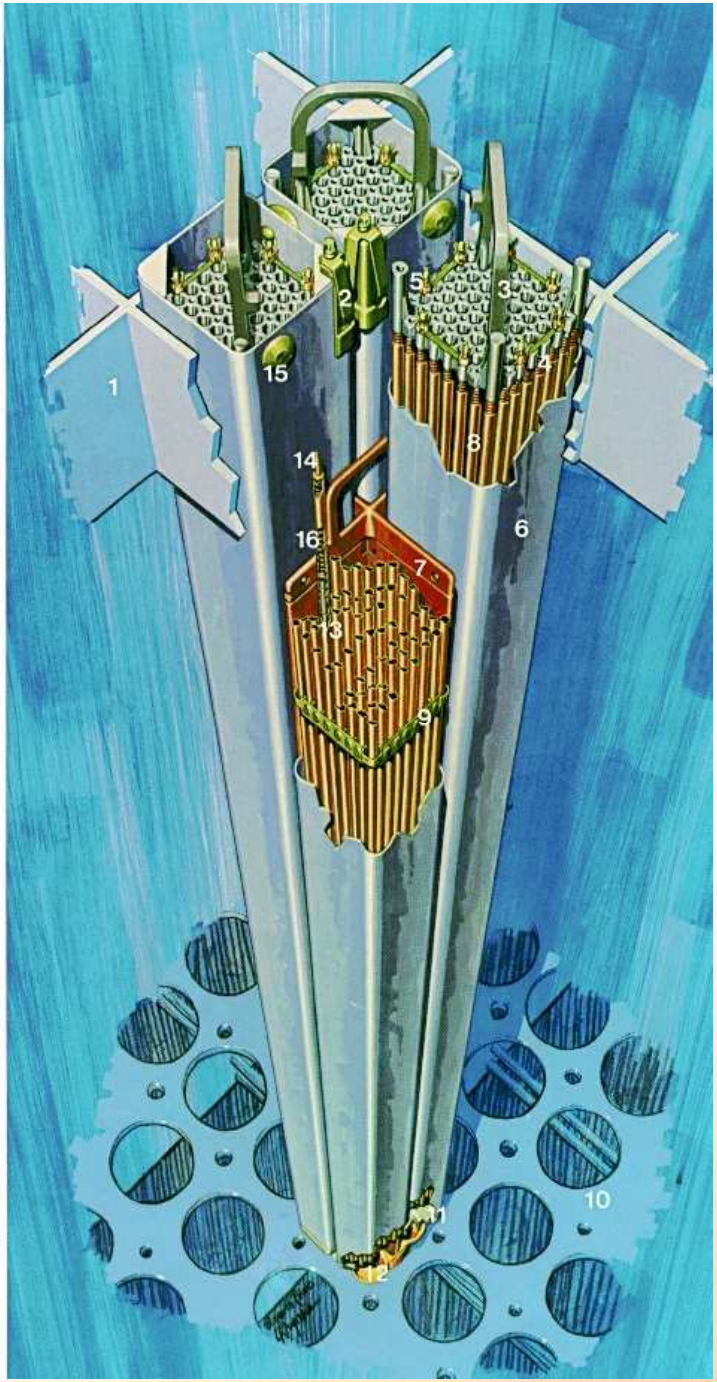
BWR/6 FUEL ASSEMBLIES & CONTROL ROD MODULE

1.TOP FUEL GUIDE
2.CHANNEL FASTENER
3.UPPER TIE PLATE
4.EXPANSION SPRING
5.LOCKING TAB
6.CHANNEL
7.CONTROL ROD
8.FUEL ROD
9.SPACER
10.CORE PLATE ASSEMBLY
11.LOWER TIE PLATE
12.FUEL SUPPORT PIECE
13.FUEL PELLETS
14.END PLUG
15.CHANNEL SPACER
16.PLENUM SPRING

GENERAL ELECTRIC



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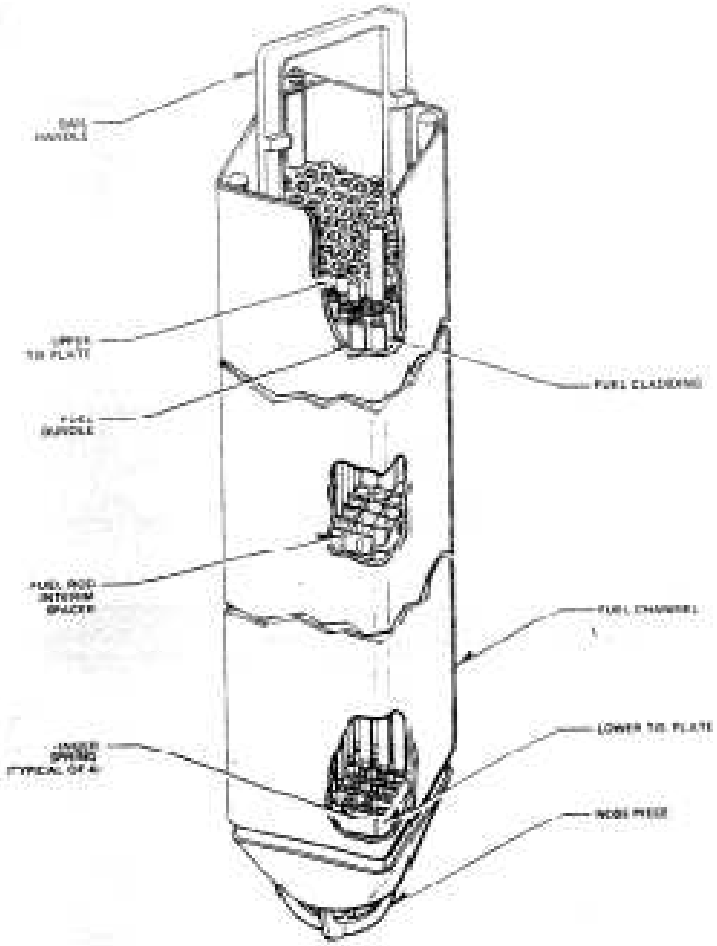
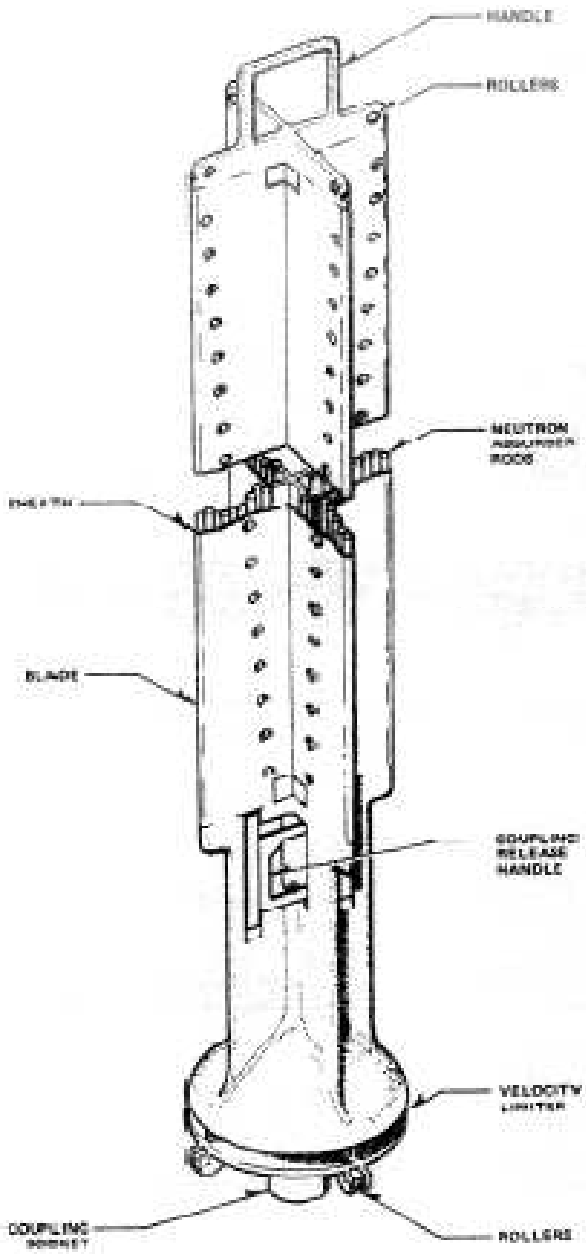
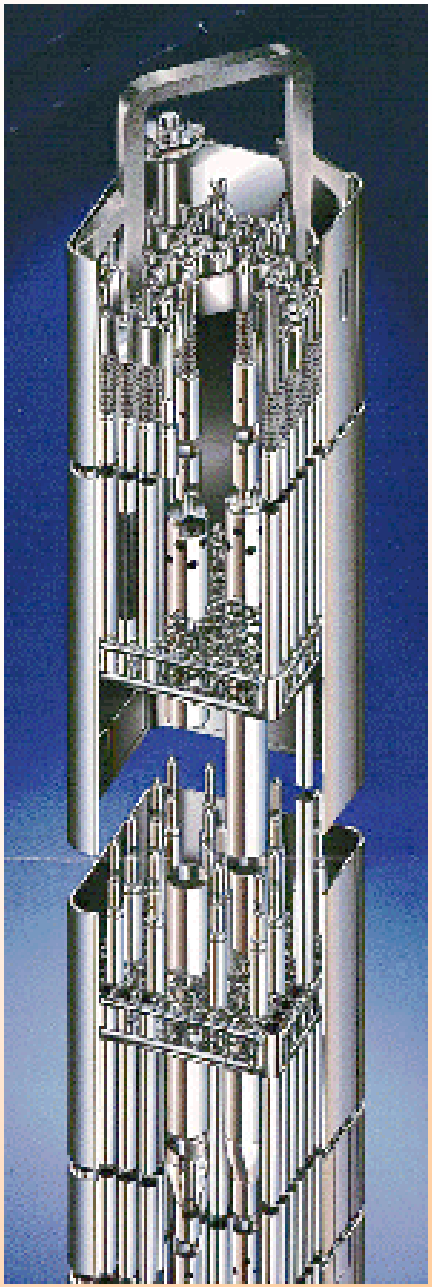


Fuel Assembly



Control Rod



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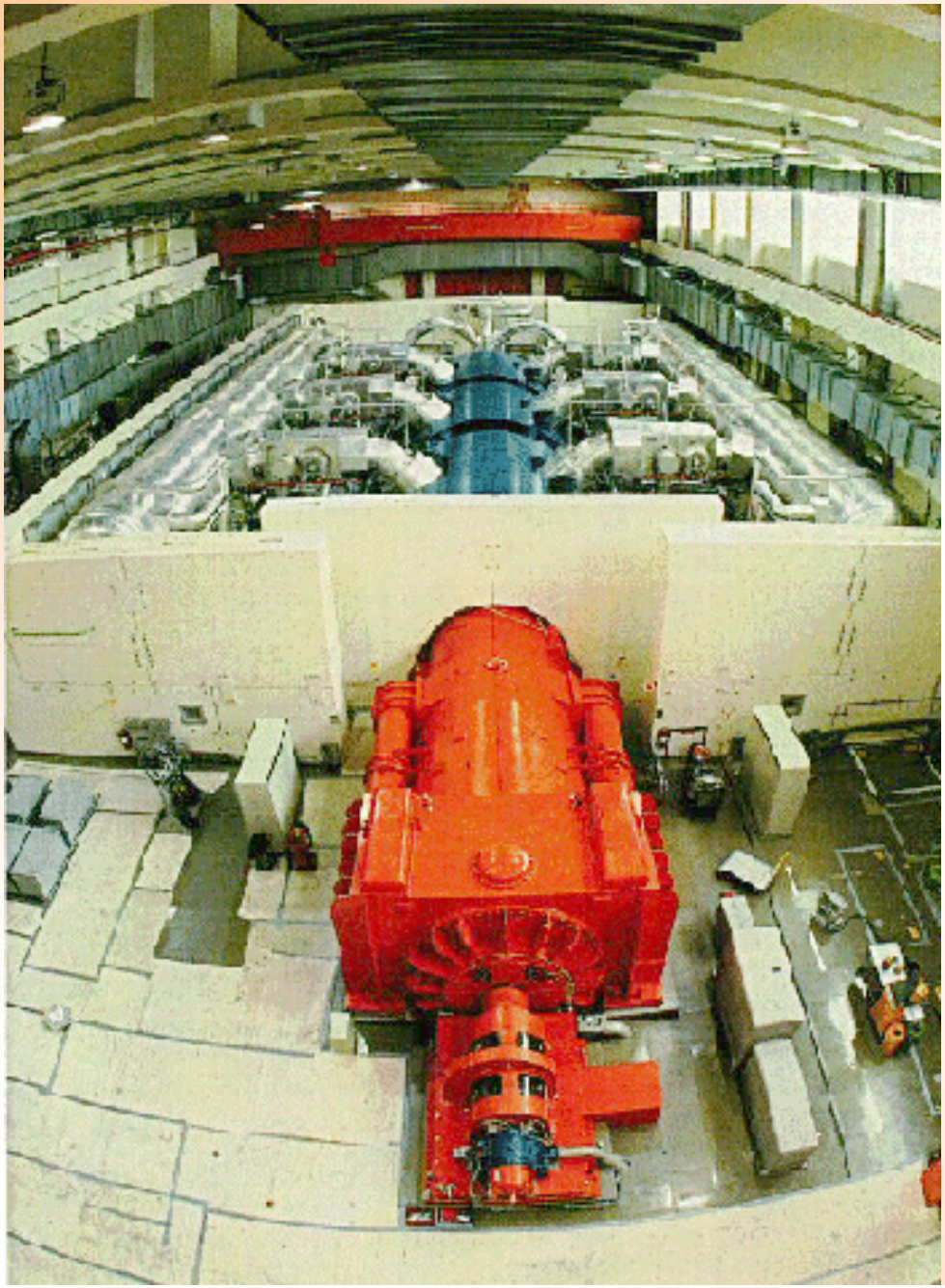
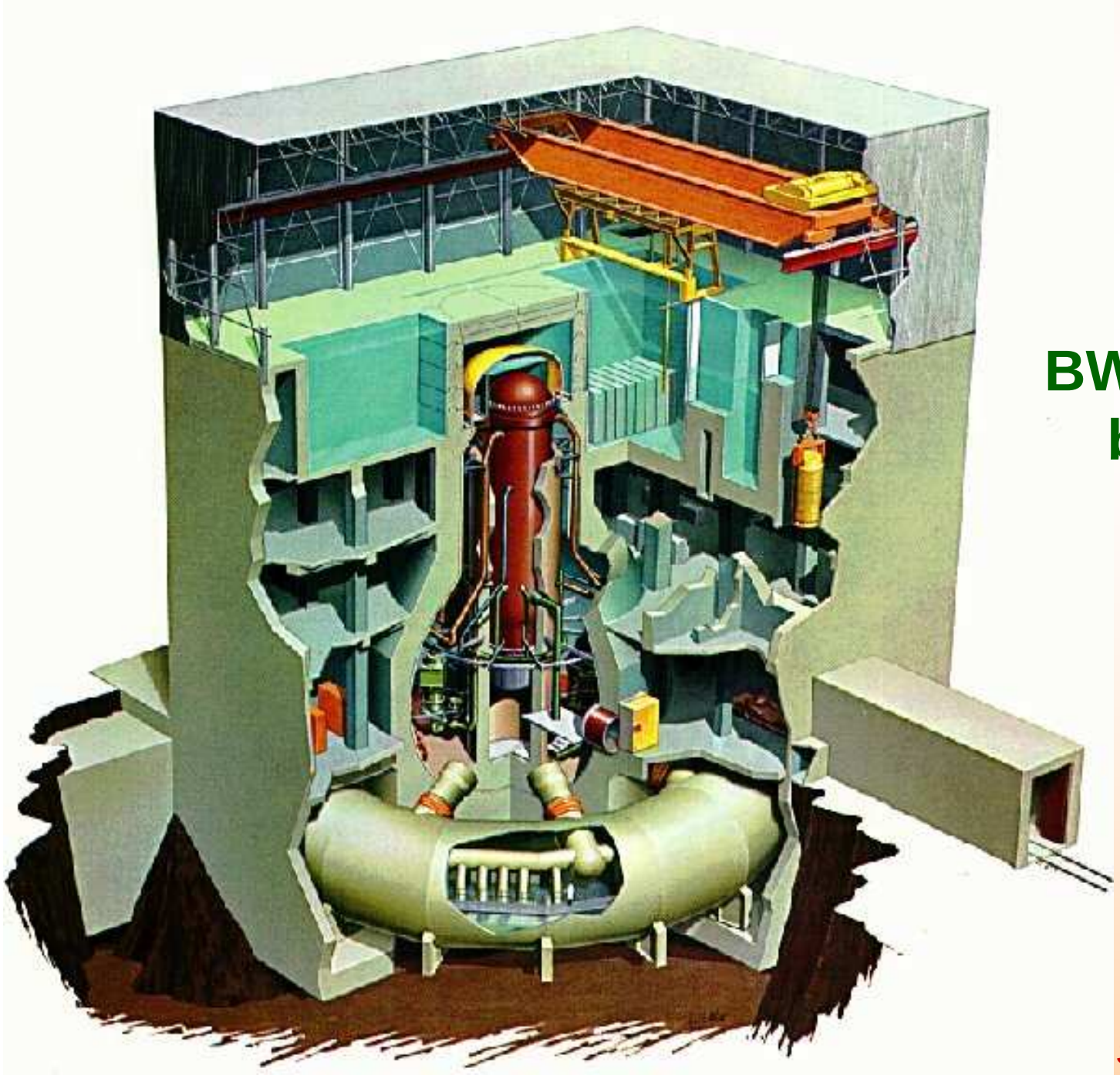


- **Turbine generator with shielding**



BWR reactor building layout

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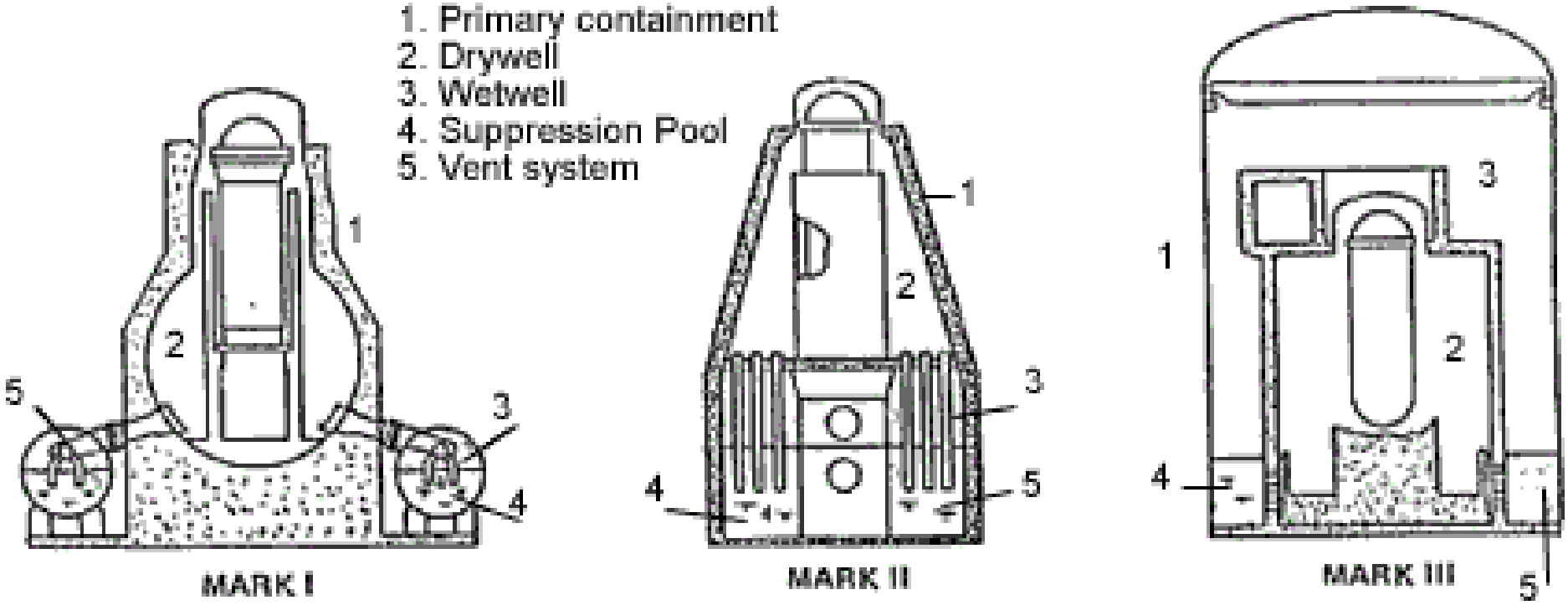
BWR Containment



General Electric pressure suppression system designs