Operational Reactor Safety

22.091/22.903

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Professor of the Practice

Boiling Water Reactors

Lecture 15

Topics to be Covered

- Steam Cycle
- Recirculation
- Chimney
- Steam separation
- Heat removal
- Operating with voids
- Plant systems
- Reactor Protective System
- Safety Systems

BWR Plant Layout

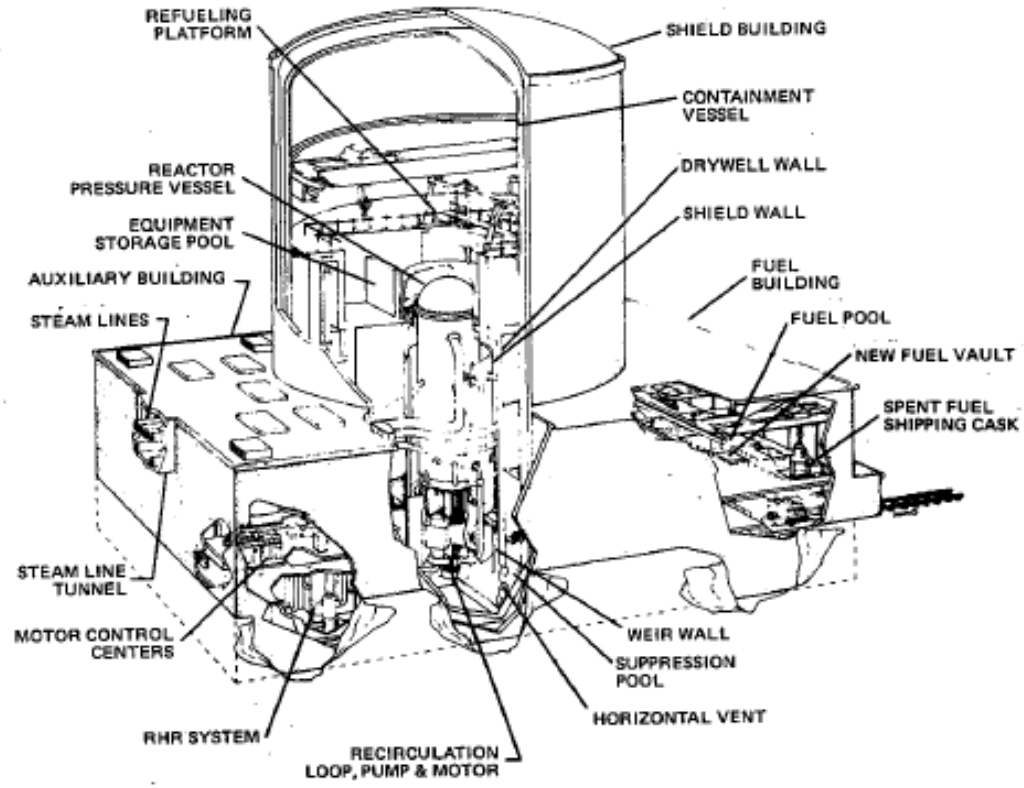
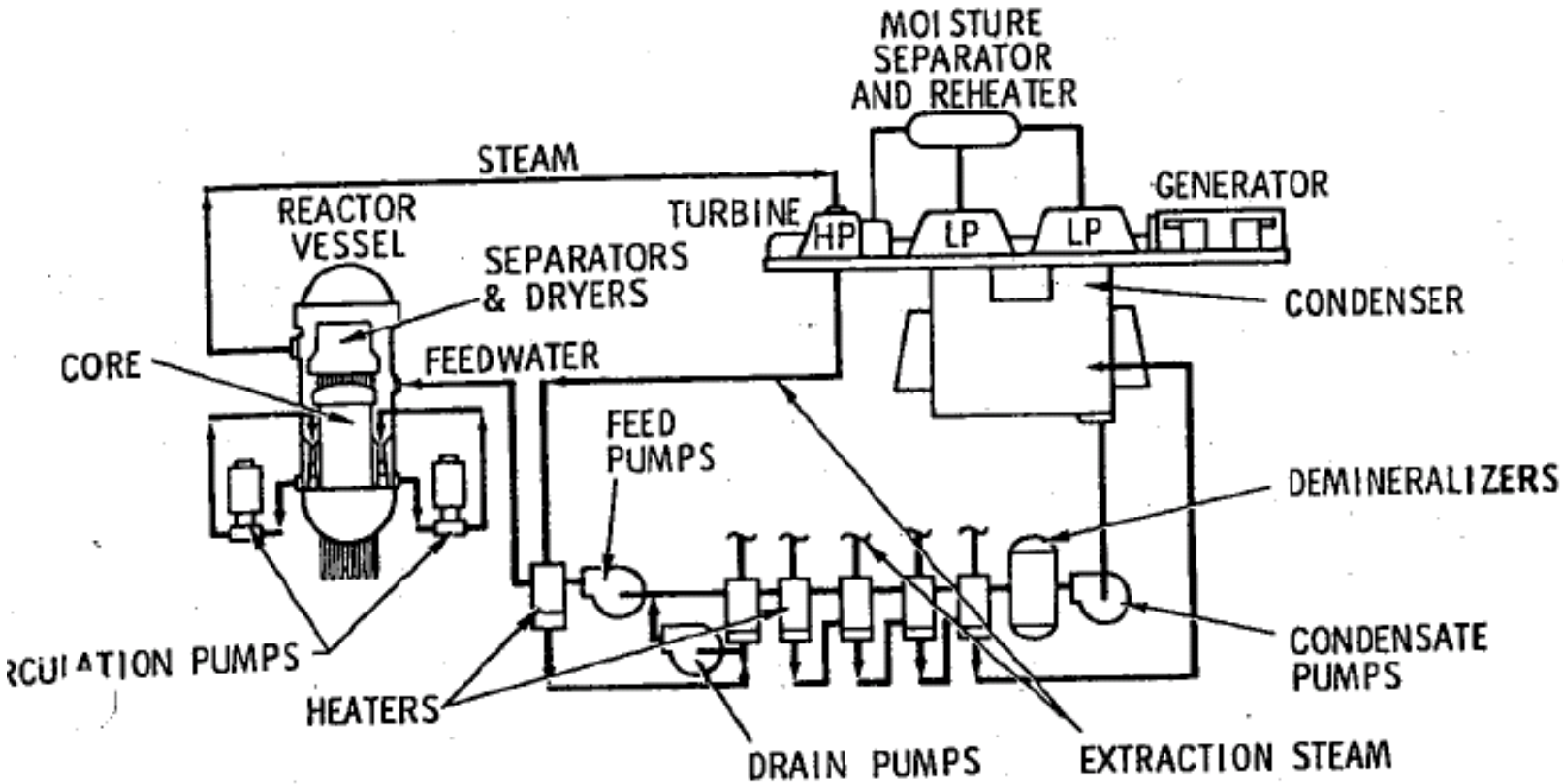


Figure 7-1. Reactor Building, Fuel Building, and Auxiliary Building

BWR Plant Schematic



BWR Early

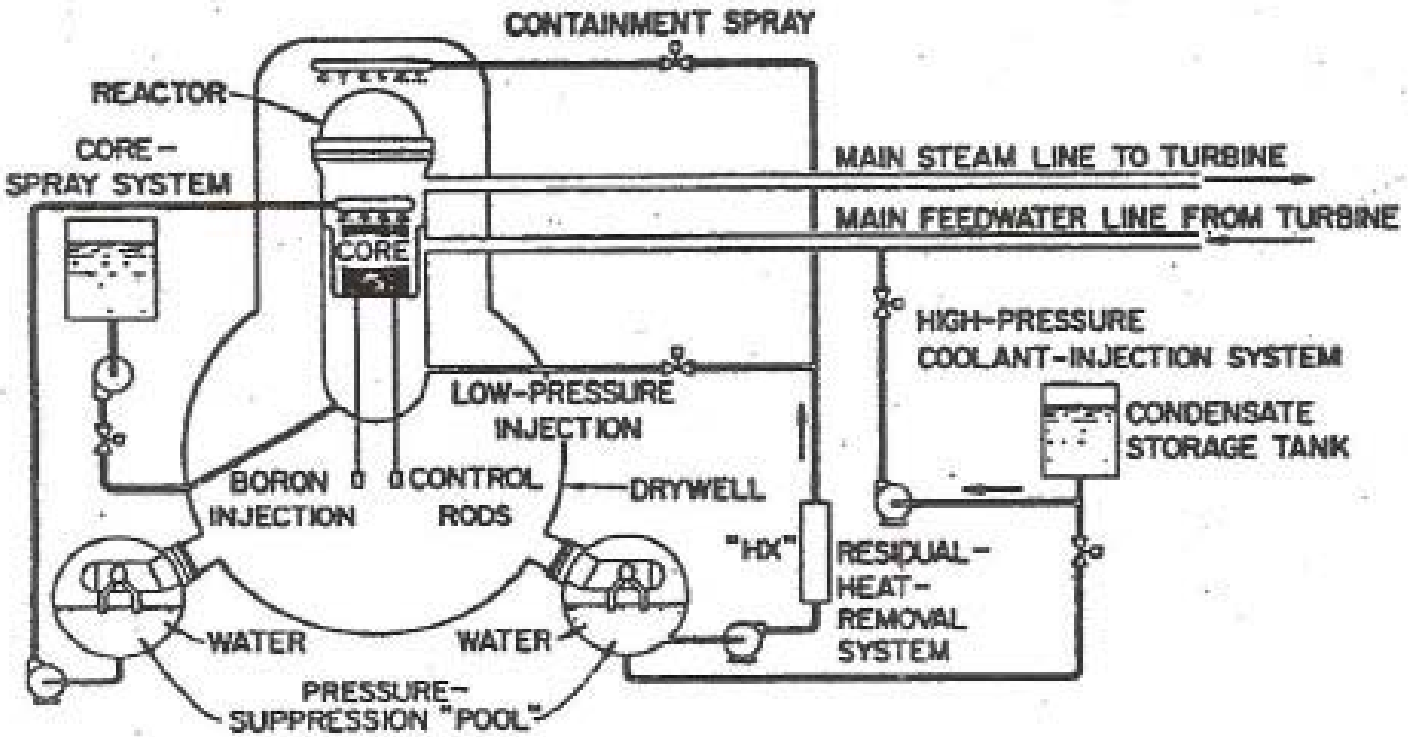


FIGURE 14-6
Engineered safety systems for an early BWR. (From W. B. Cottrell, "The ECCS Rule-Making Hearing," *Nuclear Safety*, vol. 15, no. 1, Jan.–Feb. 1974.)

Reactor Assembly

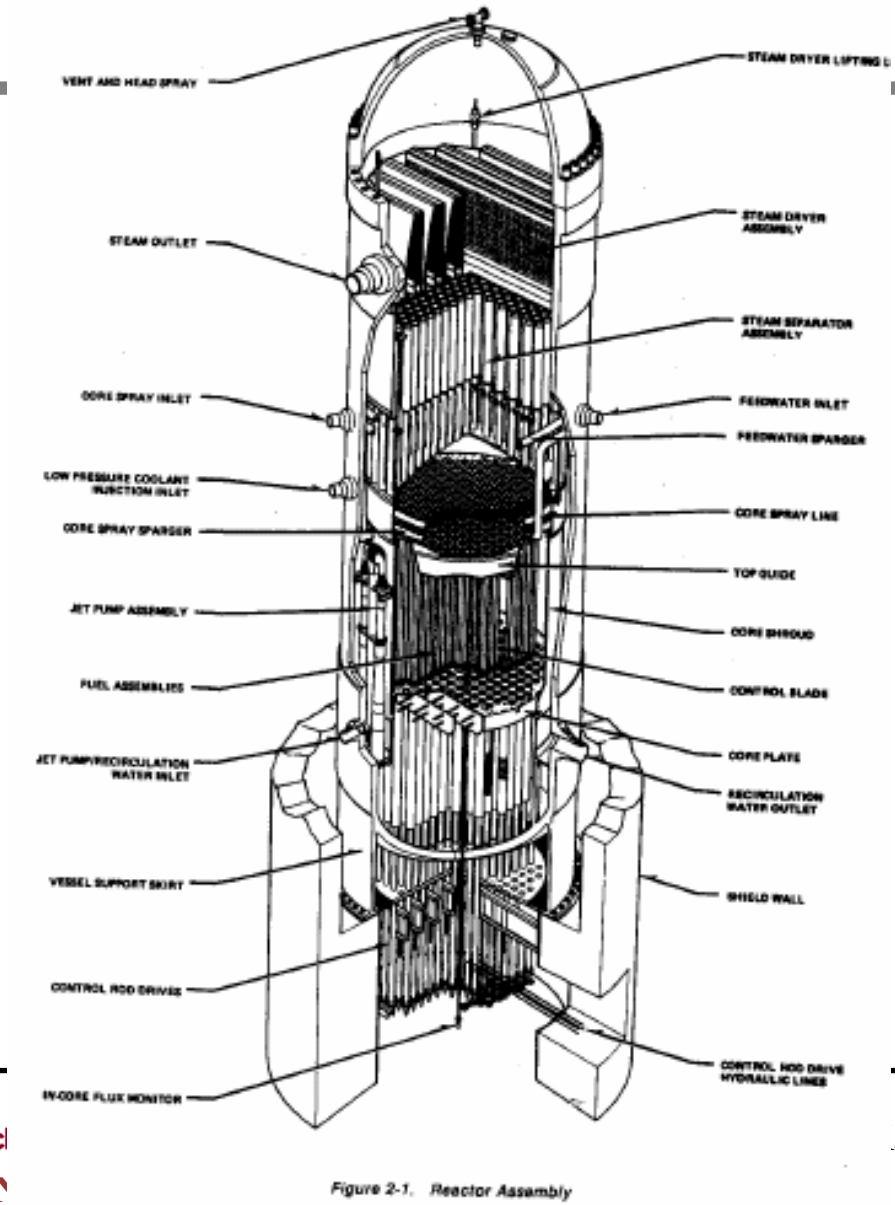
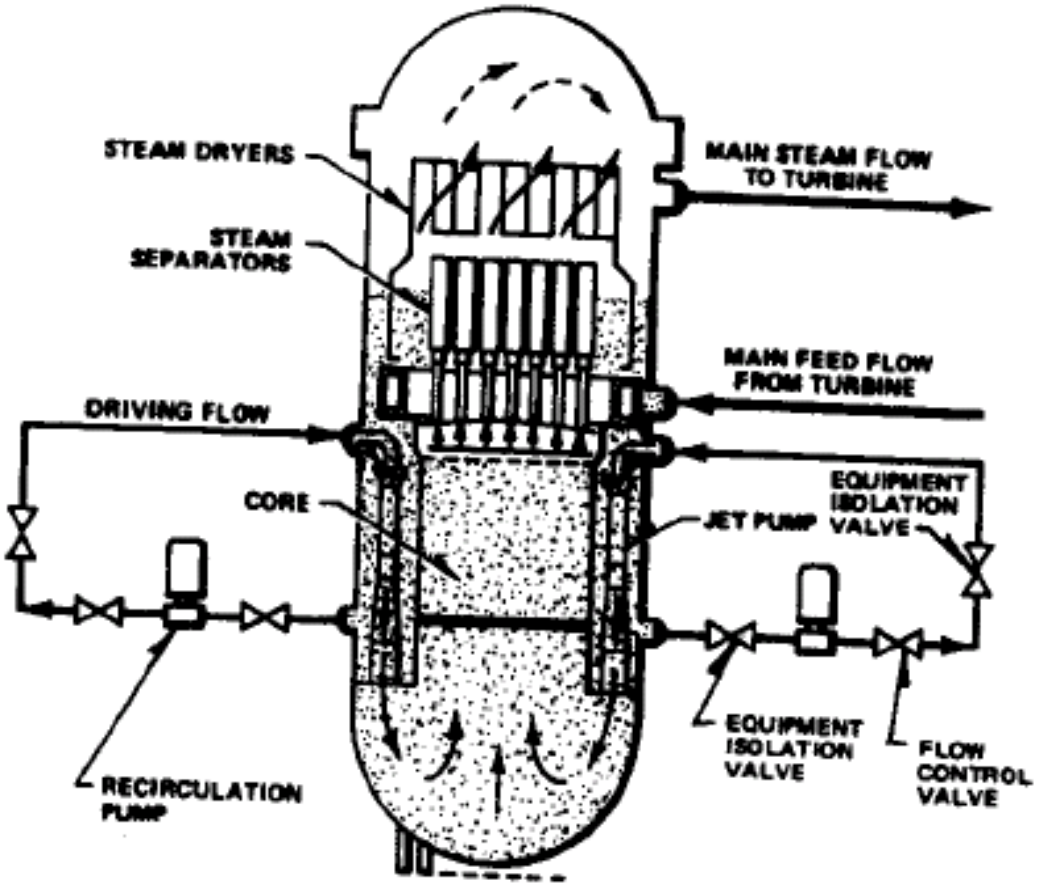


Figure 2-1. Reactor Assembly

Steam and Recirculation System



Jet Pumps – Recirculation System

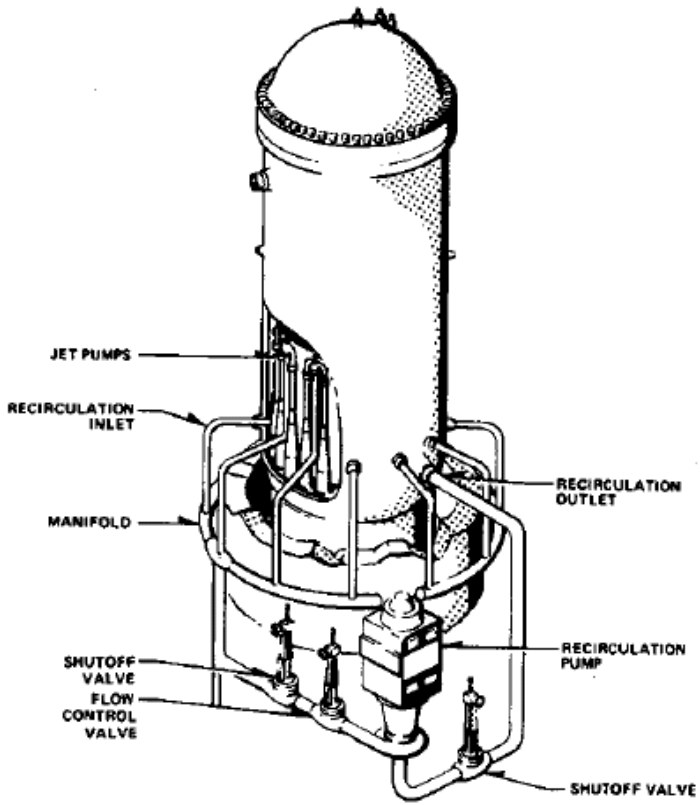
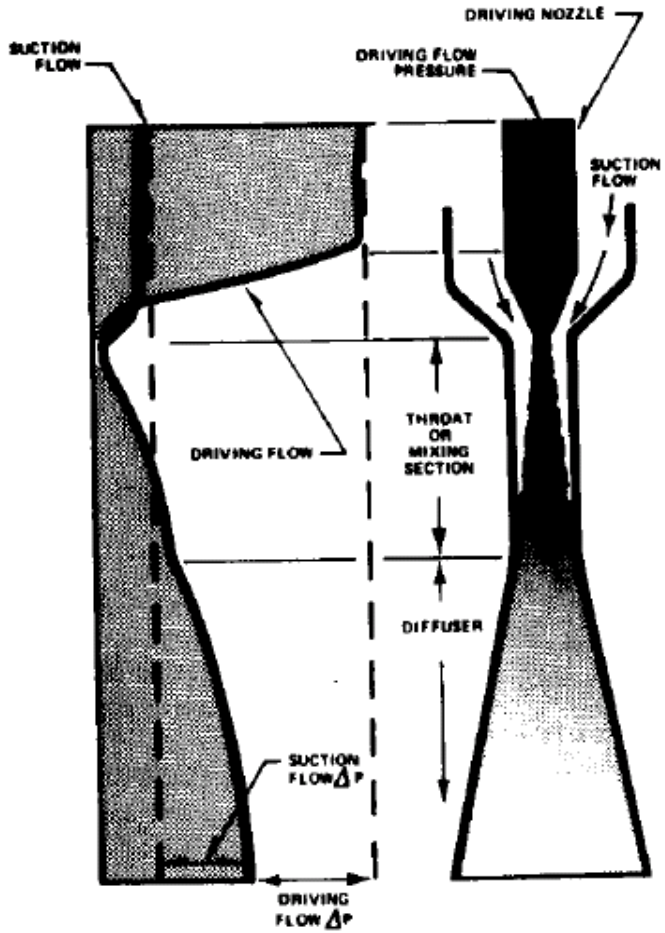
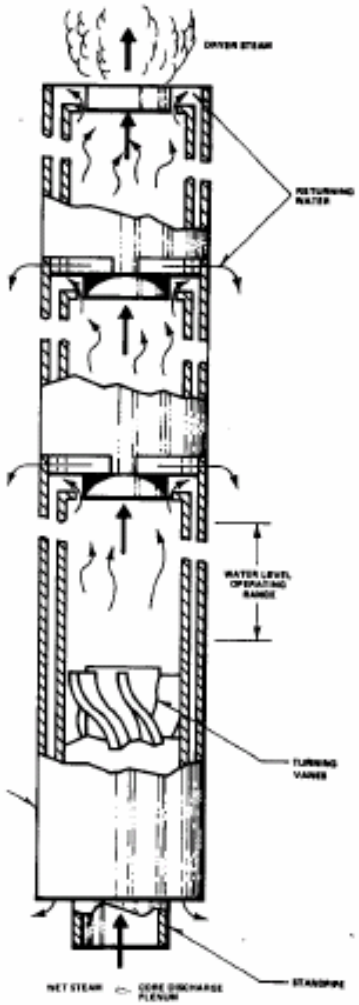


Figure 2-5. BWR Vessel Arrangement for Jet Pump Recirculation System



Steam Separator and Dryer



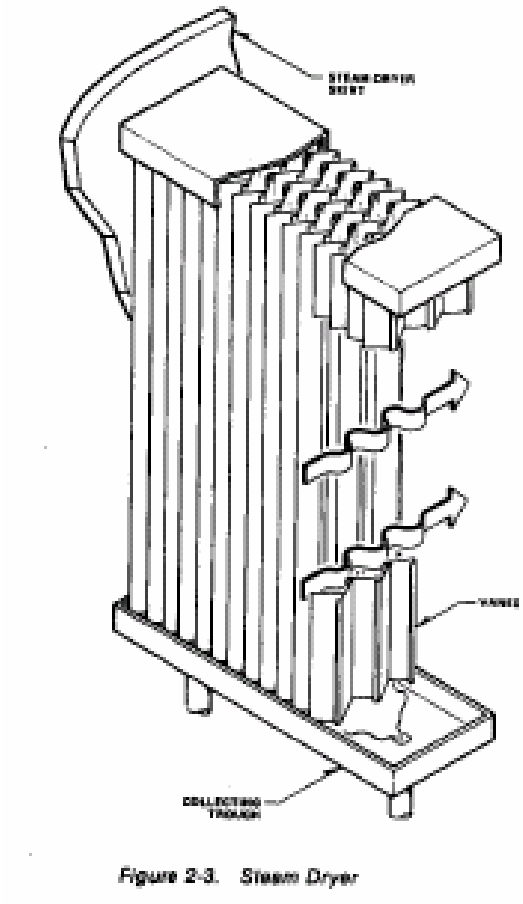


Figure 2-3. Steam Dryer

Key Systems of BWRs

- Standby Liquid Control System (SLCS)
  - For redundant shutdown – contains boron
- Reactor Core Isolation Cooling System (RCIC)
  - Deals with loss of feedwater flow
- Emergency Core Cooling System (ECCS)
  - Safety Relief Valve – Automatic Depressurization System
  - High Pressure Coolant Injection System (HPCI)
  - Low Pressure Coolant Injection System (LPCI)
- Control Rod Drive System
  - Hydraulic Control Units – from bottom of reactor vessel
- Residual Heat Removal System – decay heat removal

ECCS

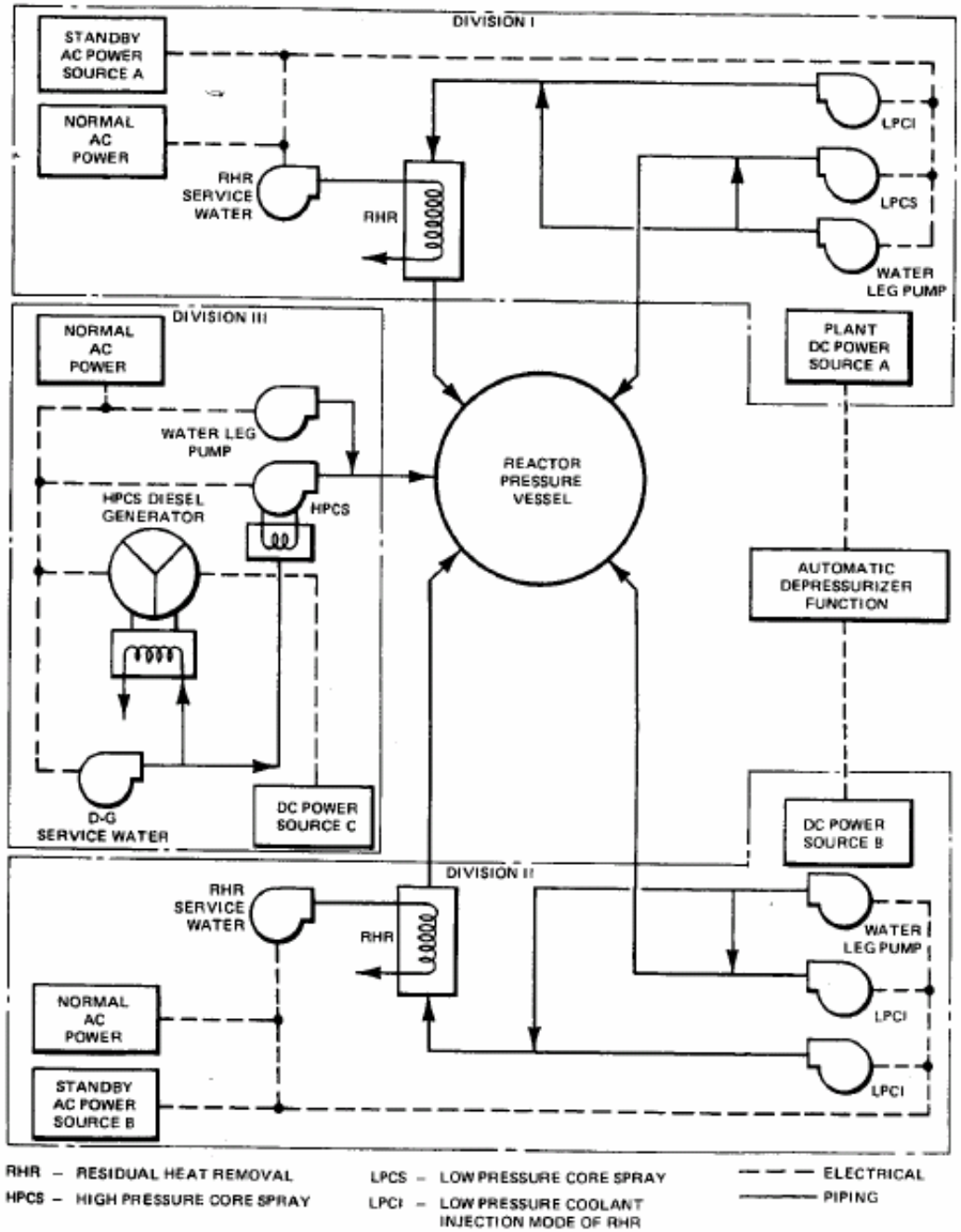


Figure 4-7. Emergency Cooling System Network

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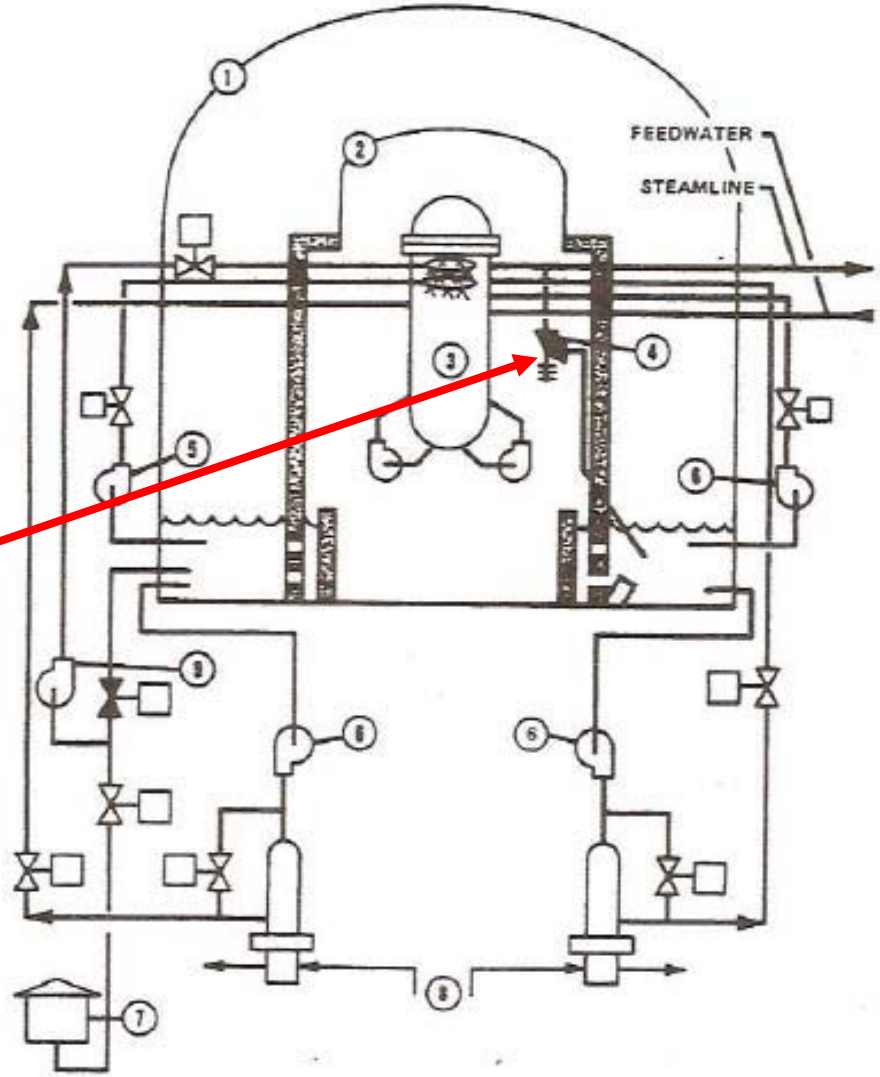
ADS

ADS Valve



1. CONTAINMENT
2. DRYWELL
3. RPV
4. SAFETY/RELIEF VALVE DEPRESSURIZATION
5. LOW PRESSURE SPRAY
6. LOW PRESSURE COOLING INJECTION FUNCTION OF RESIDUAL HEAT REMOVAL SYSTEM
7. CONDENSATE STORAGE TANK
8. SERVICE WATER
9. HIGH PRESSURE CORE SPRAY

Figure 4-6. Emergency Core Cooling System

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Reactor Power Control

- Control rods – gross power changes
- Recirculation Flow - +/- 25 % power
  - Increase flow – increase power
- Turbine Control – Pressure control - constant
  - Generator demands more power – turbine slows down – pressure decreases – more steam created - increase turbine power –then increase recirculation flow to compensate for reactivity loss.
- Recall BWRs have negative void coefficient and Positive pressure coefficient

Reactor Trip Systems

- High Pressure in Drywell
- Low water level in reactor vessel
- High pressure in reactor vessel
- High neutron flux
- High water level in scram discharge volume (control rods)
- Closing of turbine stop or fast closure of turbine control valves
- Main steam line isolation
- High radiation levels in main steam lines
- Leak detection
- Low pressure in turbine inlet

Trip Functions

- Insertion of control rods (hydraulic control units in bottom)
- Nuclear System Isolation
  - Reactor Coolant Pressure Boundary
  - Containment Isolation
  - Closed System Isolation

Homework

- Read BWR handouts
- Problem 3.3 El Wakil

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