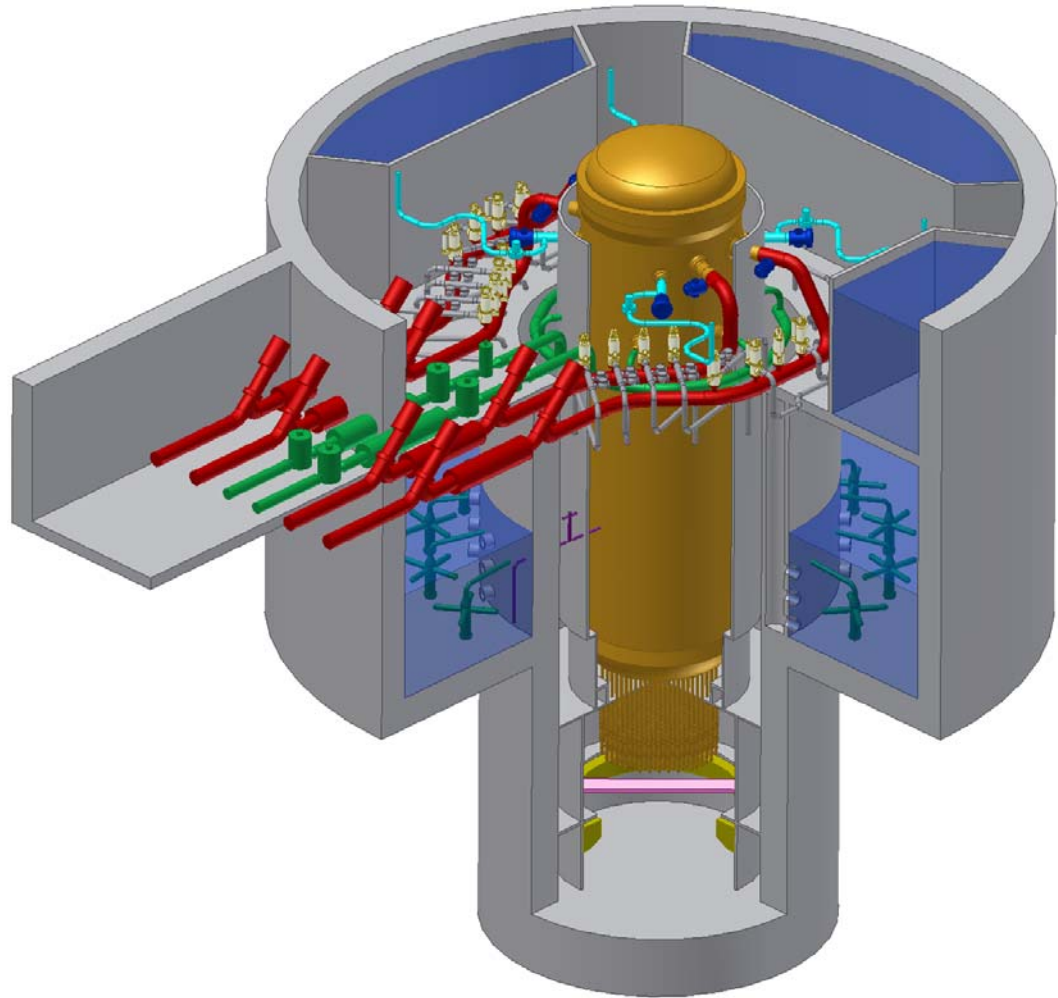
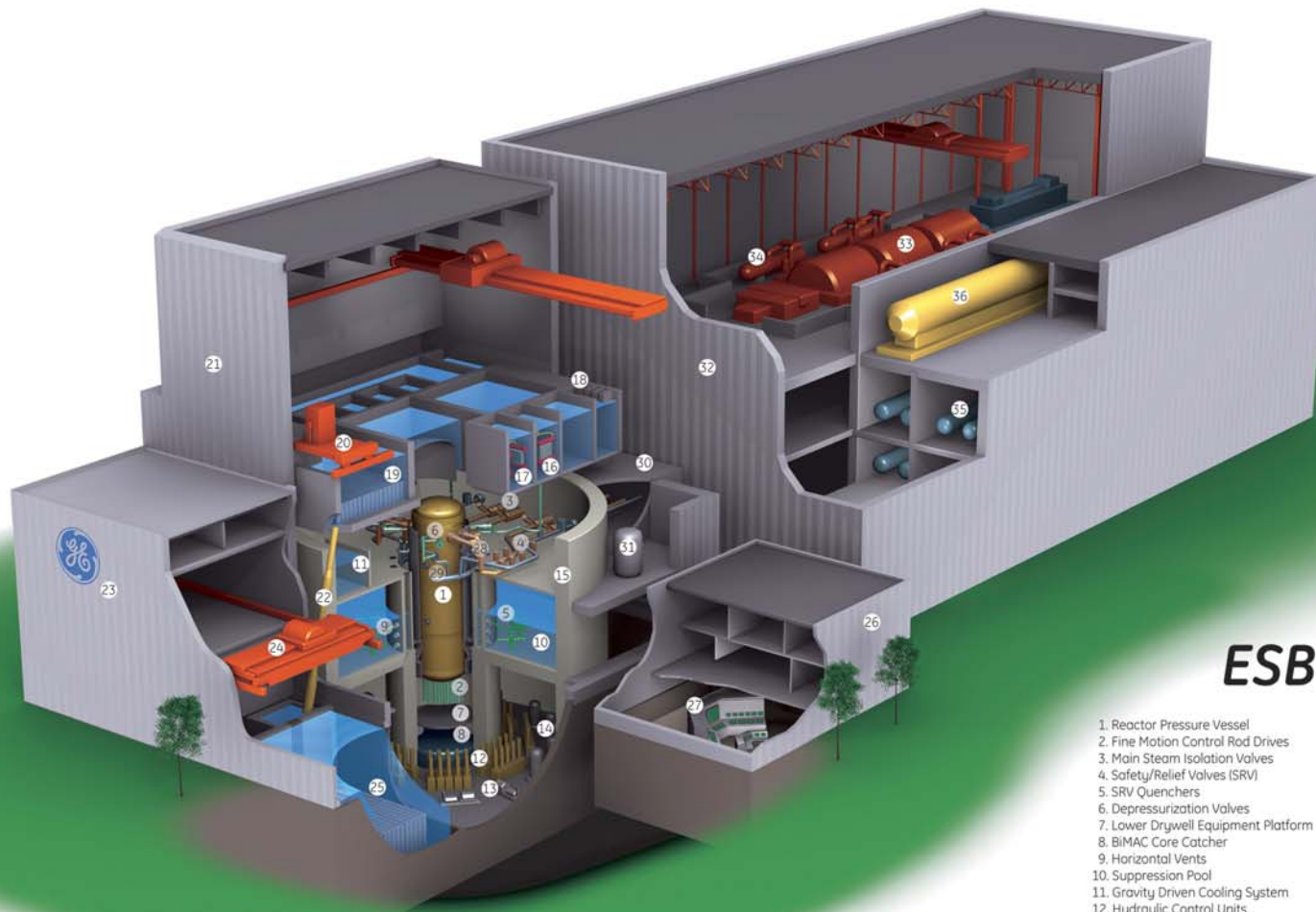


ESBWR Overview



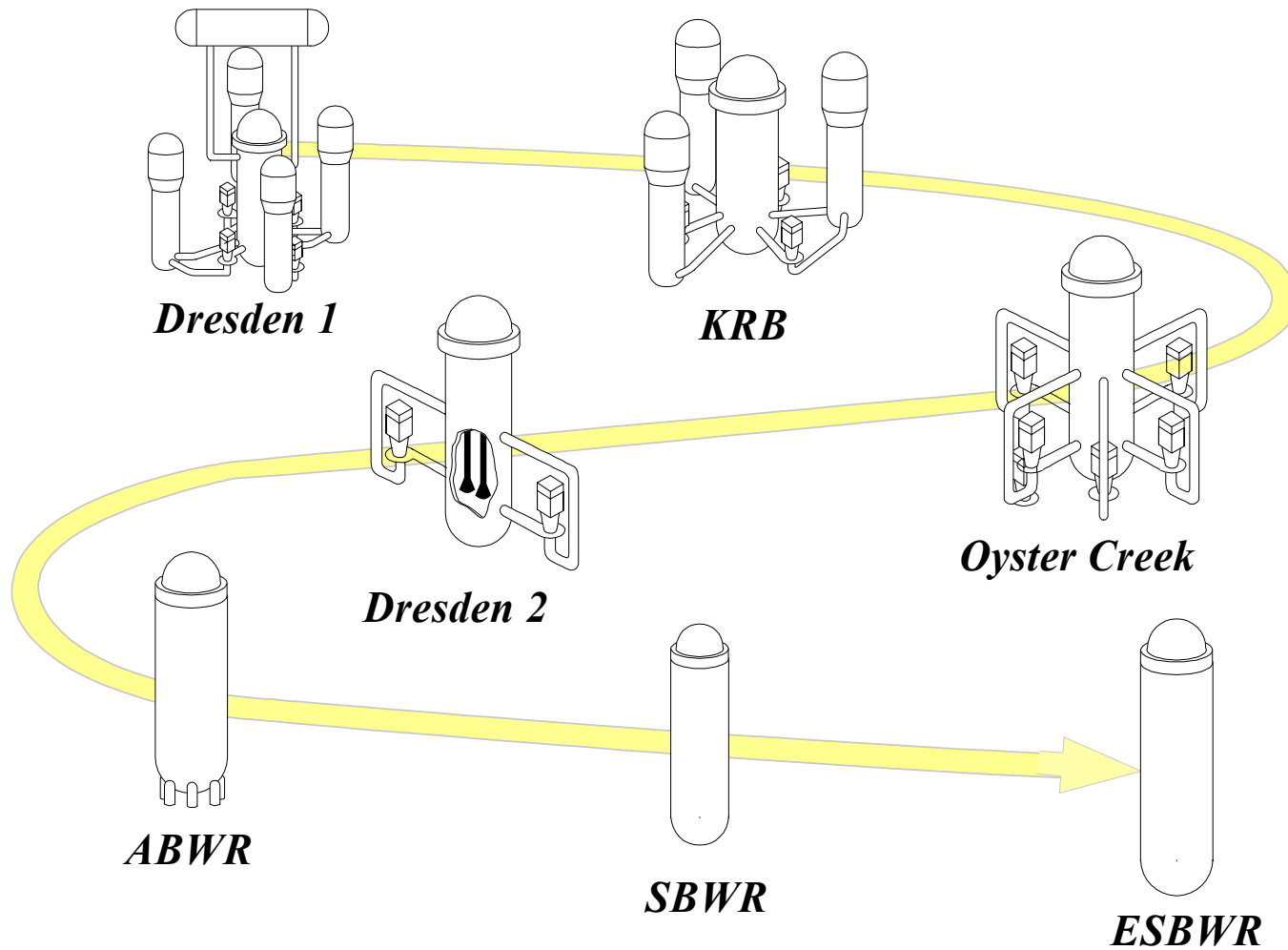
J. Alan Beard
March 23, 2006



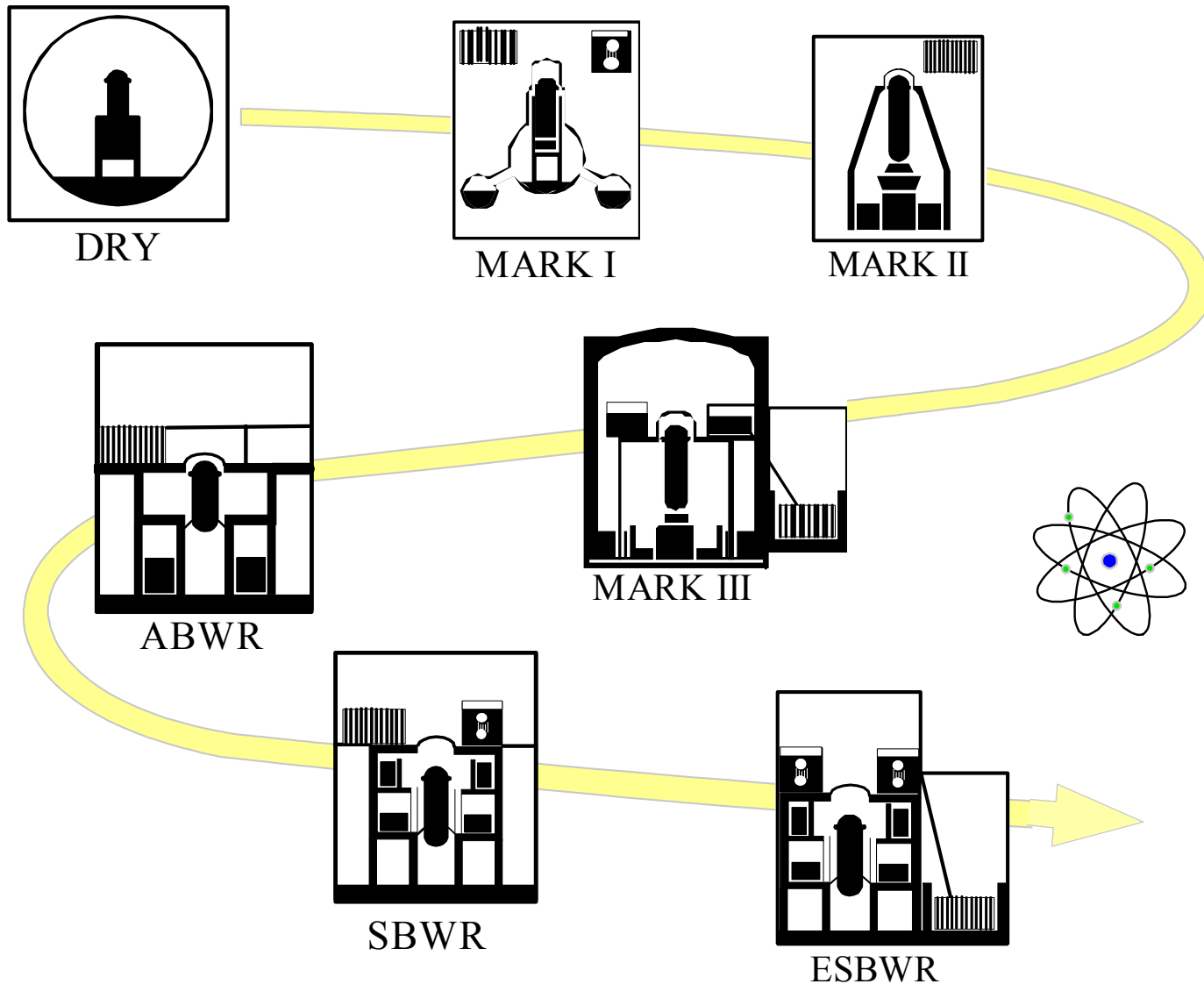
ESBWR

- | | |
|---|---|
| 1. Reactor Pressure Vessel | 19. Buffer Fuel Storage Pool |
| 2. Fine Motion Control Rod Drives | 20. Refueling Machine |
| 3. Main Steam Isolation Valves | 21. Reactor Building |
| 4. Safety/Relief Valves (SRV) | 22. Inclined Fuel Transfer Machine |
| 5. SRV Quenchers | 23. Fuel Building |
| 6. Depressurization Valves | 24. Fuel Transfer Machine |
| 7. Lower Drywell Equipment Platform | 25. Spent Fuel Storage Pool |
| 8. BIMAC Core Catcher | 26. Control Building |
| 9. Horizontal Vents | 27. Main Control Room |
| 10. Suppression Pool | 28. Feedwater Lines |
| 11. Gravity Driven Cooling System | 29. Feedwater Lines |
| 12. Hydraulic Control Units | 30. Steam Tunnel |
| 13. Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) Pumps | 31. Standby Liquid Control System Accumulator |
| 14. RWCU/SDC Heat Exchangers | 32. Turbine Building |
| 15. Containment Vessel | 33. Turbine-Generator |
| 16. Isolation Condensers | 34. Moisture Separator Reheater |
| 17. Passive Containment Cooling System | 35. Feedwater Heaters |
| 18. Moisture Separators | 36. Direct Contact Feedwater Heater and Tank |

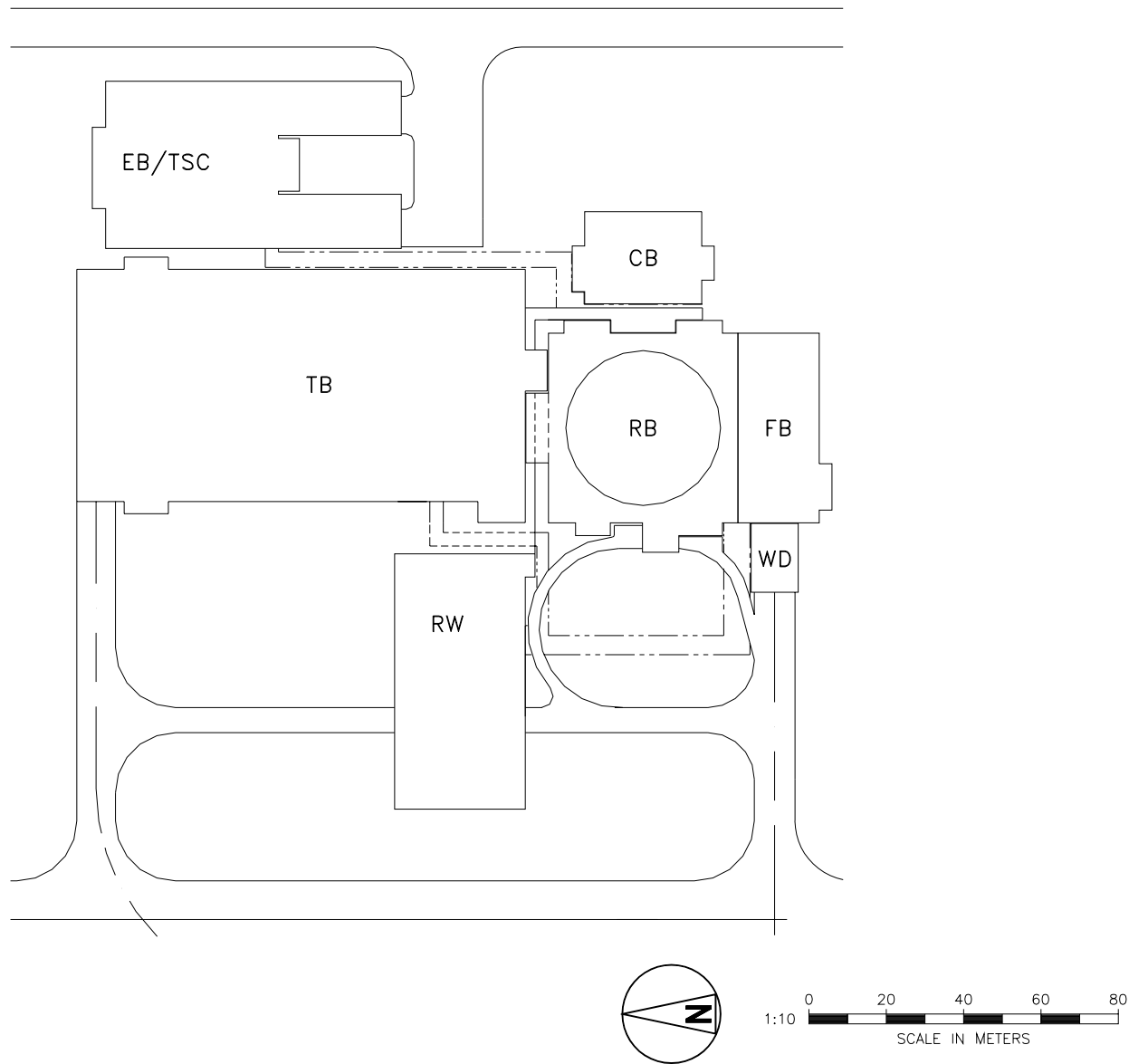
BWR Evolution



Containment Evolution

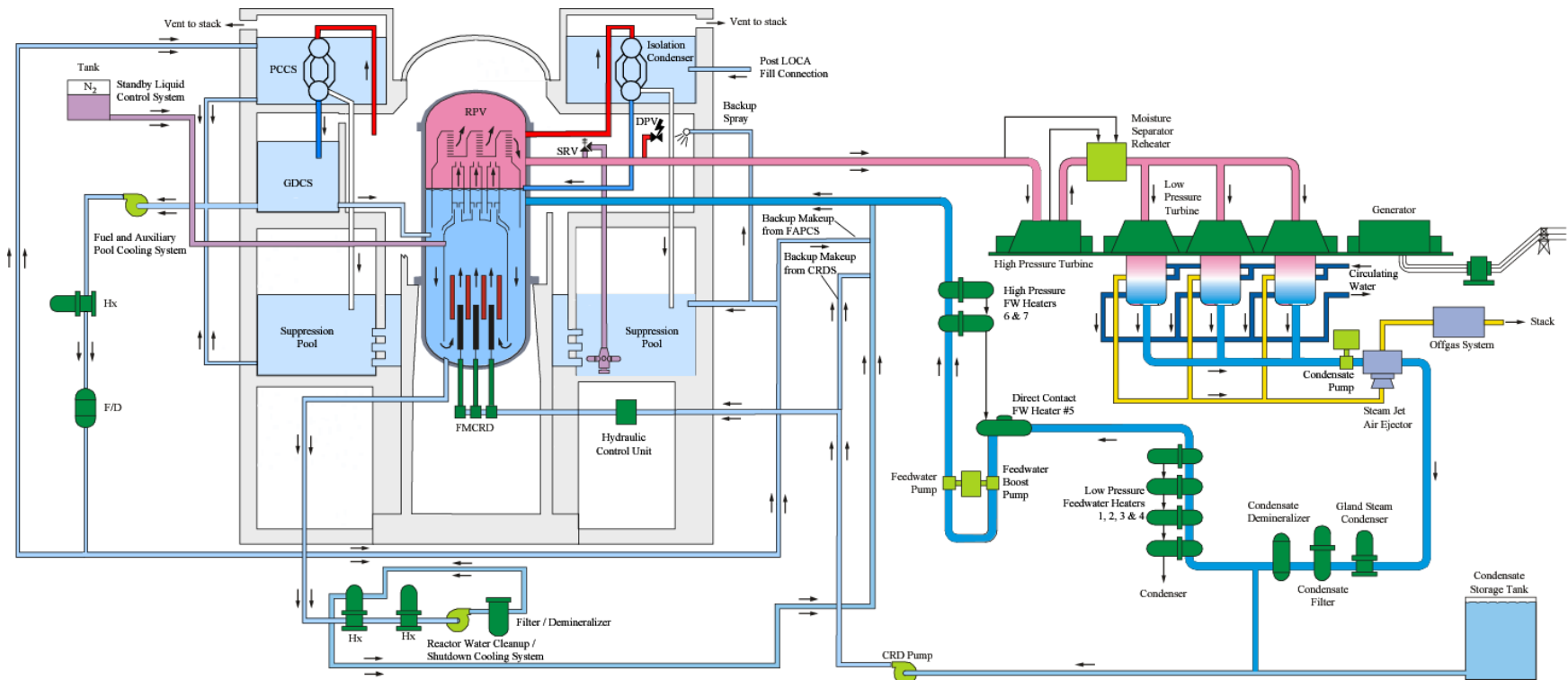


Power Block Arrangement



ESBWR Basic Parameters

- 4,500 Megawatt Core Thermal Power
- ~1, 575 to 1,600 Megawatt Electric Gross
 - > Nominal Summer Rating
- Natural Circulation
 - > No recirculation pumps
- Passive Safety Systems
 - > 72 hours passive capability

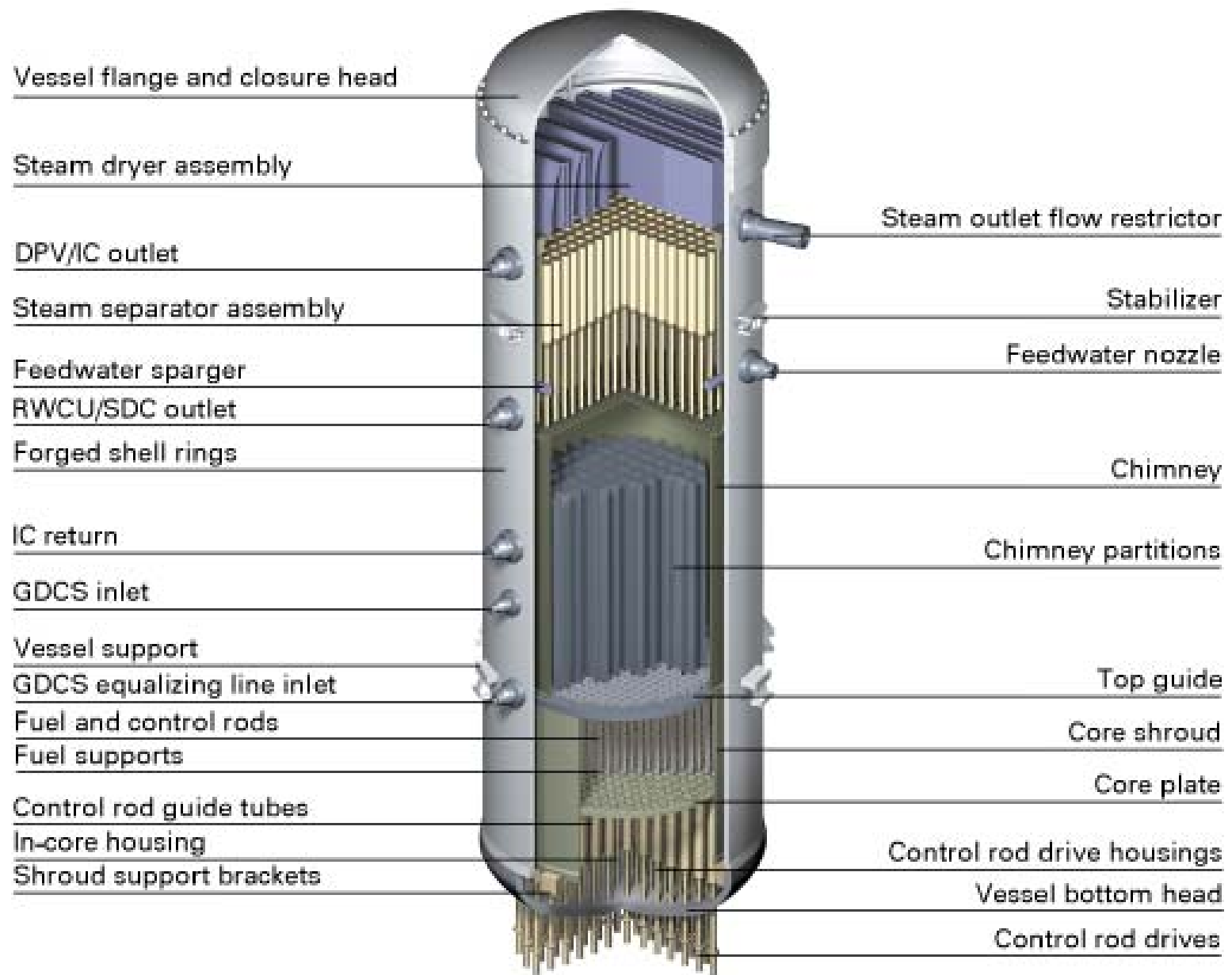


What's different about ESBWR

ABWR	ESBWR
Recirculation System + support systems	Eliminated
HPCF System (2 each)	} Eliminated need for ECCS pumps Utilize passive and stored energy
LPFL (3 each)	
Residual Heat Removal (3 each)	
Safety Grade Diesel Generators (3 each)	Non-safety, combined with cleanup system
RCIC	Eliminated – only 2 non-safety grade diesels
SLC –2 pumps	Replaced with IC heat exchangers
Reactor Building Service Water (Safety Grade) And Plant Service Water (Safety Grade)	Replaced pumps with accumulators
	Made non-safety grade

Optimized Parameters for ESBWR

<u>Parameter</u>	<u>BWR/4-Mk I</u> (Browns Ferry 3)	<u>BWR/6-Mk III</u> (Grand Gulf)	<u>ABWR</u>	<u>ESBWR</u>
Power (MWt/MWe)	3293/1098	3900/1360	3926/1350	4500/1590
Vessel height/dia. (m)	21.9/6.4	21.8/6.4	21.1/7.1	27.7/7.1
Fuel Bundles (number)	764	800	872	1132
Active Fuel Height (m)	3.7	3.7	3.7	3.0
Power density (kw/l)	50	54.2	51	54
Recirculation pumps	2(large)	2(large)	10	zero
Number of CRDs/type	185/LP	193/LP	205/FM	269/FM
Safety system pumps	9	9	18	zero
Safety diesel generator	2	3	3	zero
Core damage freq./yr	1E-5	1E-6	1E-7	3E-8
Safety Bldg Vol (m ³ /MWe)	115	150	160	< 130



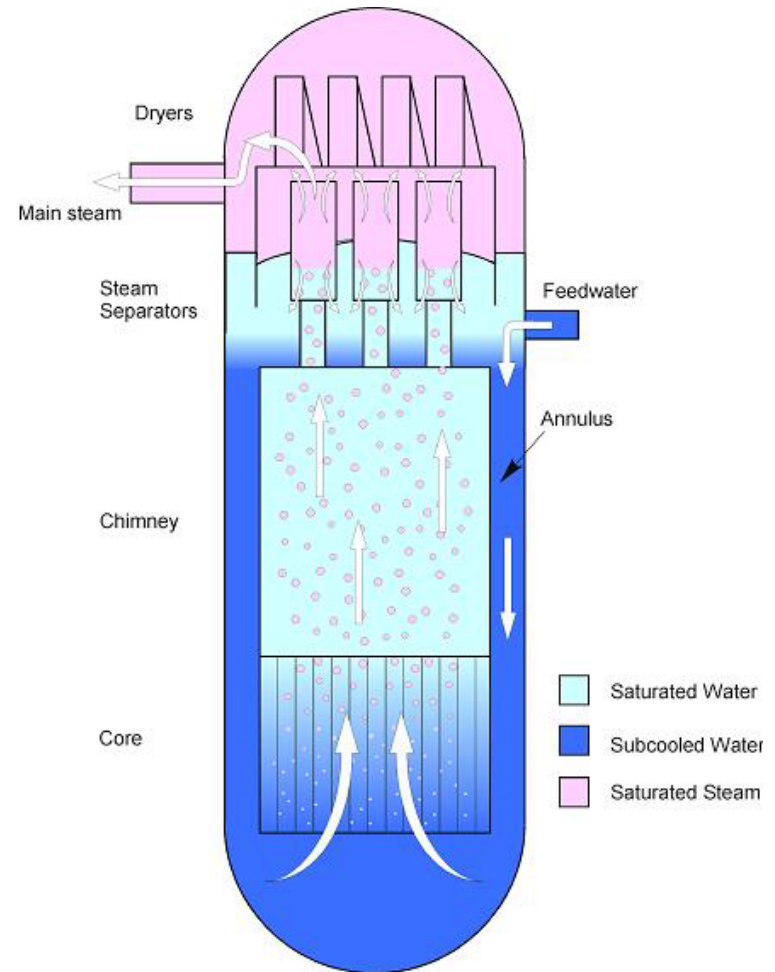
Other Design Improvements

- 110% Steam Bypass
 - > Island Mode of Operation
- Fine Motion Control Rod Drives (FMCRD)
- Shoot-out Steel Eliminated
- Integrated Head Vent Pipe
- Improved Incore Instrumentation
 - > Start-up Range Neutron Monitor (SRNM)
 - > Gamma Thermometer
 - No Traversing Incore Probe (TIP)

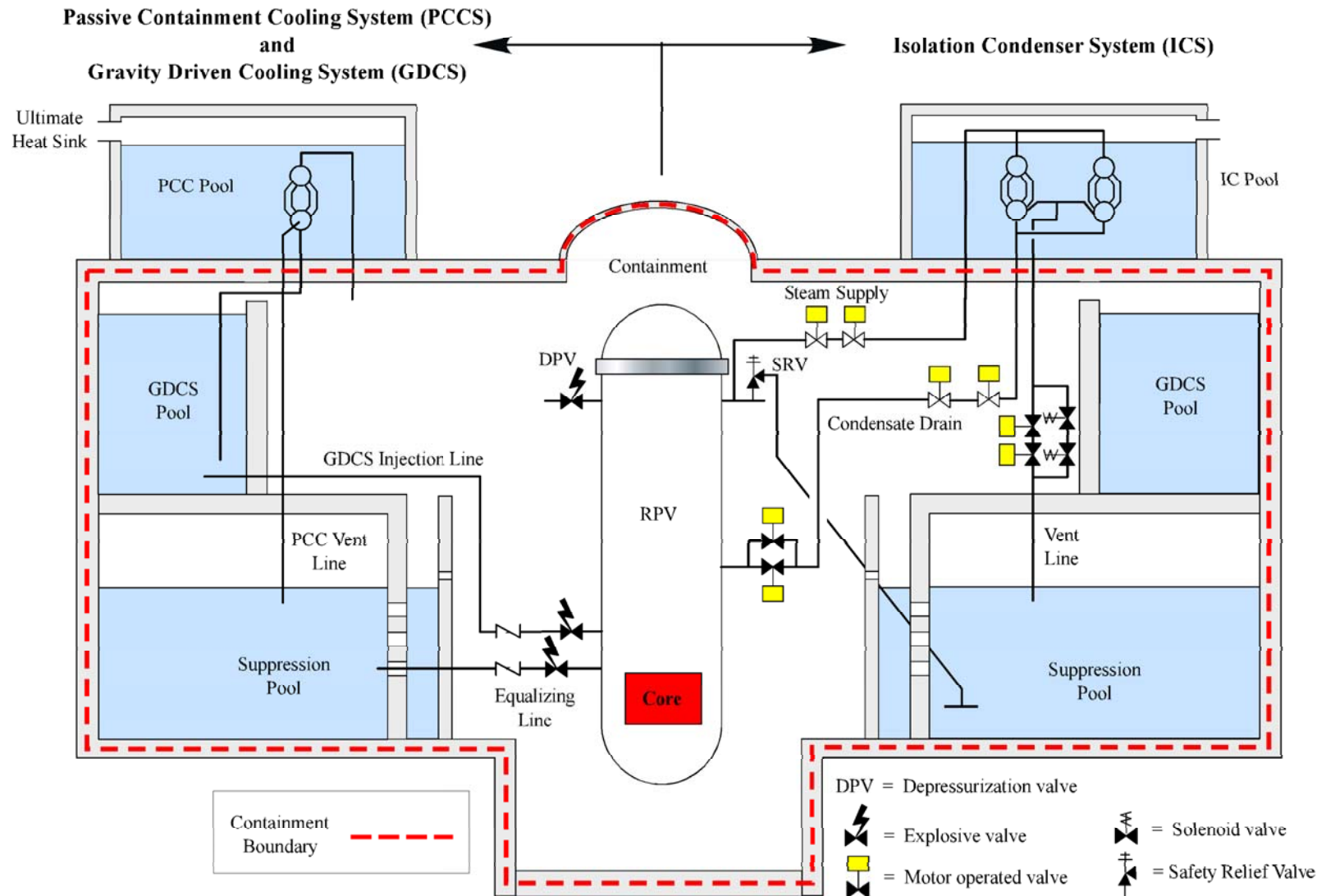
Natural Circulation

Simplification without performance loss ..

- **Passive safety/natural circulation**
 - Increase the volume of water in the vessel
 - Increase driving head
- **Significant reduction in components**
 - Pumps, motors, controls, HXers
- **Power Changes with Control Rod Drives**
 - Minimal impact on maintenance



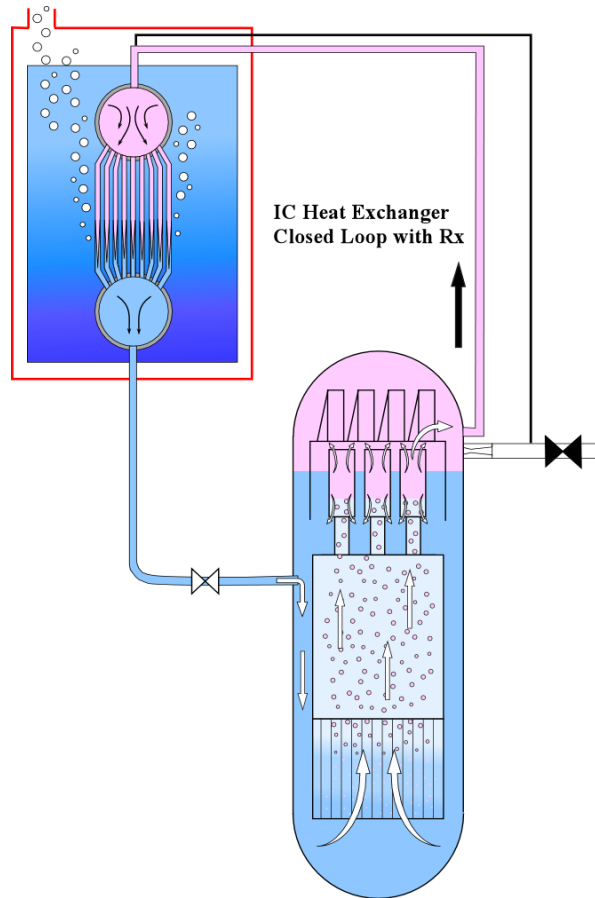
Passive Safety



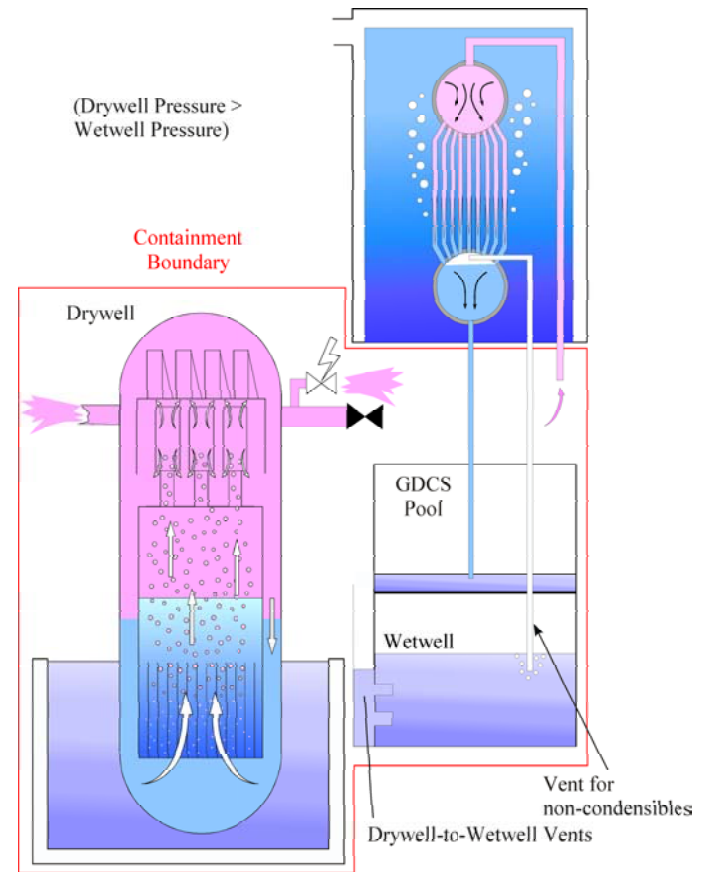
imagination at work

Passive Safety Systems ...

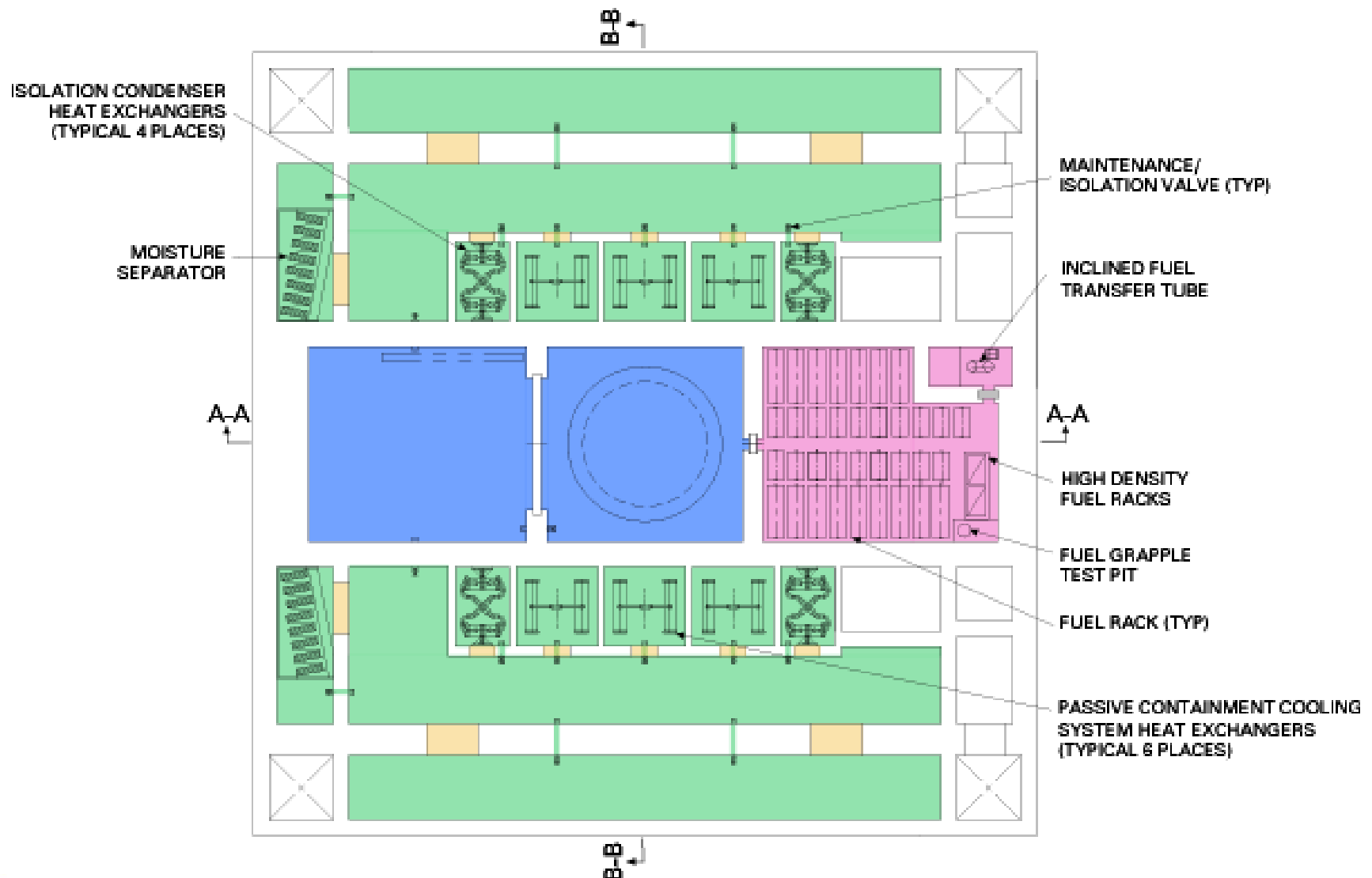
Isolation Condenser System



Passive Containment Cooling



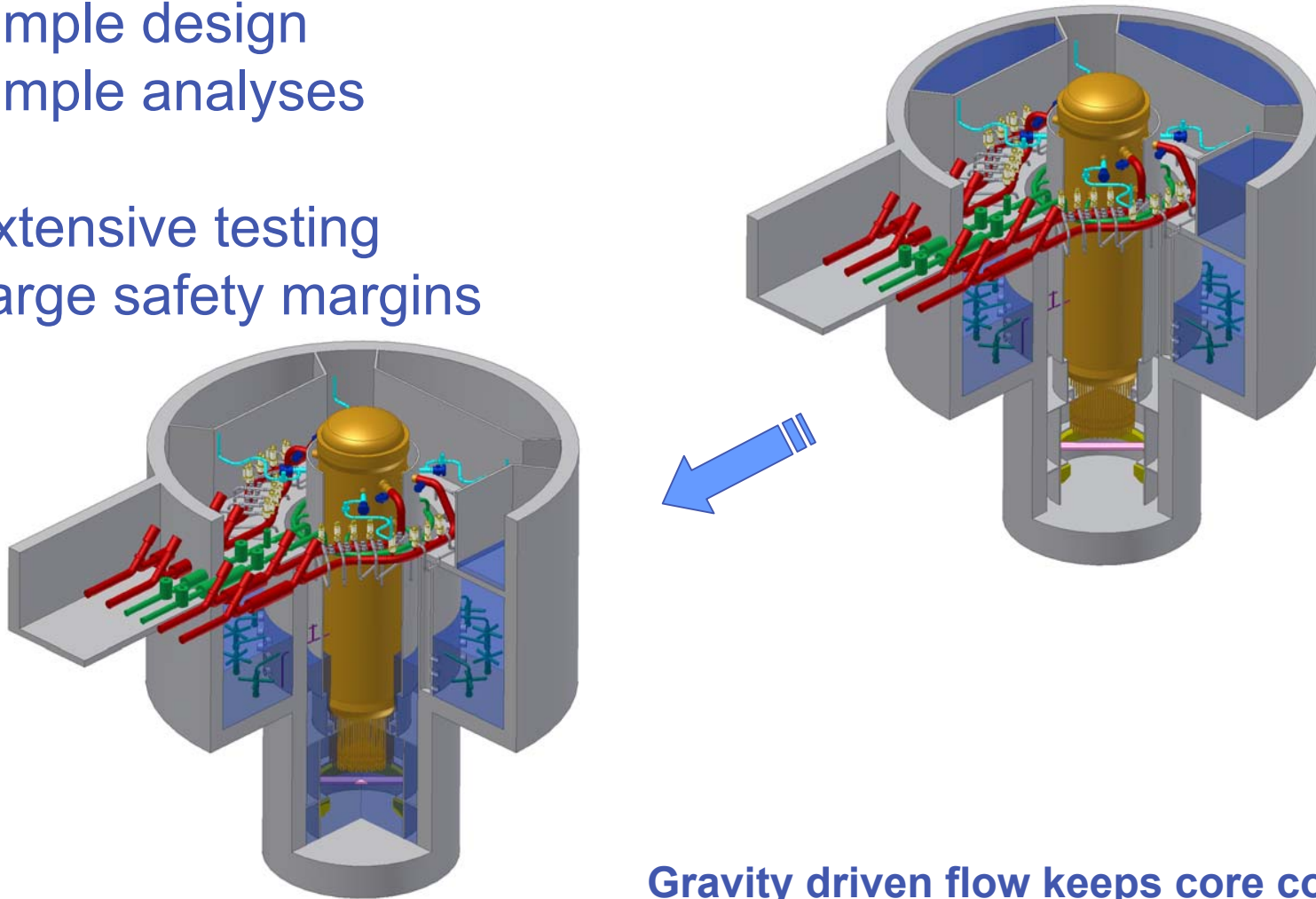
72 Hours Passive Capability



Gravity Driven Cooling System ...

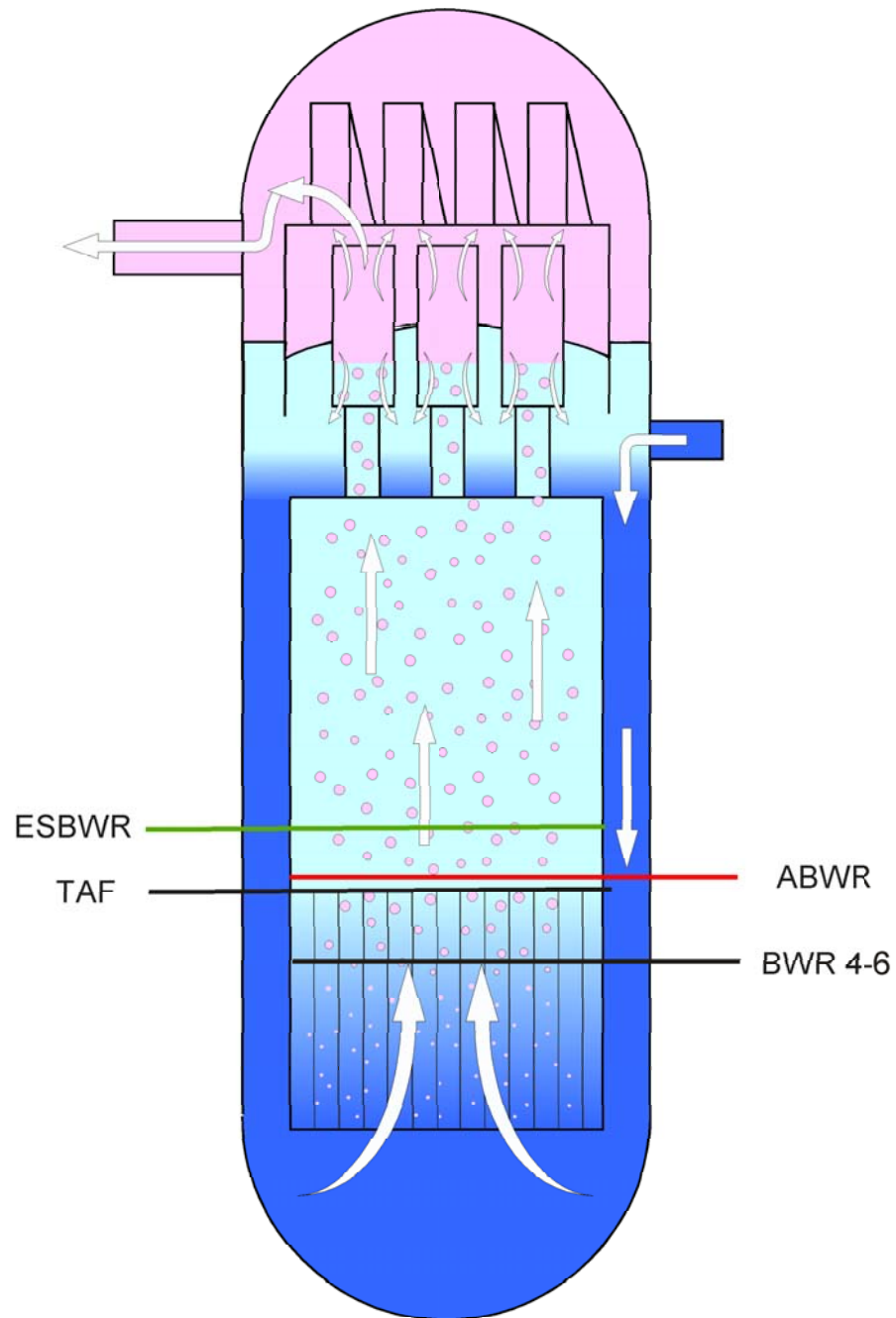
Simple design
Simple analyses

Extensive testing
Large safety margins

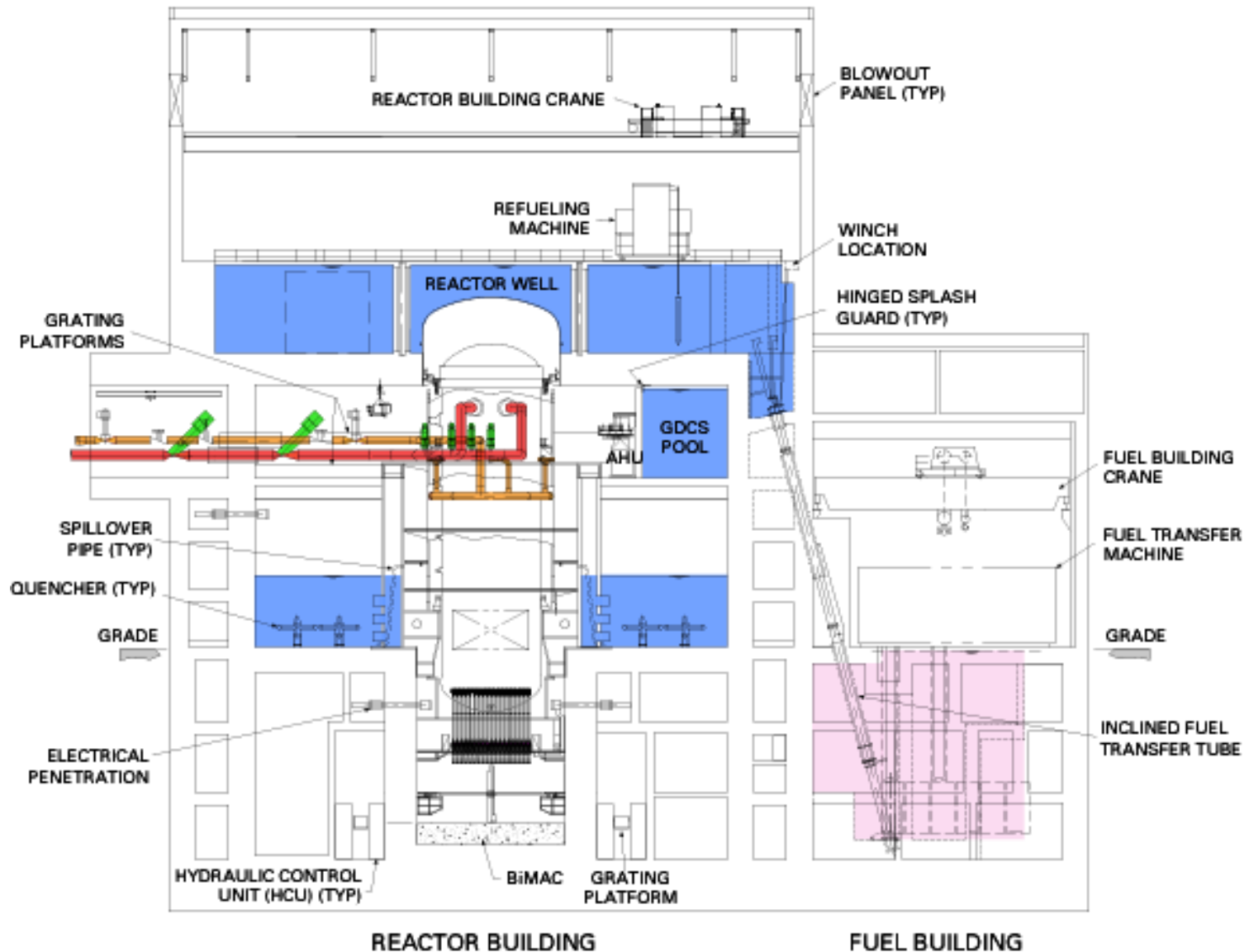


Gravity driven flow keeps core covered

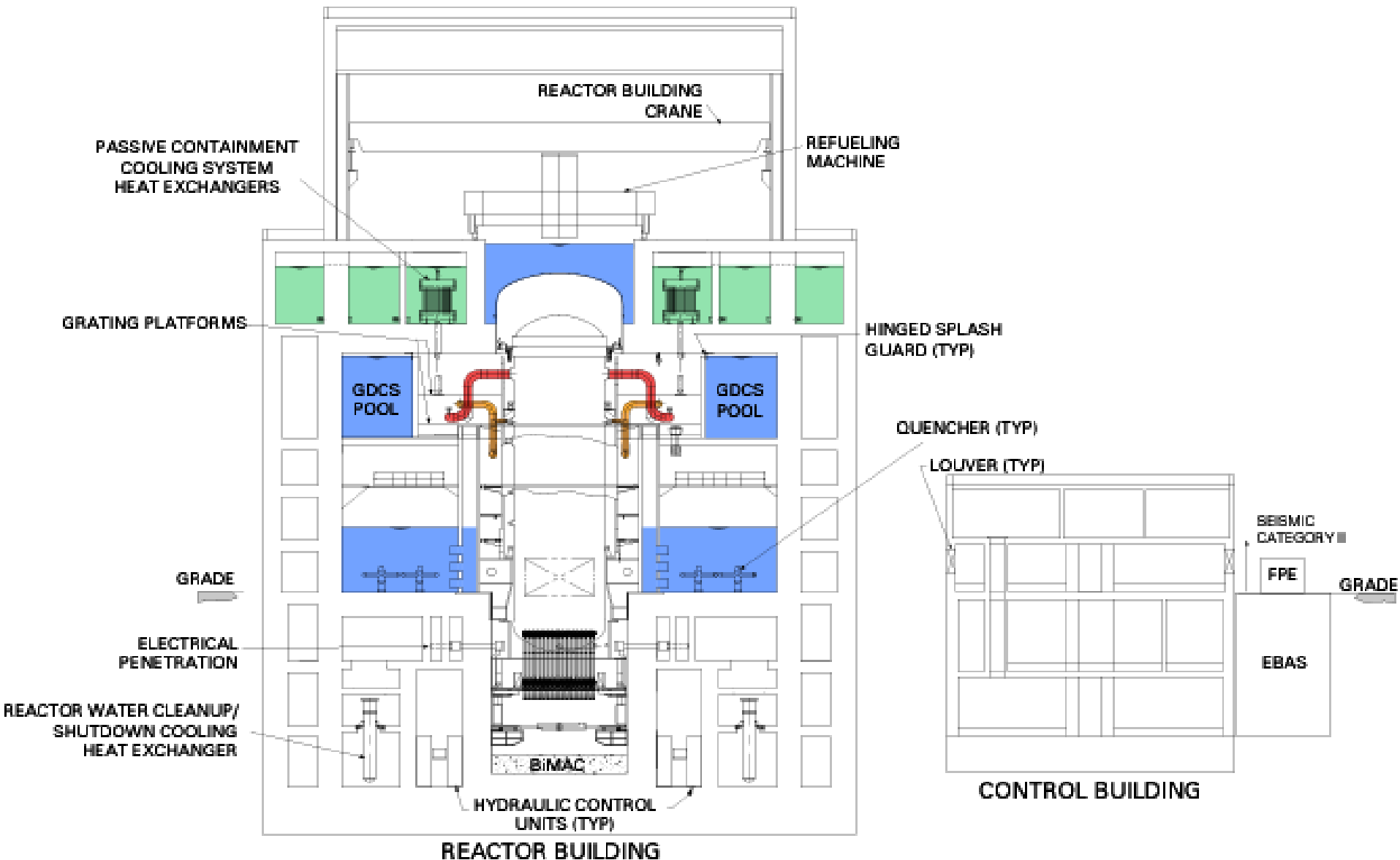
LOCA Water Level Response



Reactor and Fuel Building

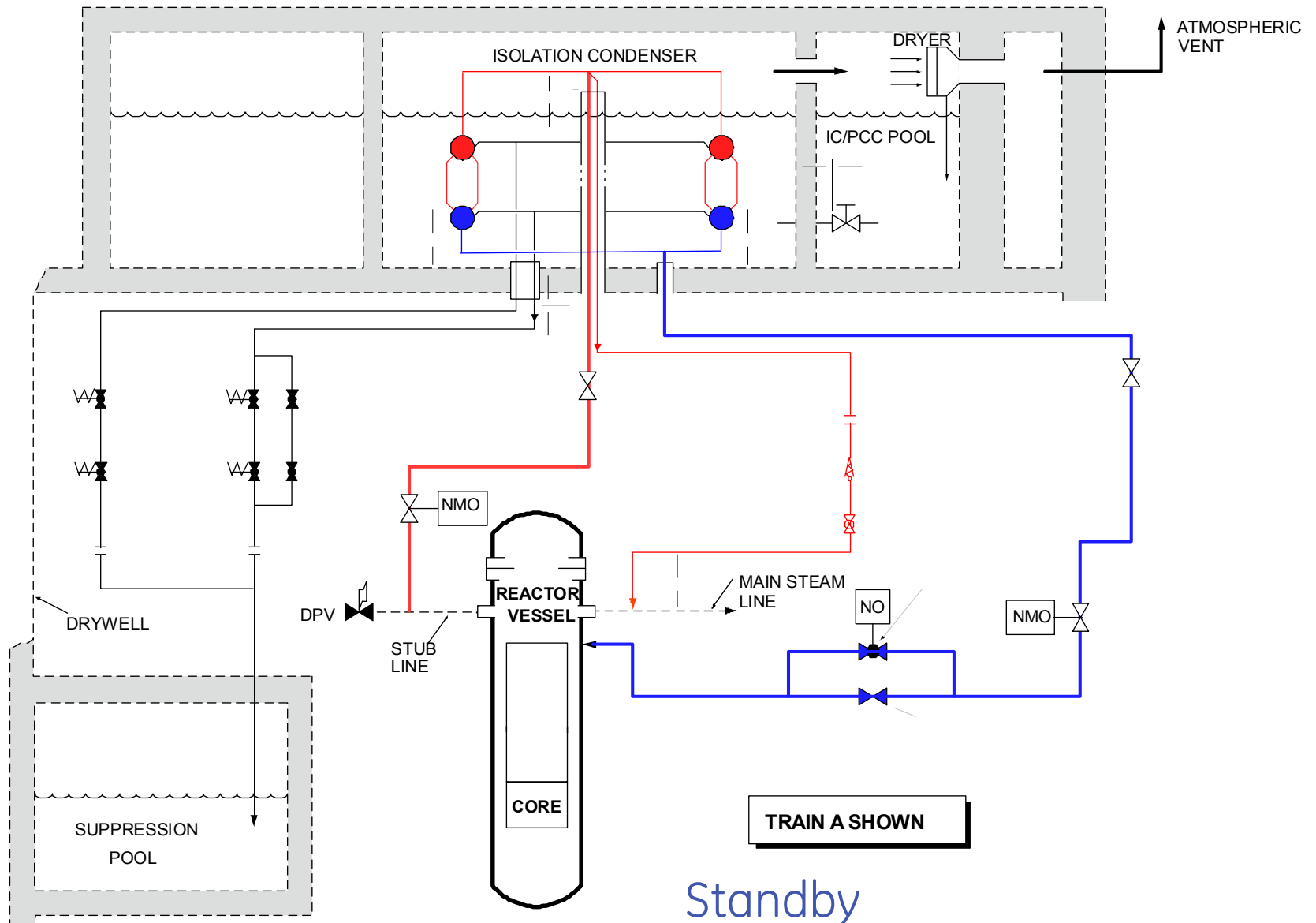


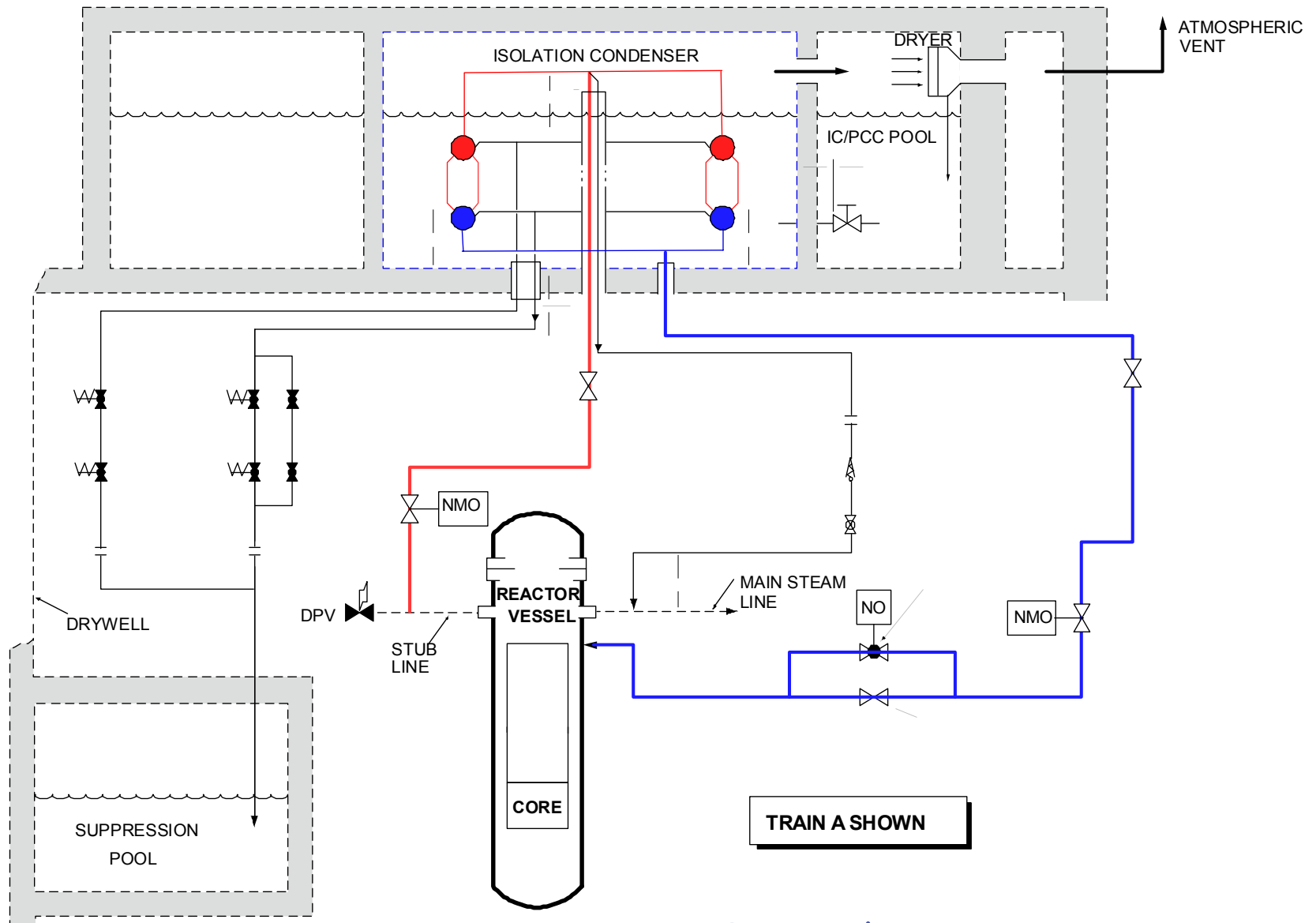
Containment



Isolation Condensers

- ICs provide passive decay heat removal
 - > Single Failure Criteria apply
 - > No lift of the Safety Relief Valves (SRVs)
 - > Operates in all Design Basis Conditions except medium and large break LOCAs
 - > ICs transport decay heat direct from NSSS to the Ultimate Heat Sink
 - > No steaming in the primary containment
 - > Rapidly reduces RPV pressure
 - > Redundant Active Components

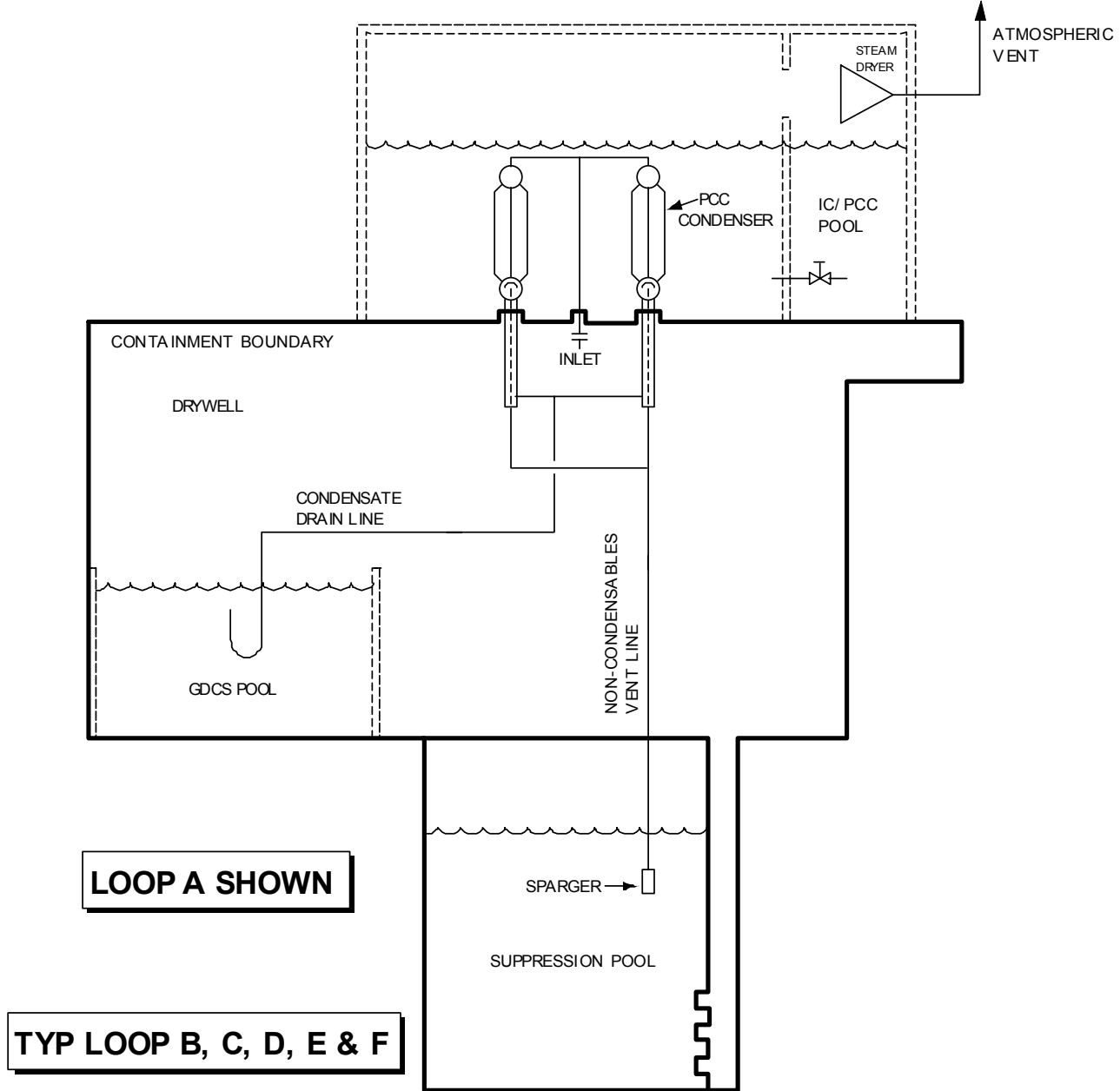




Operation

Passive Containment Cooling

- PCCs provide passive decay heat removal from the primary containment
 - > Operates in medium and large break LOCAs
 - > Provides backup of ICs if needed
 - RPV is depressurized using DPVs
 - > Entirely Passive
 - ~40 hours with demineralized water
 - > PCCs transport decay heat direct from Primary Containment to the Ultimate Heat Sink



imagination at work

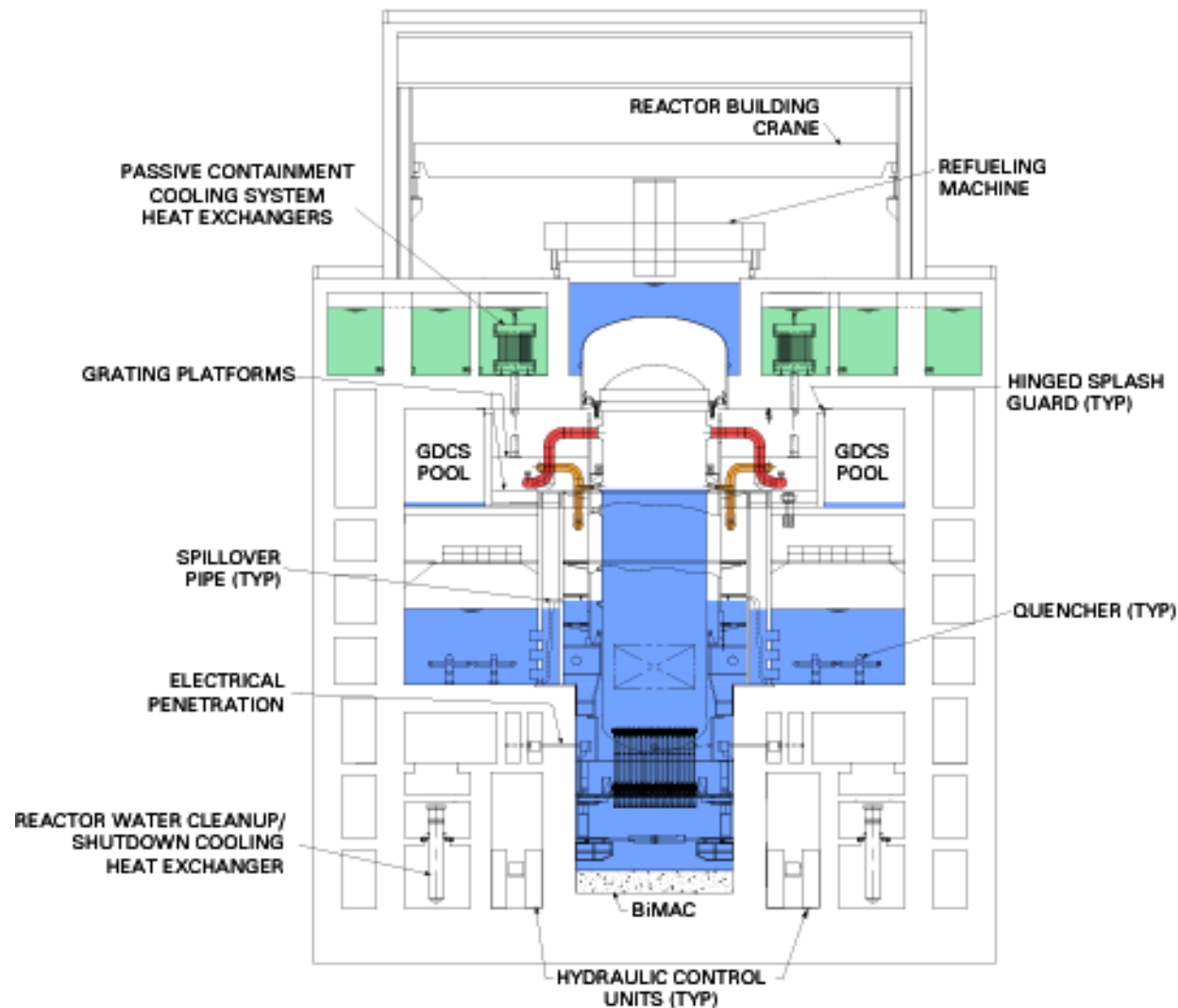
Emergency Core Cooling (ECC)

- Gravity Driven Cooling System (GDACS)
 - > Three Pools
 - > Four Trains
- Automatic Depressurization System (ADS)
 - > 10 of 18 Safety Relief Valves (SRV)
 - Pneumatic actuation
 - No relief mode
 - > 8 Depressurization Valves (DPV)
 - Squib actuated
 - Each squib can be fired by 2 divisions

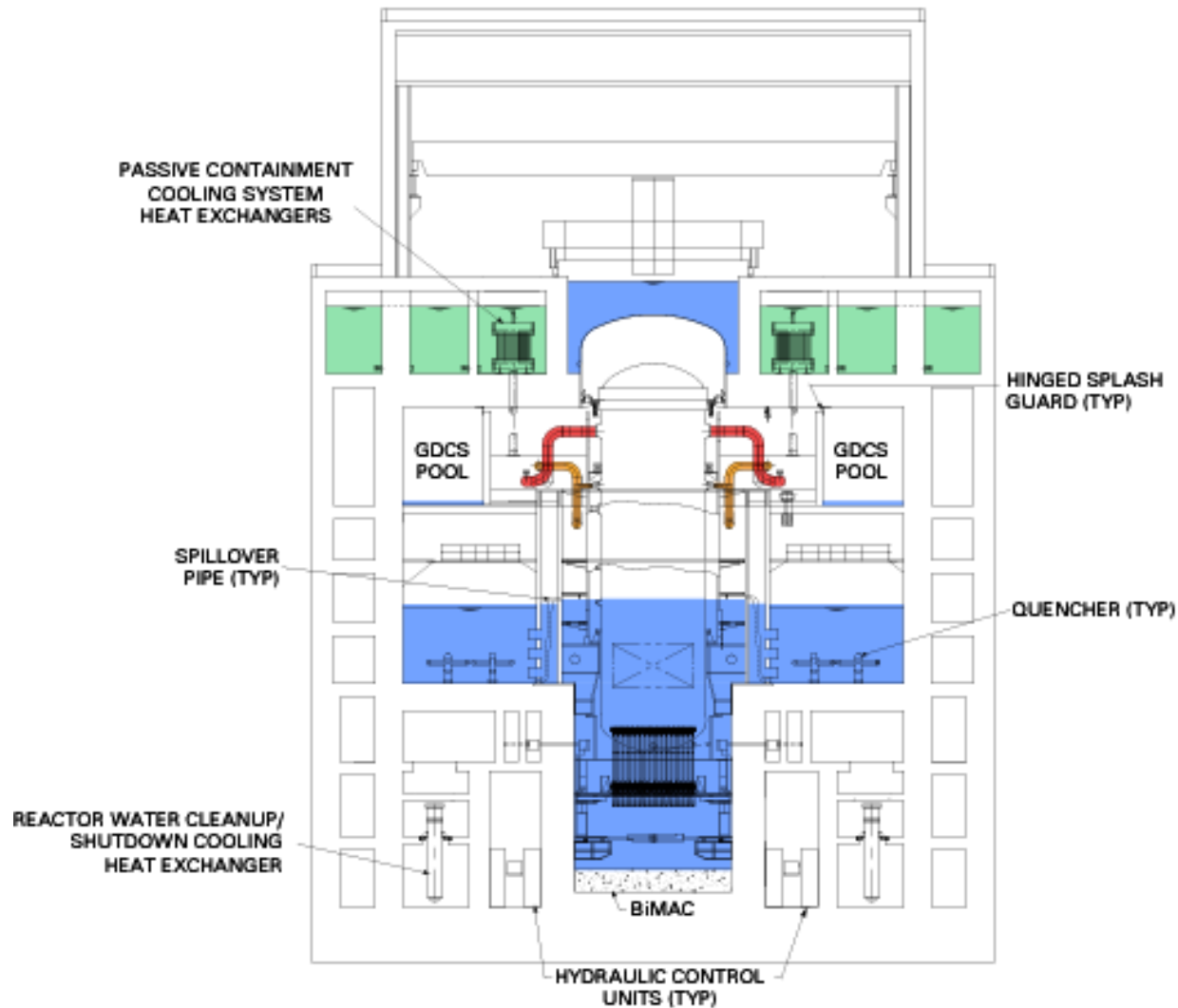
Emergency Core Cooling (cont)

- GDCS lines are squib actuated
- Core remains covered for entire range of Design Basis Accidents
 - > No fuel heat-up
- Complies with 10 CFR 50.46
 - > Codes have been approved by NRC
- Stored water is sufficient to flood containment and RPV to above the top of fuel
 - > 1 meter above TAF or better
 - All events

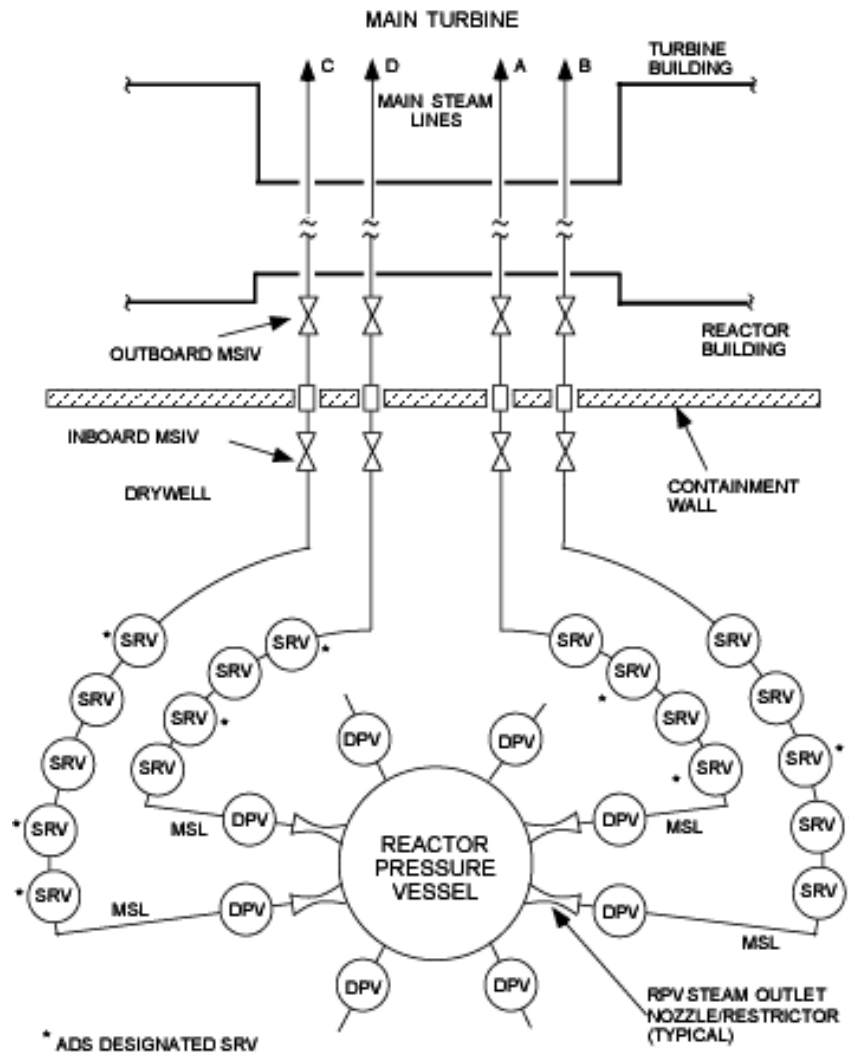
ESBWR Water Level Management – FW Line Break



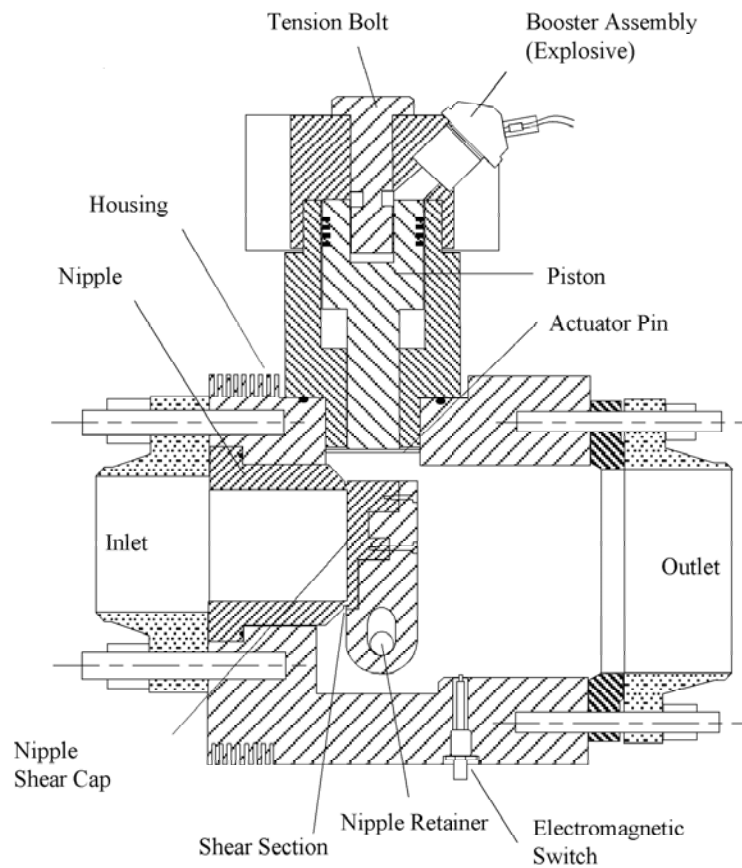
ESBWR Water Level Management – BDL Break



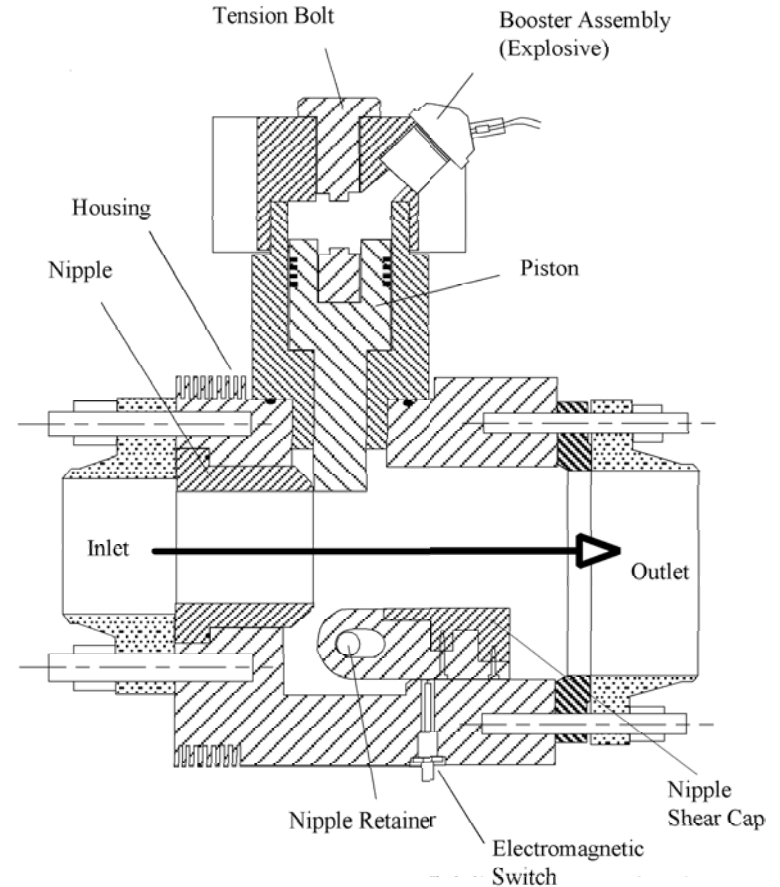
MSIV, SRV and DPV Arrangement



Depressurization Valve (DPV)

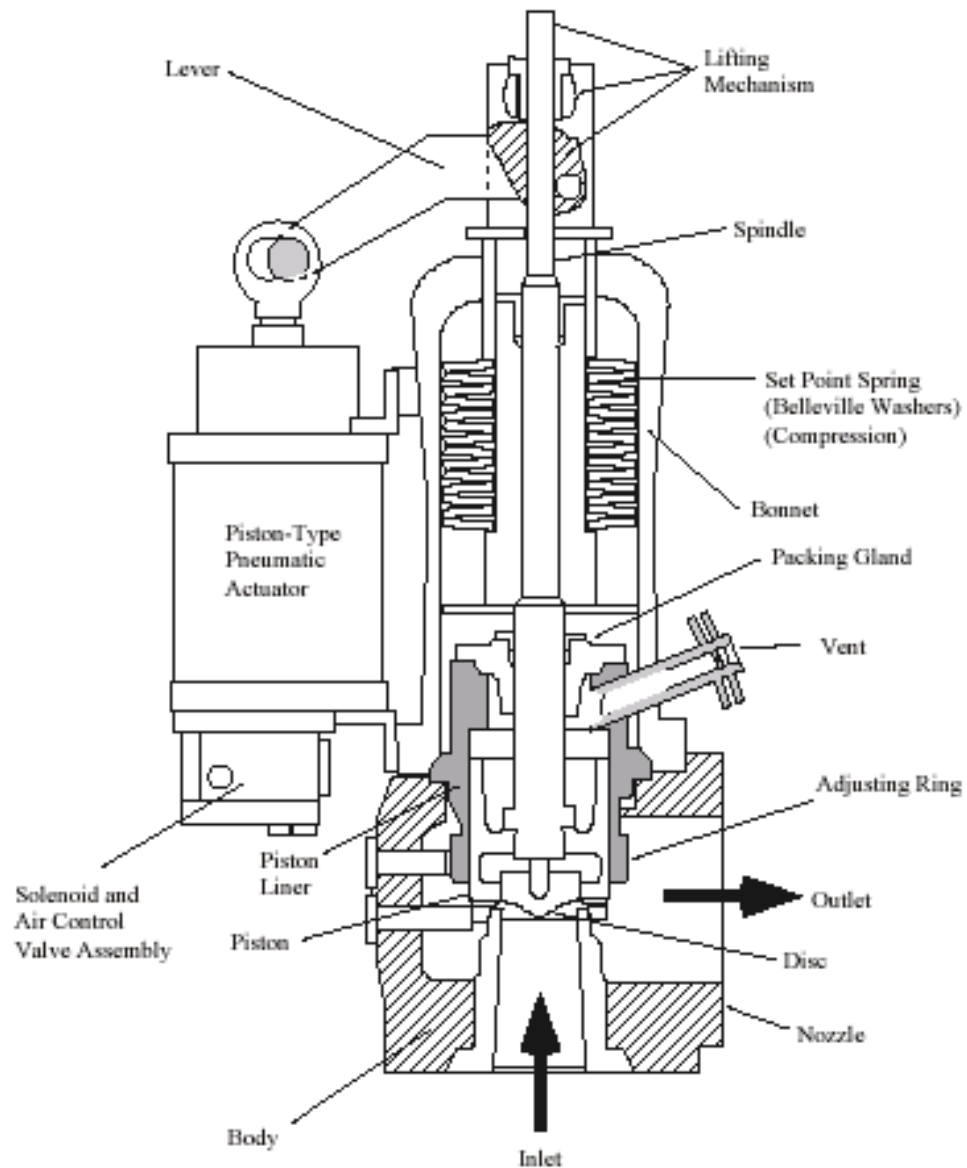


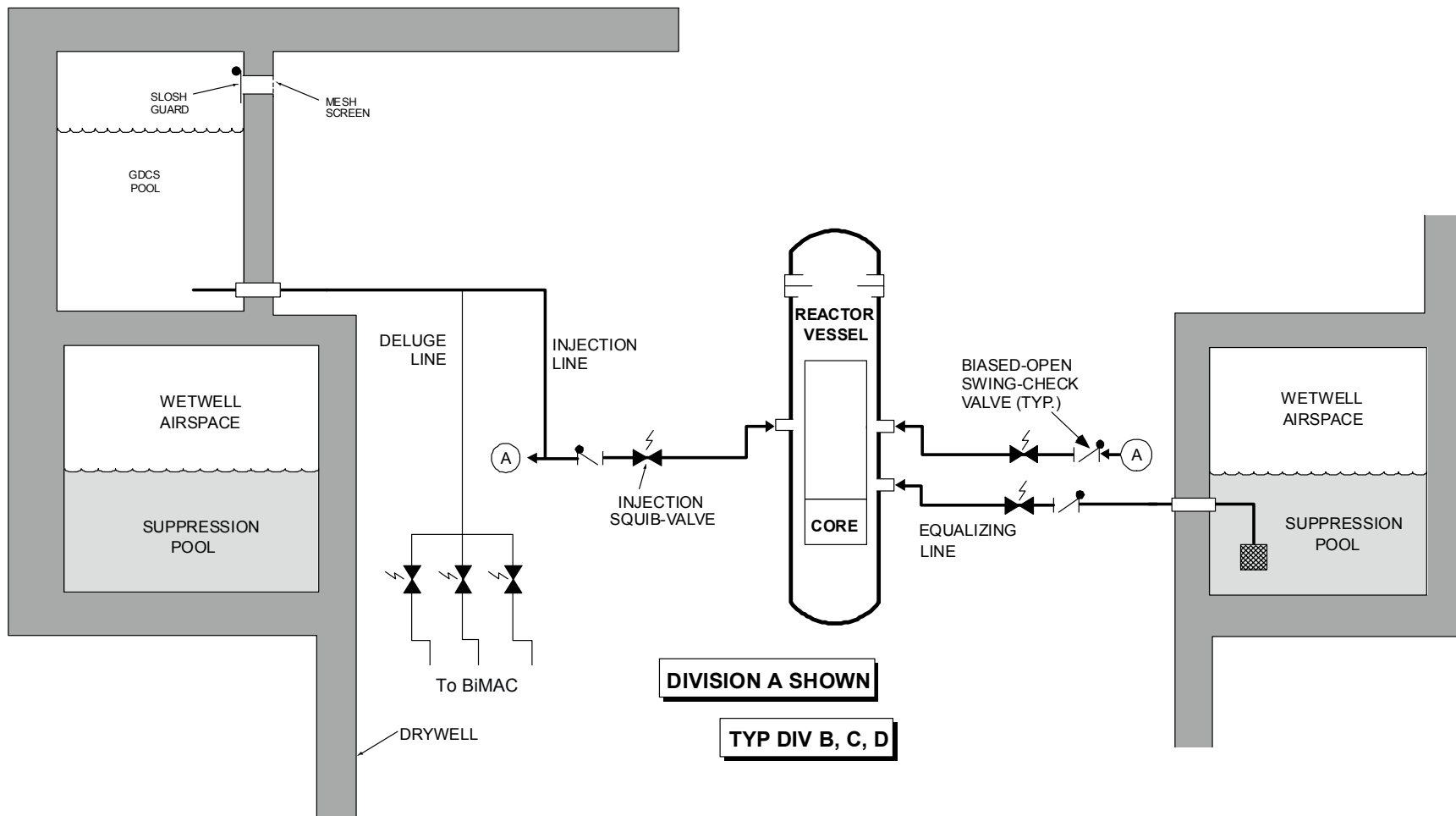
Unfired - Closed



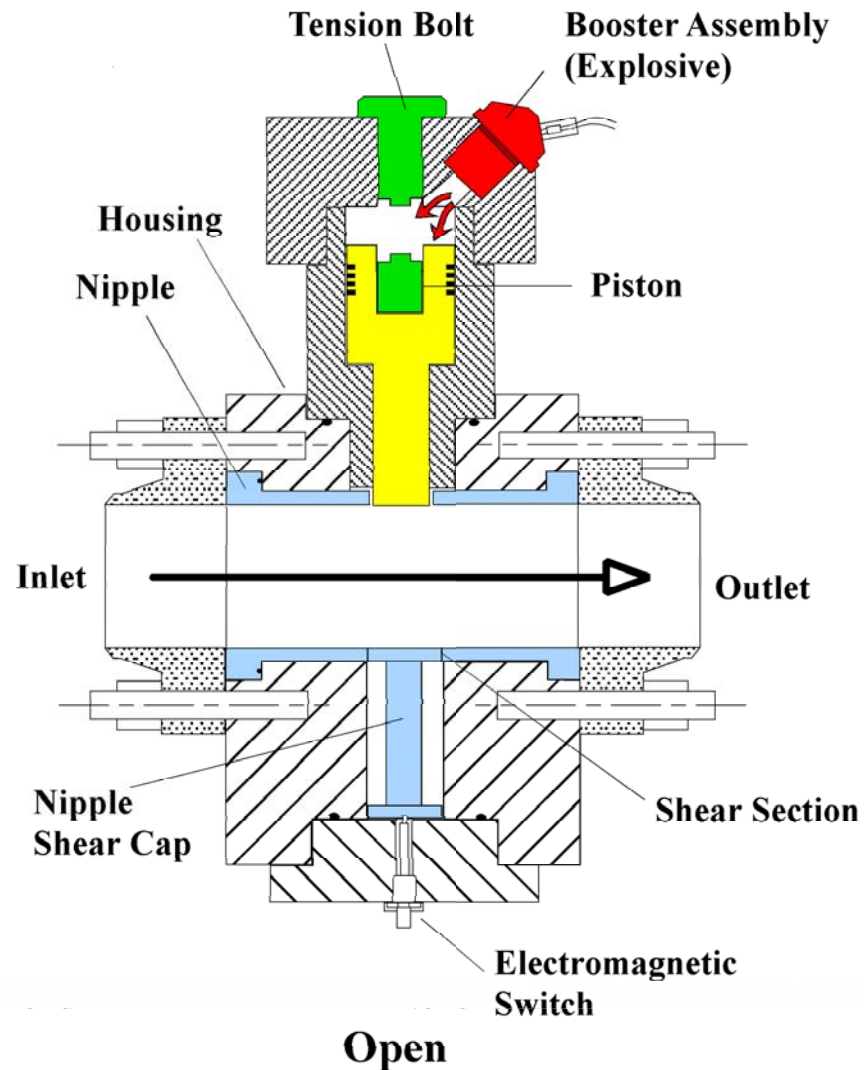
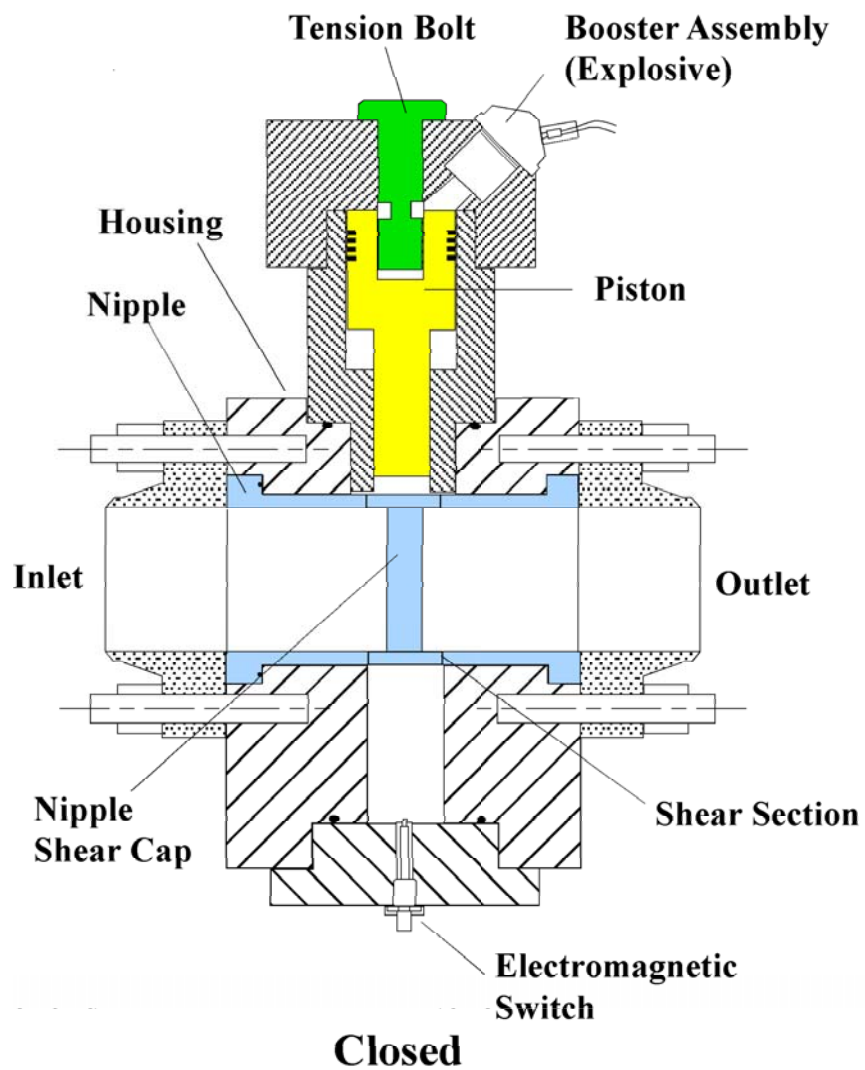
Fired - Open

**Depressurization Valve
Cross Section**





Gravity-Driven Cooling System



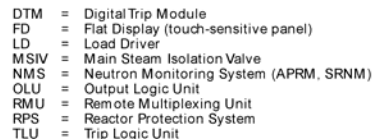
Other Safety-Related Passive Systems

- Digital Instrumentation and Control
 - > Reactor Trip and Isolation
 - > Engineered Safety Features
- Standby Liquid Control (SLC)
 - > Two Pressurized Tanks of Boron
- Emergency Breathing Air System
 - > Main Control Room Habitability
- Vacuum Breakers
- BiMAC

ESBWR Safety System Logic Control (SSLC) Framework

Reactor Protection System

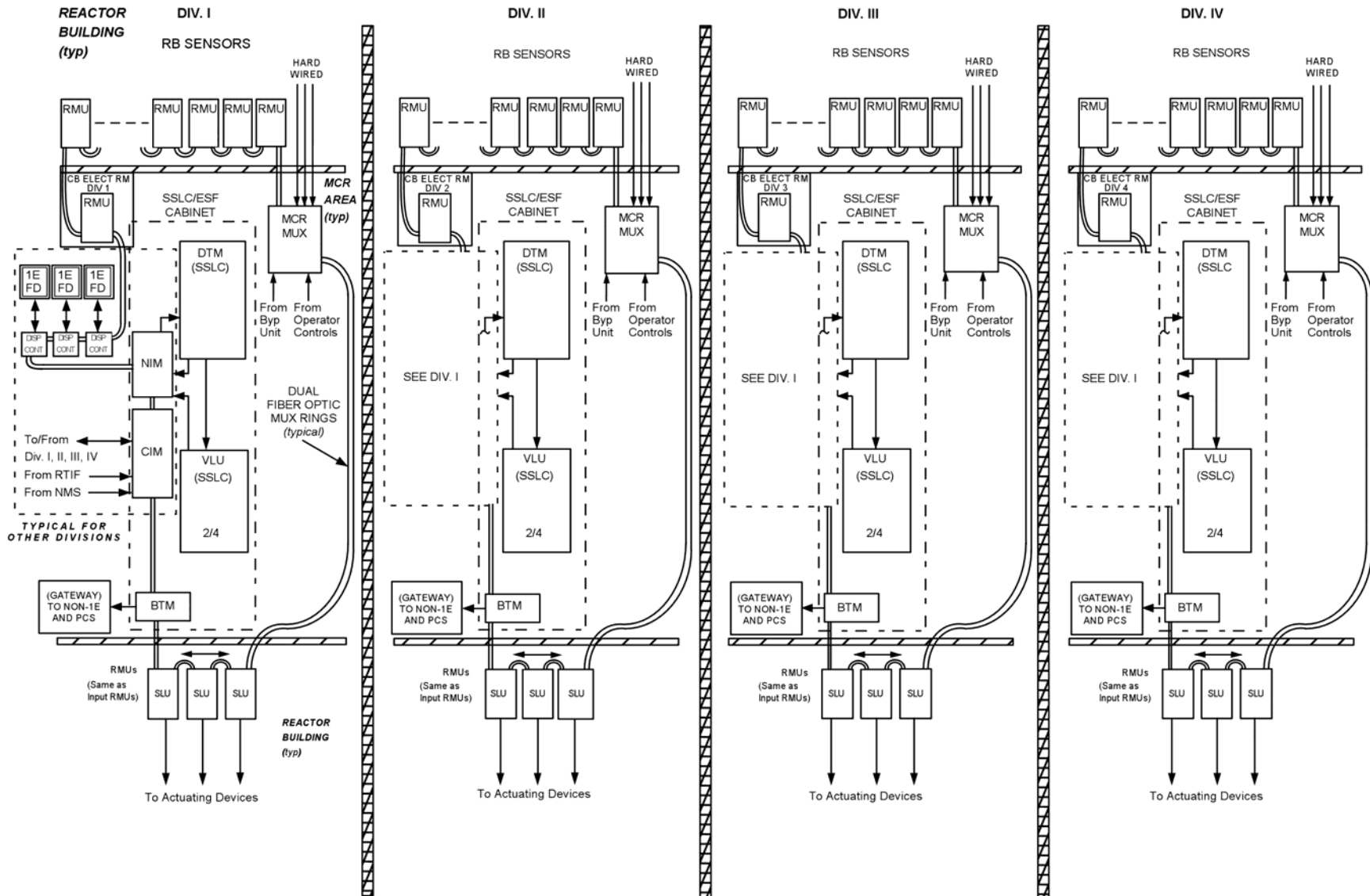
- > Based on ABWR design
 - 2/4 logic
 - Fail safe
 - Deterministic
 - Diverse from ECCS
- > Any two unbypassed same parameters exceeding limits always cause a scram with:
 - Any single logic failure
 - Any division of sensors bypass status
 - Any division of logic bypass status (independent from sensor bypass)
 - Any single power failure
 - Any possible main control room RPS control configuration
- > Each division makes a per parameter trip decision
- > Each division informs other divisions of its trip data (via communication module and isolated fiber optics)
- > Each division makes a 2/4 per parameter decision to scram
- > Two divisions of load drivers – each driven by four divisional trip outputs – control HCU scram solenoids



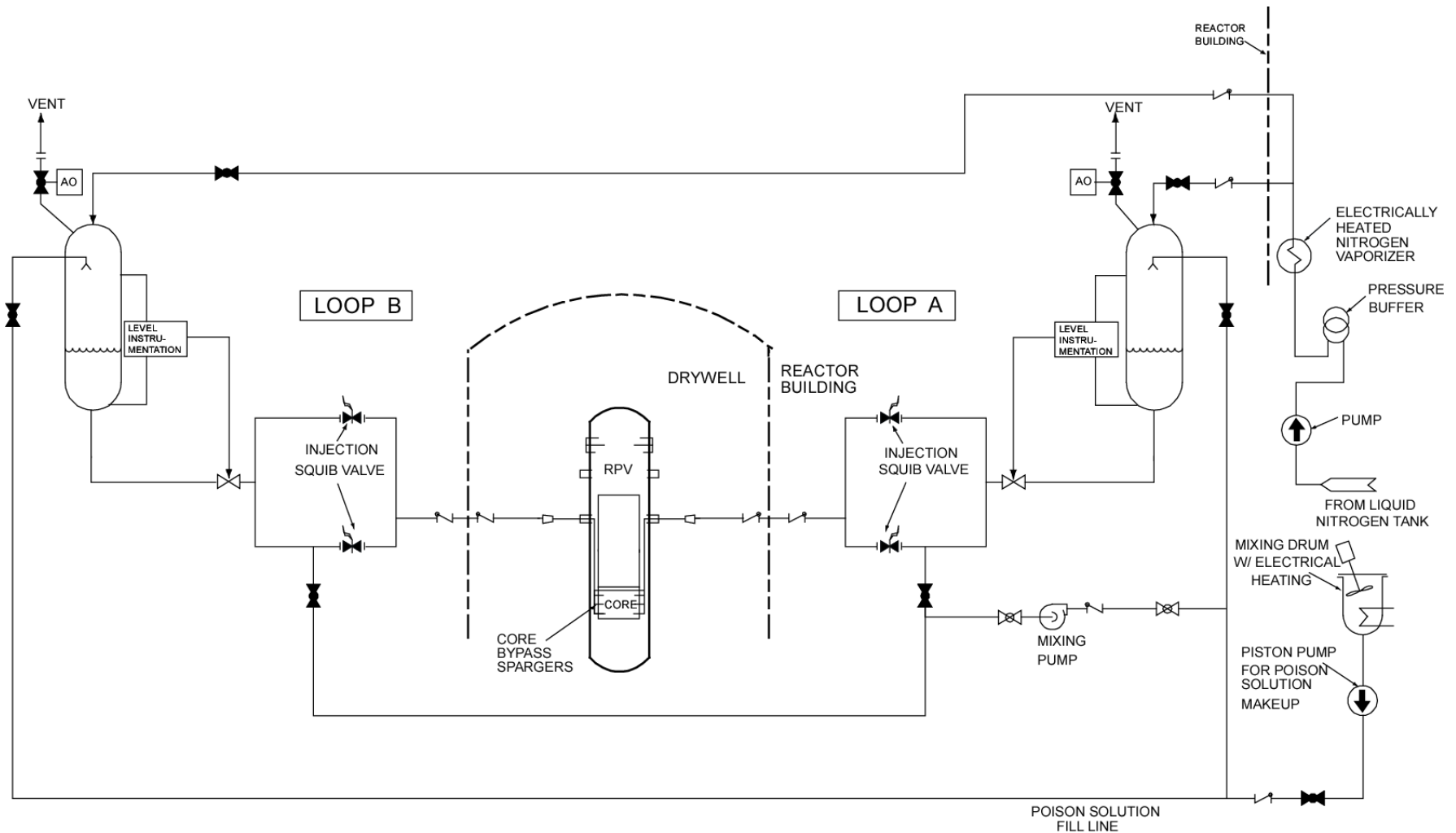
ESBWR Safety System Logic Control (SSLC) Framework

Engineering Safety Features Logics (SSLC/ESF)

- > Based on ABWR design
 - 2/4 logic
 - Fail As-Is
 - Deterministic
 - Diverse from RPS
- > Any two unbypassed same parameters exceeding limits always initiate ECCS with:
 - Any single logic failure
 - Any division of sensors bypass status
 - Any single power failure
- > Each division makes a per parameter trip decision
- > Each division makes a dual 2/4 per parameter decision to initiate
- > Each division informs other divisions of its trip data (via communication module and isolated fiber optics)
- > Each divisional redundant 2/4 logic drives an output load driver
- > Redundant load drivers per division wired in series
- > Design is single failure proof (logic and power) to actuate when required
- > Design is single failure proof to prevent inadvertent actuation
- > Any one of two power divisions can actuate one of the two actuators (squib valve or SRV solenoid) and open the valve



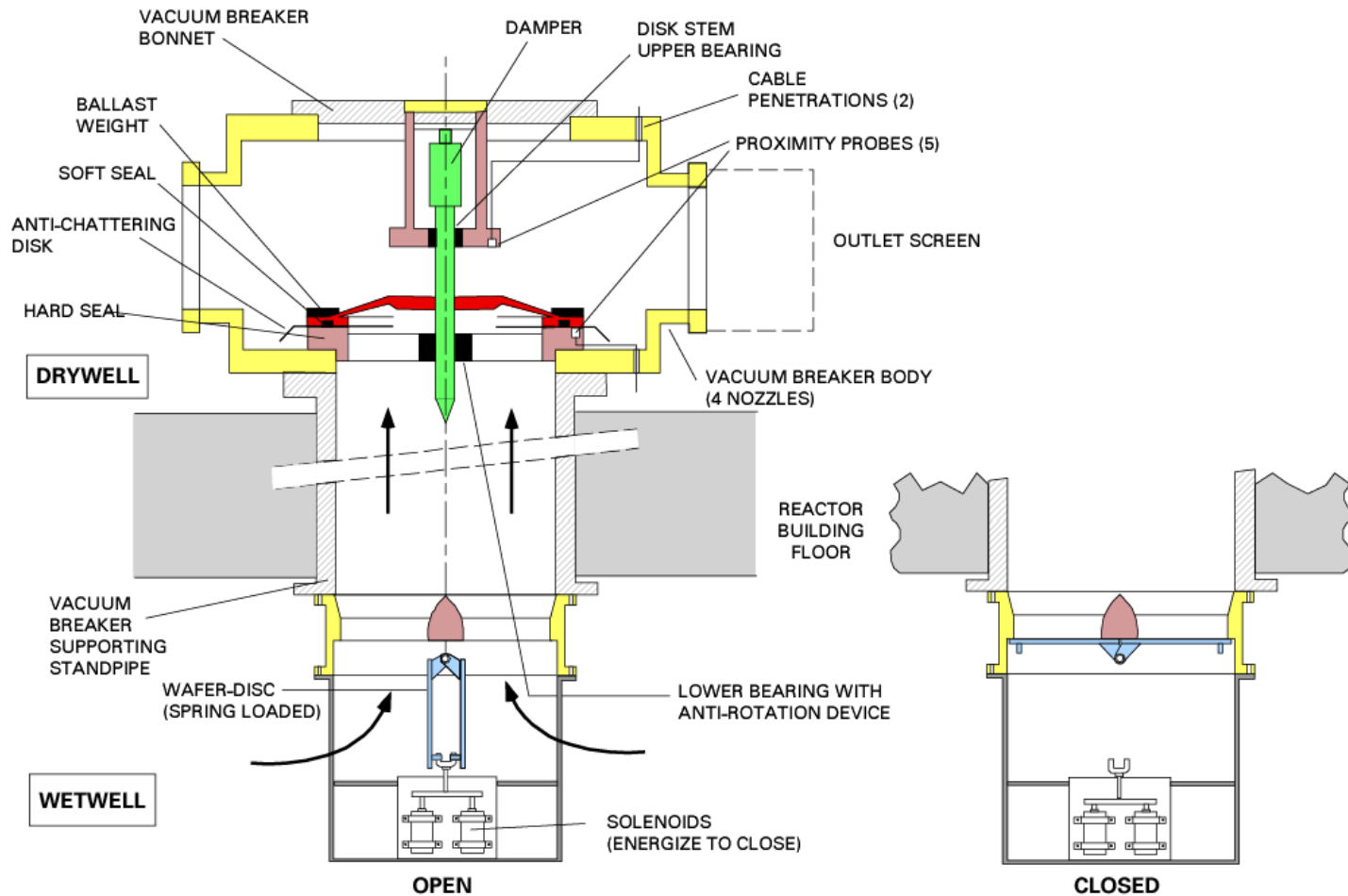
Standby Liquid Control



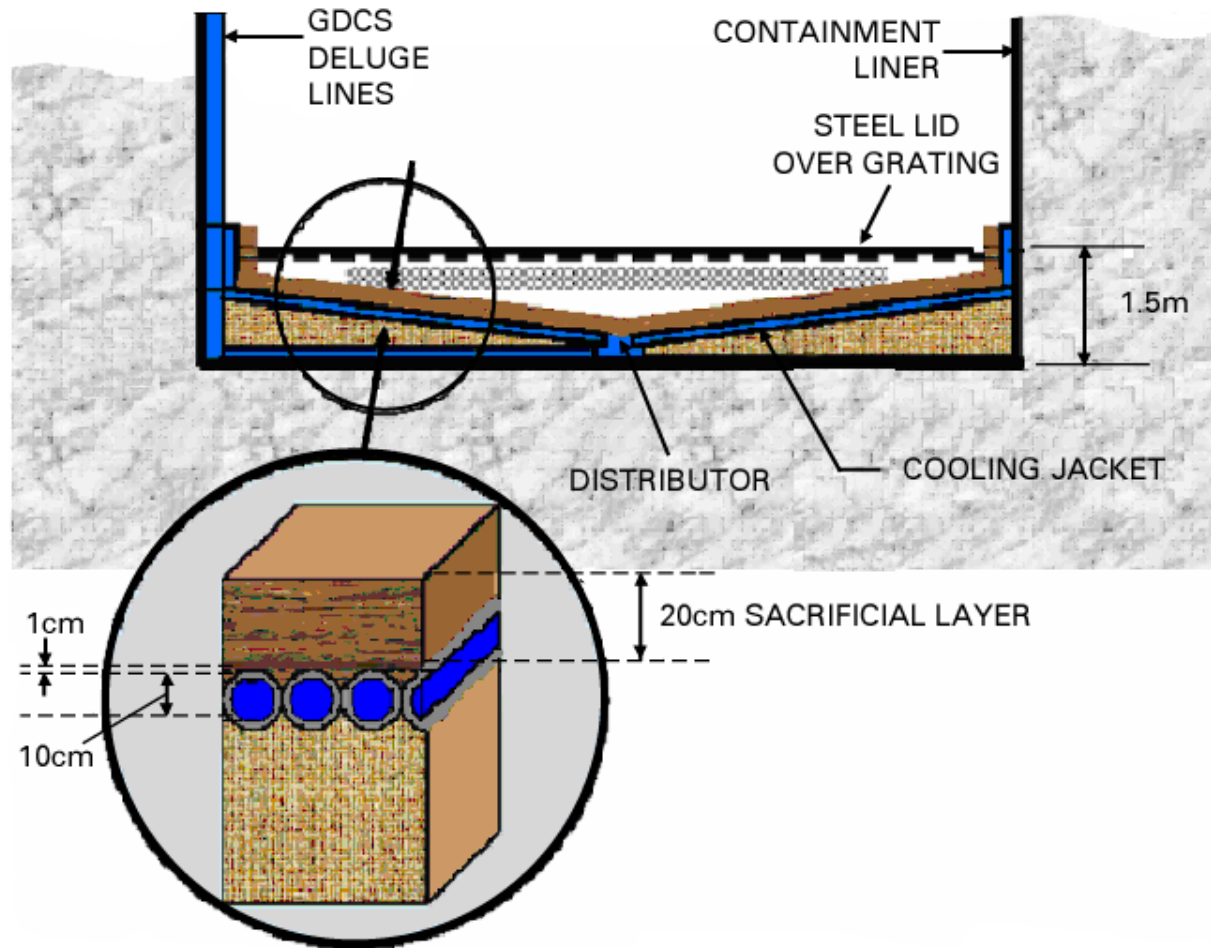
Emergency Breathing Air System

- Main Control Room Habitability
 - > Pressurized space 1/8 inch water gauge
 - 100 CFM
 - > EBAS safety-related
 - Single Failure Proof
 - 72 hour passive capability
 - > MCR HVAC non-safety related
 - With AC power available
 - 2 x 100% trains
 - HEPA and Charcoal filtration

Vacuum Breaker



Basemat Internal Melt Arrest Coolability BiMAC



Fine Motion Control Rod Drives (FMCRD)

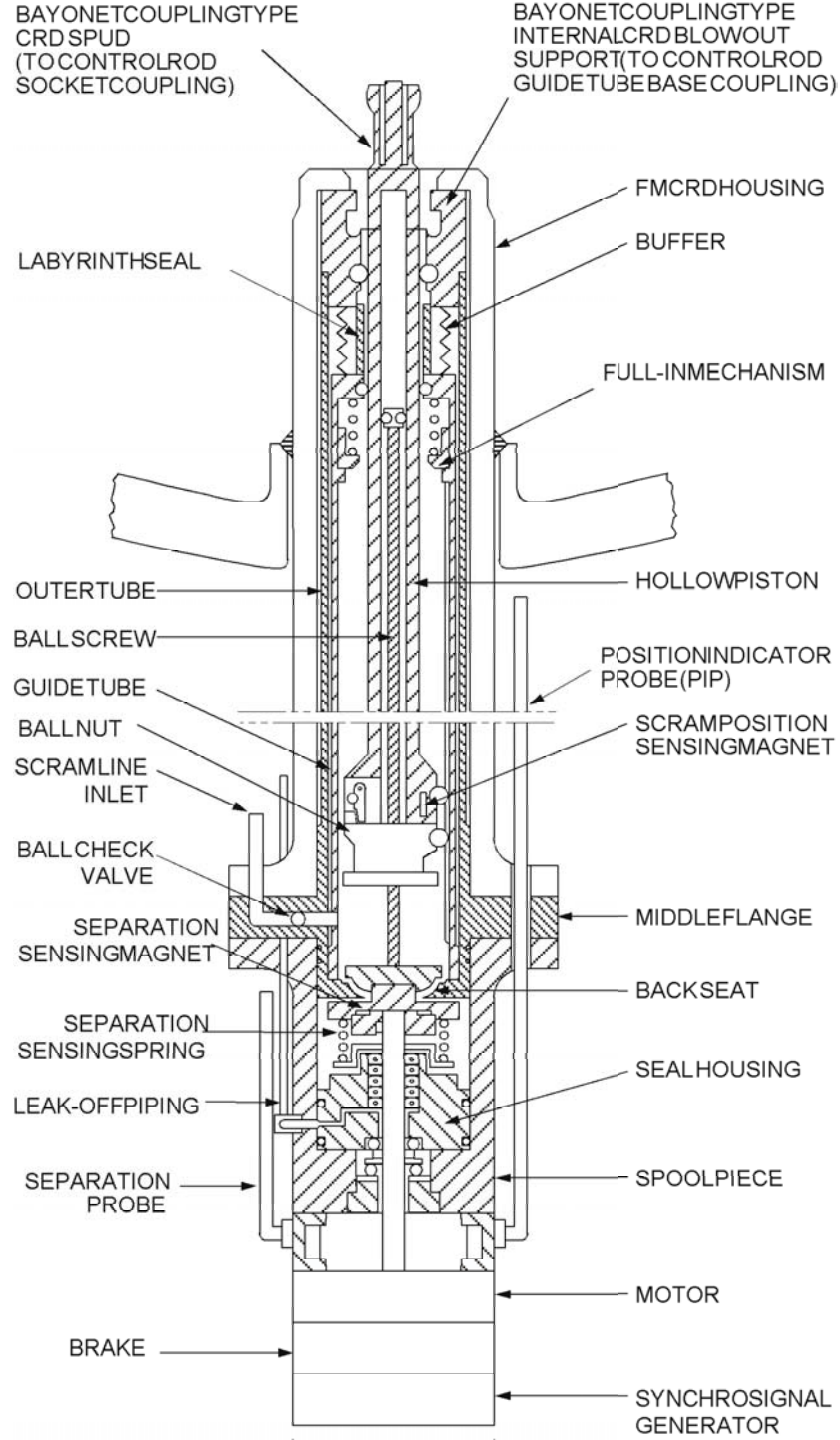
- 269 Control Rods
- Hydraulic Scram
 - > 1 HCU for 2 FMCRDs
 - > FMCRDs for 1 HCU are separated in core
 - > No Scram Discharge Volume
 - Qualified to insert at ATWS pressures
 - > Rapid Insertion
 - ~1.1 seconds full out to full in
 - > Reduced maintenance
- Shoot-out Steel is eliminated
 - > Self arresting

FMCRD (cont)

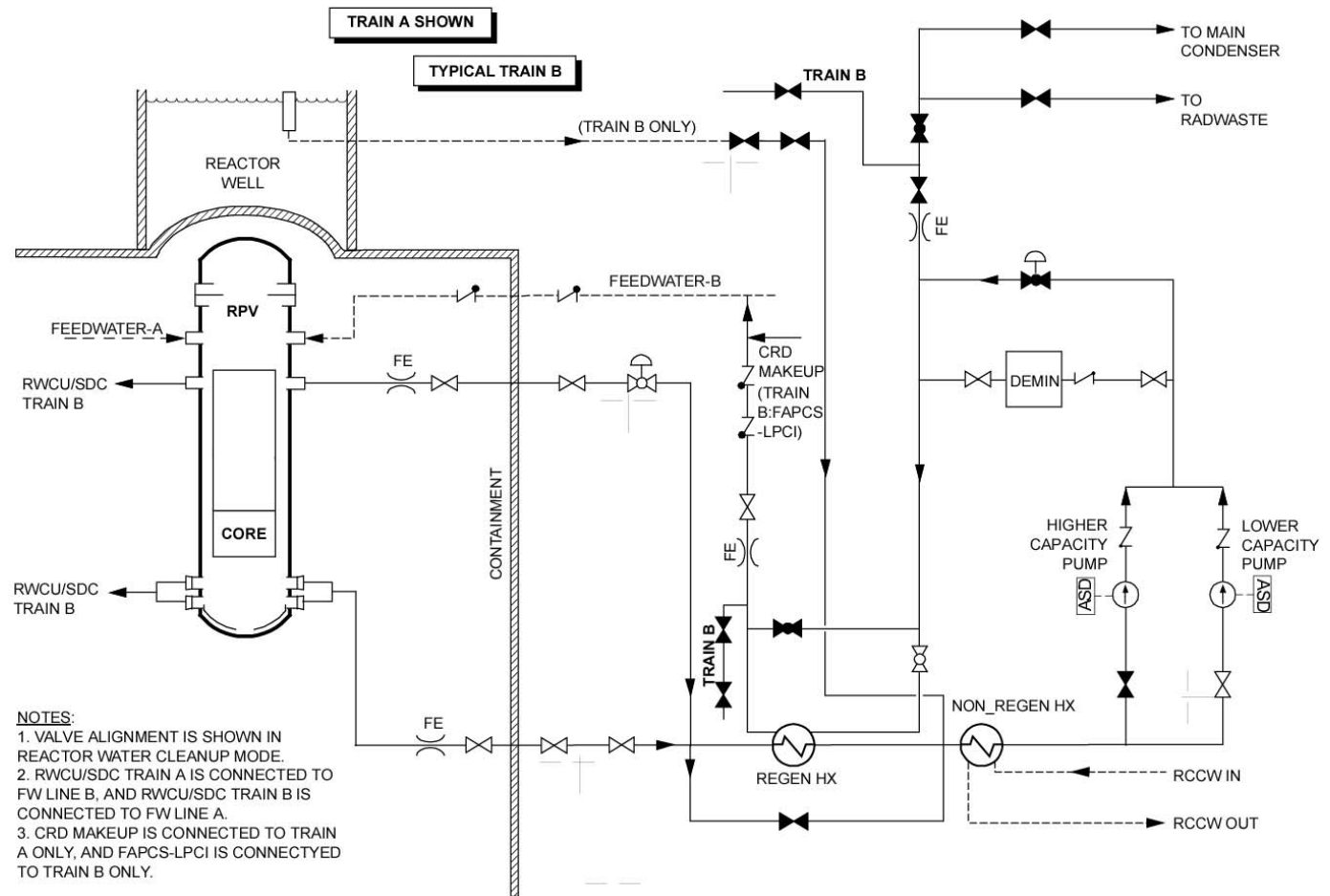
- Insertion and Withdrawl by Electric Motor
 - > No overshoot
 - > Can be ganged in groups as large as 26
 - > Positioning Increments of ~3 inches
 - > Rod Control and Information System (RCIS)
- Rod Drop Accident is no longer Credible
 - > Detection of blade failure to follow drive
 - > Check of blade to drive coupling integrity

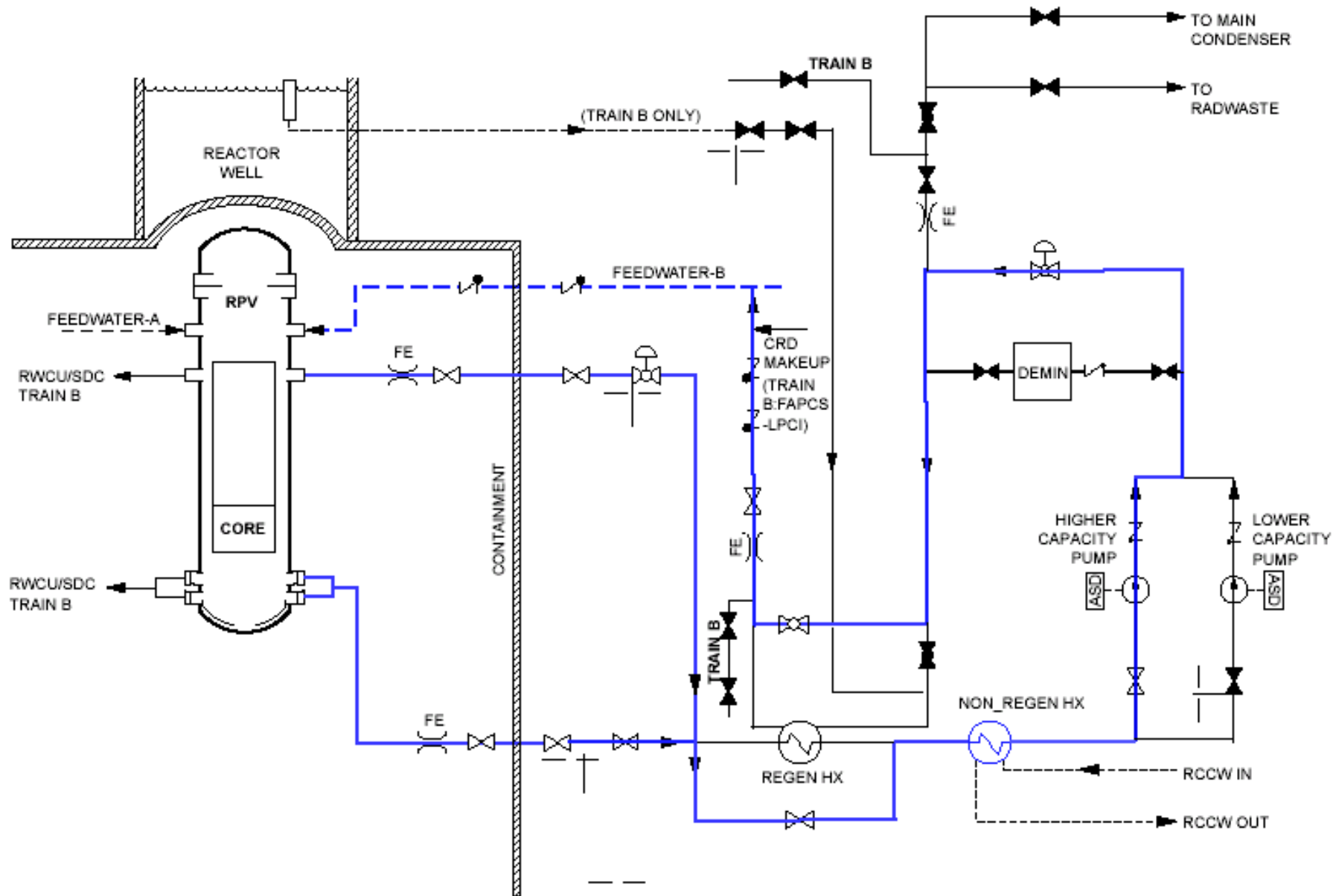
FMCRD (cont)

- Power adjustments are made with rod movement
 - > Select Control Rod Rapid Insertion (SCRRI), provides a means for rapid power reduction
 - > Simultaneously moves all rods to pre-programmed target position
- Maintenance
 - > Hydraulic portions surveillance primarily
 - > Electrical requires no break of pressure boundary



Reactor Water Cleanup (RWCU)





Shutdown Cooling

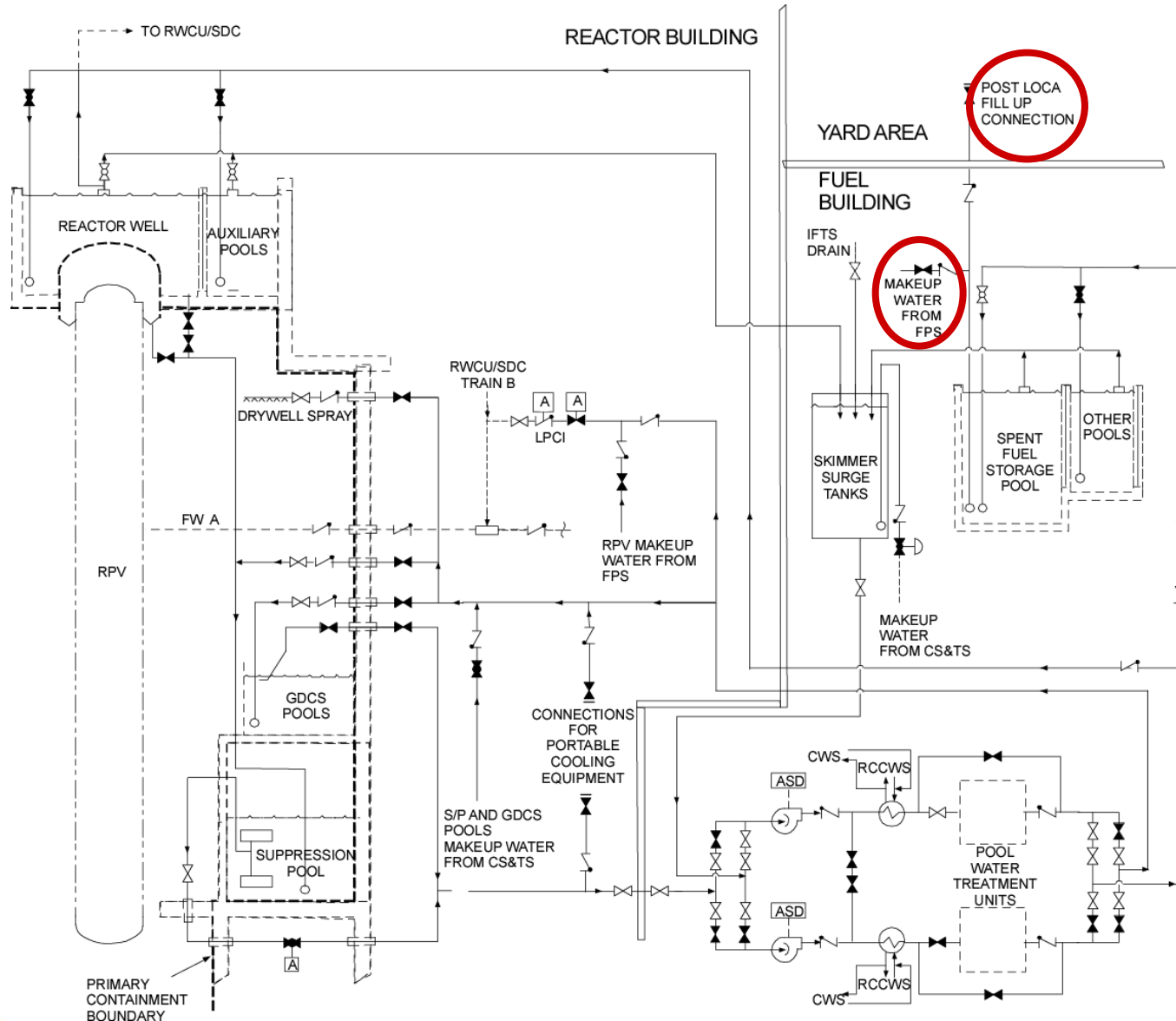
Fuel and Auxiliary Pool Cooling and Cleanup (FAPCS)

- 2 Subsystems
 - > Main
 - 2 trains, nominally 100%
 - > ICC and PCC Pool
- Normal Operating Modes
 - > Spent Fuel Pool Cleaning and Cleanup
 - > IC/PCCS Pool Cooling and Cleanup
 - > GDCS Pool Cooling and Cleanup
 - > Suppression Pool Cooling and Cleanup

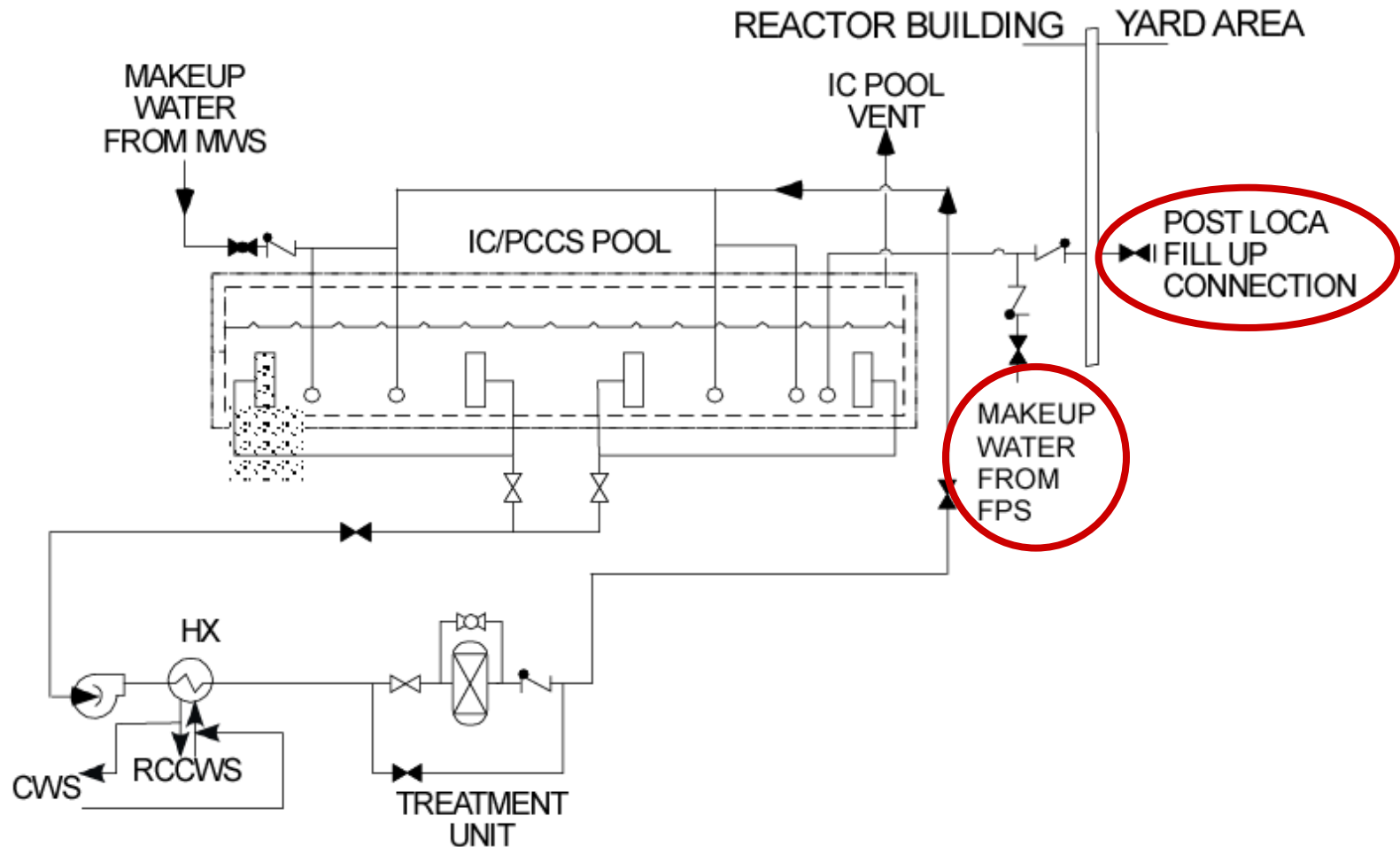
FAPCS (cont)

- FAPCS may be operated in the following modes for post-accident recovery following an accident:
 - > Spent Fuel Pool Cooling
 - > Low Pressure Coolant Injection (LPCI)
 - > Suppression Pool Cooling (SPC)
 - > Drywell Spray
 - > Alternate Shutdown Cooling (ASDC)
 - > FAPCS piping can also be used to provide makeup water to IC/PCCS pools and Spent Fuel Pool from offsite emergency water supply or Fire Protection system following a DBA

FAPCS



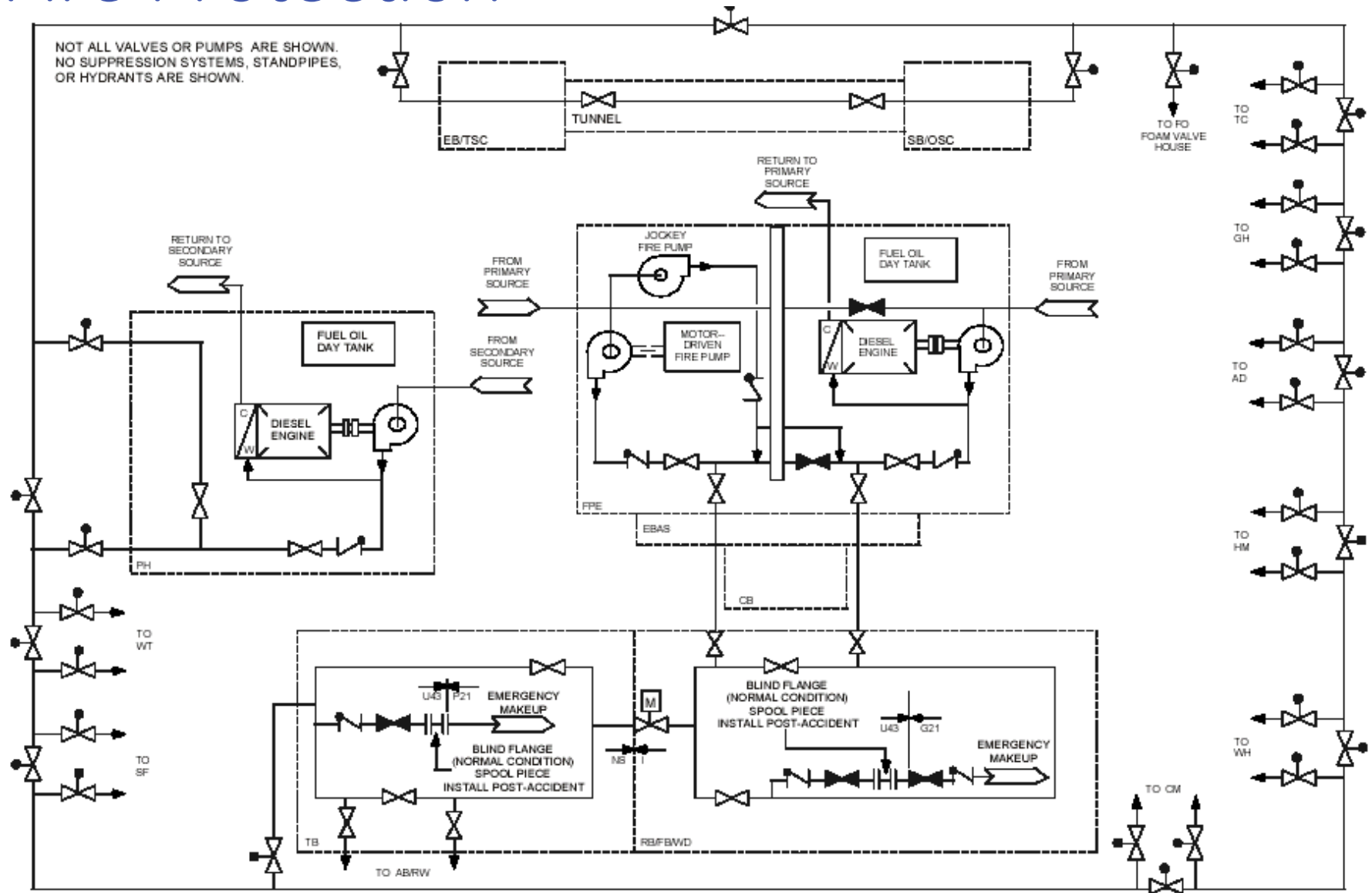
FAPCS (ICC & PCC Pool Subsystem)



Fire Protection

- One of Two RTNSS systems
 - > RTNSS applies to limited portion of system
 - Diesel driven pump and piping to FAPCS
 - Seismically analyzed but not Category I
 - Primary mission is 72 hours through 7 days
 - Secondary missions
 - Low pressure makeup
 - Makeup to IC/PCC pools if valves fail

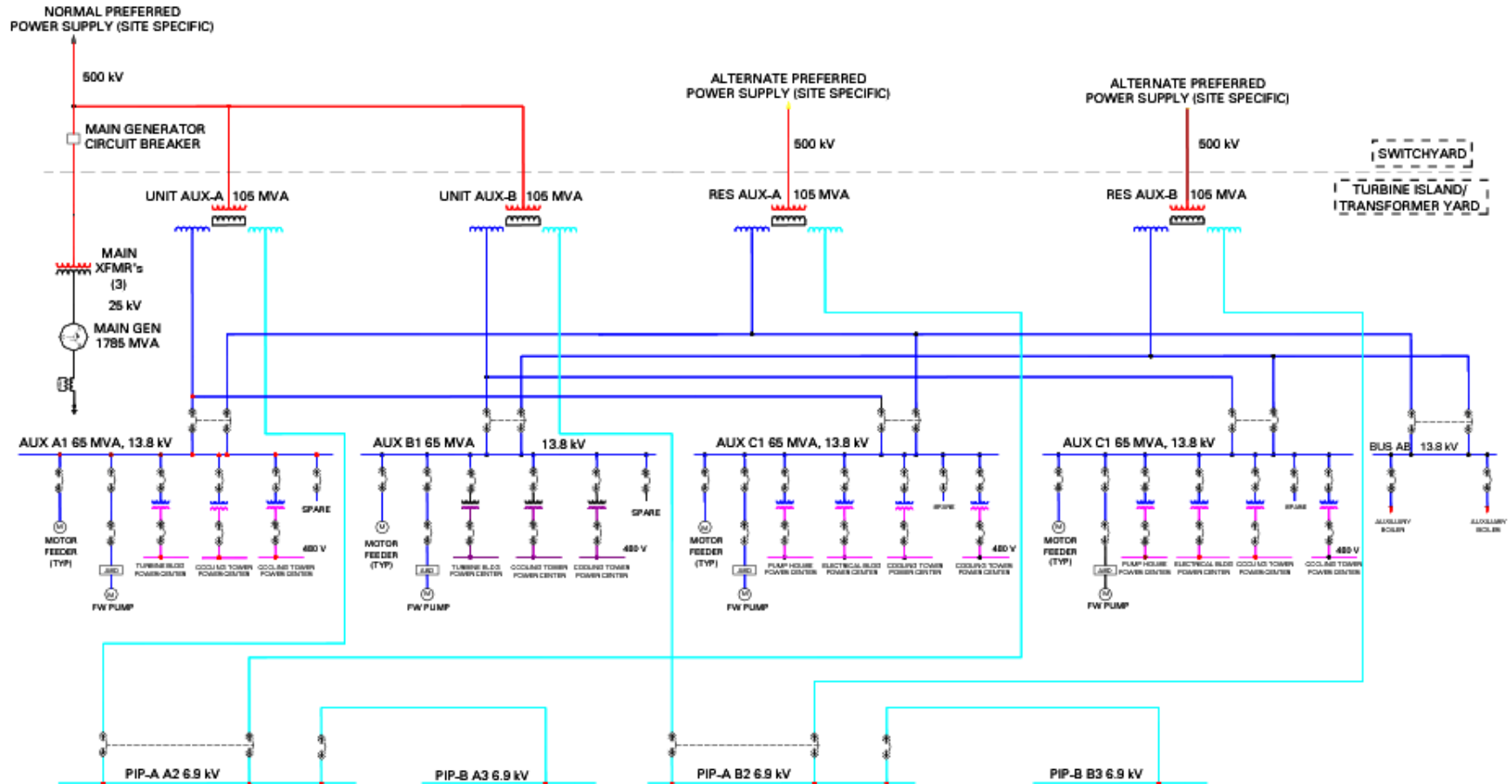
Fire Protection



Electrical System

- Designed for 100% load rejection
 - > No Scram
 - > 110% rated bypass system
 - Short term capability
 - SCRRI rapidly reduces power
 - > Hotel load operation
 - > Fast transfer available between UAT and RAT
 - > UAT and RAT are both triple winding design
 - UAT and RAT are identically sized

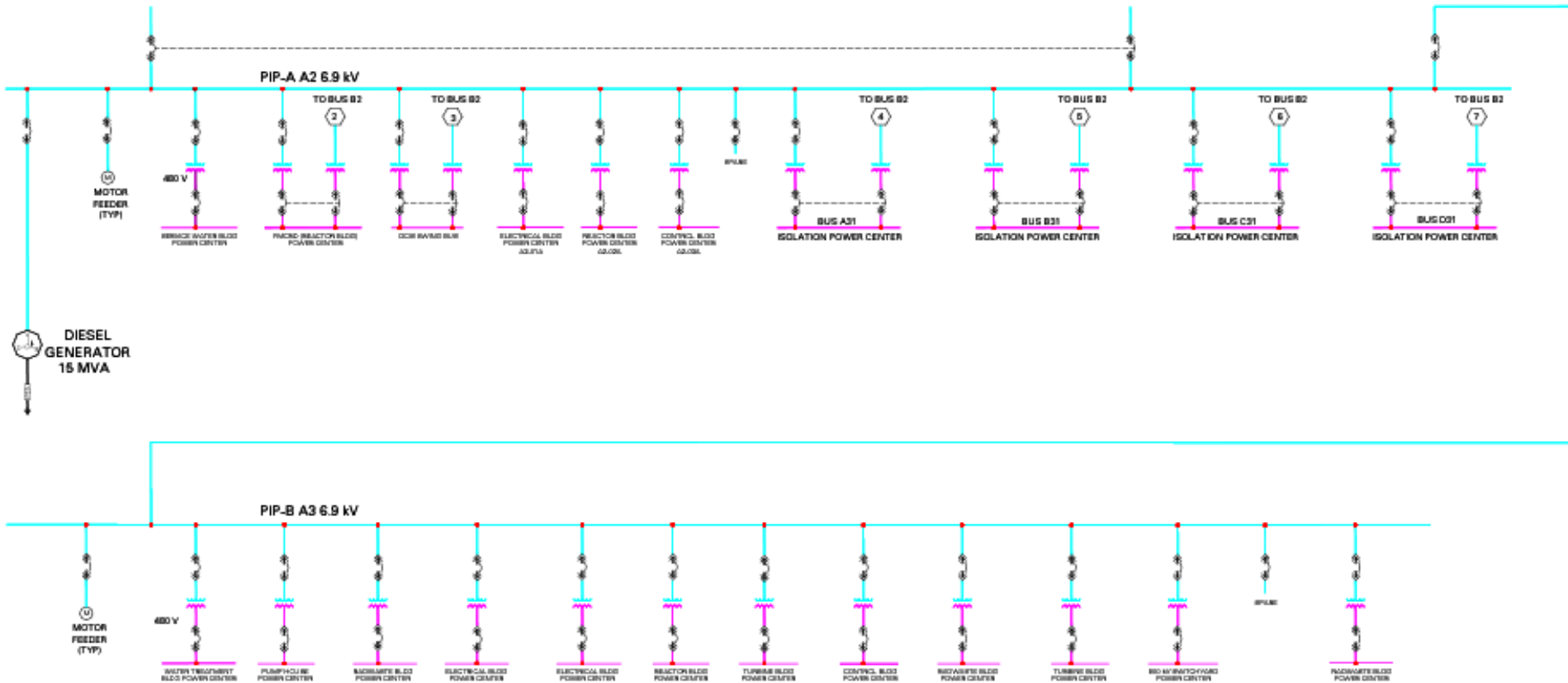
Electrical Main Single Line Diagram



Plant Investment Protection

- Backed by 2 non-safety on-site diesel generators
- Investment Protection
 - > Turbine Lube Oil
- Plant Availability
 - > Chilled Water
 - > HVAC
- Defense in Depth
 - > FAPCS and RWCU
 - Service Water and Closed Cooling Water

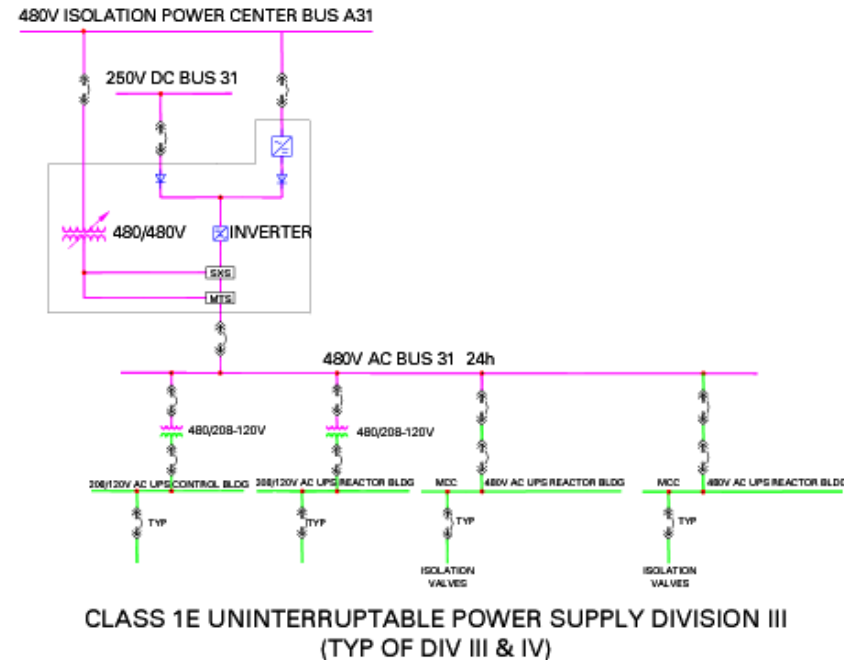
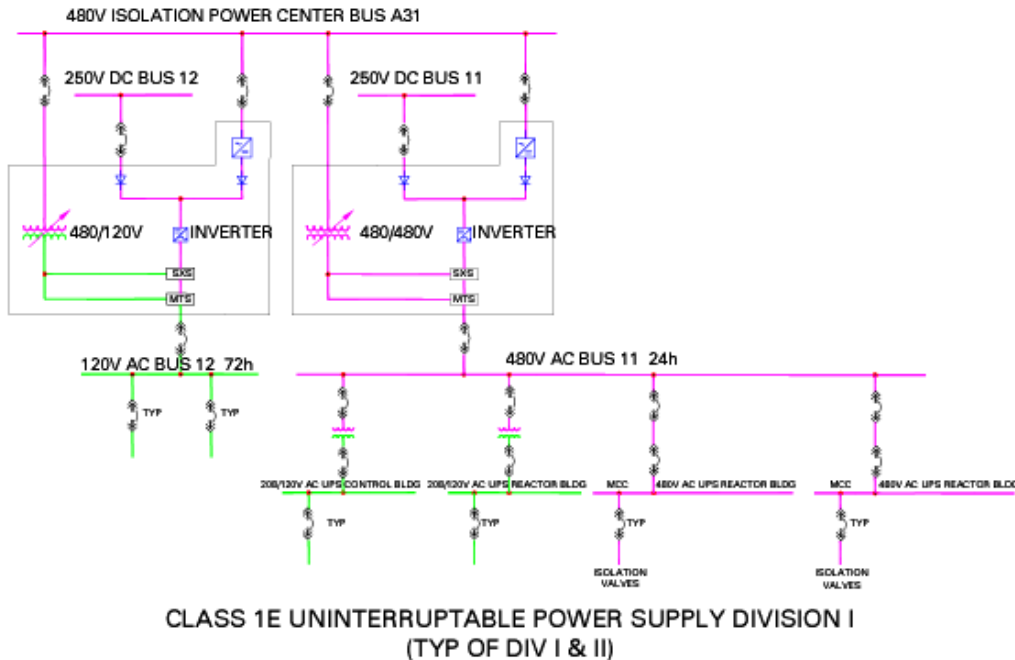
Plant Investment Protection Busses



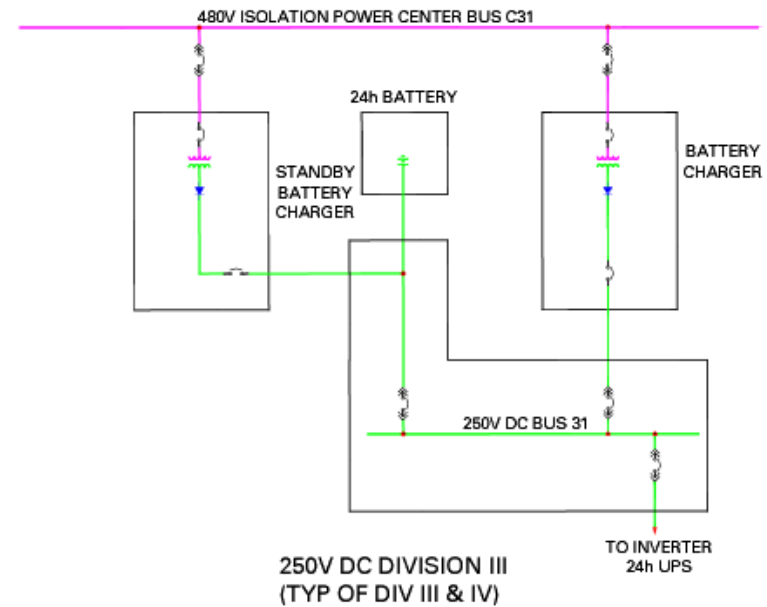
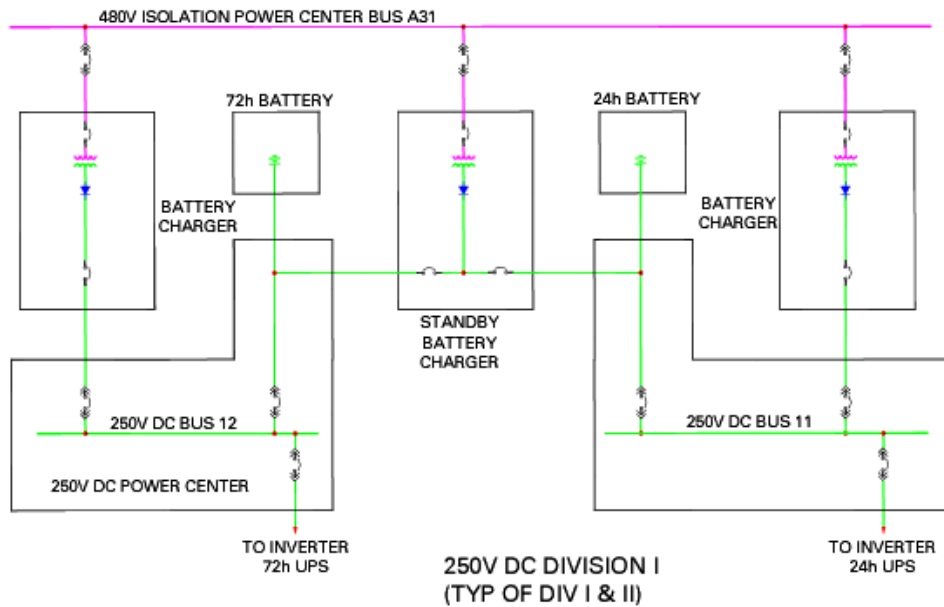
Safety Related (1E) Electrical System

- Four Divisions Safety-Related
 - > DC (battery) Backed
 - Inverted power for AC loads
 - 4 Divisions with 24 hours Capability
 - Monitor
 - Control
 - 2 divisions with 72 hours Capability
 - Monitor

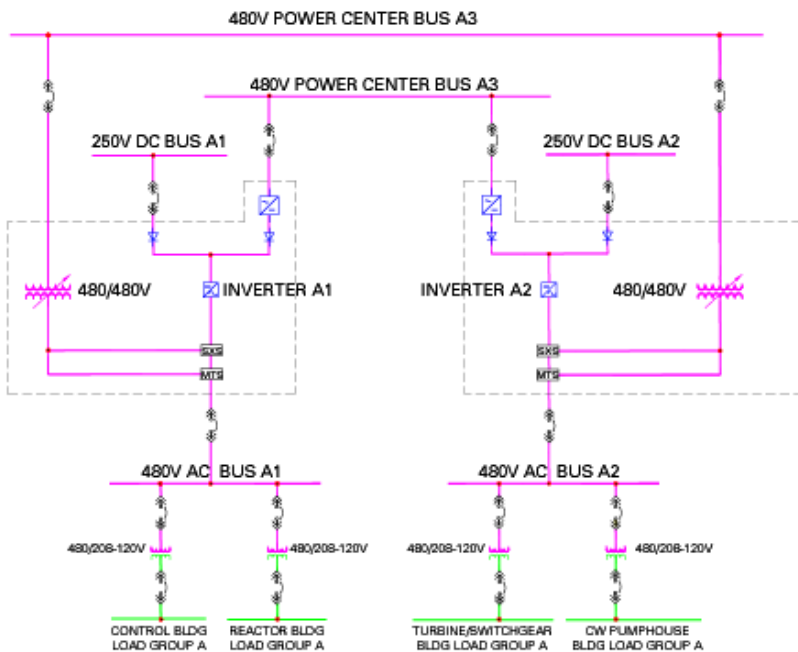
ESBWR Class 1E Uninterruptible Power



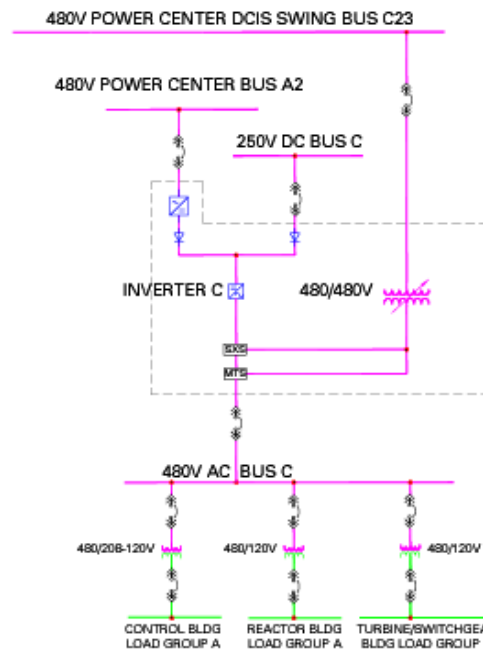
ESBWR Class 1E DC Power



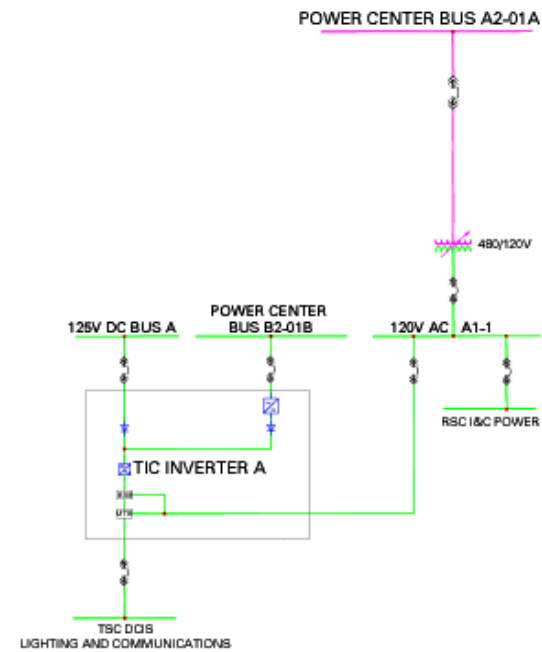
ESBWR Non-Class 1E Uninterruptible Power



NON CLASS 1E UNINTERRUPTABLE POWER SUPPLY
(TYP OF BUS A3 & B3)

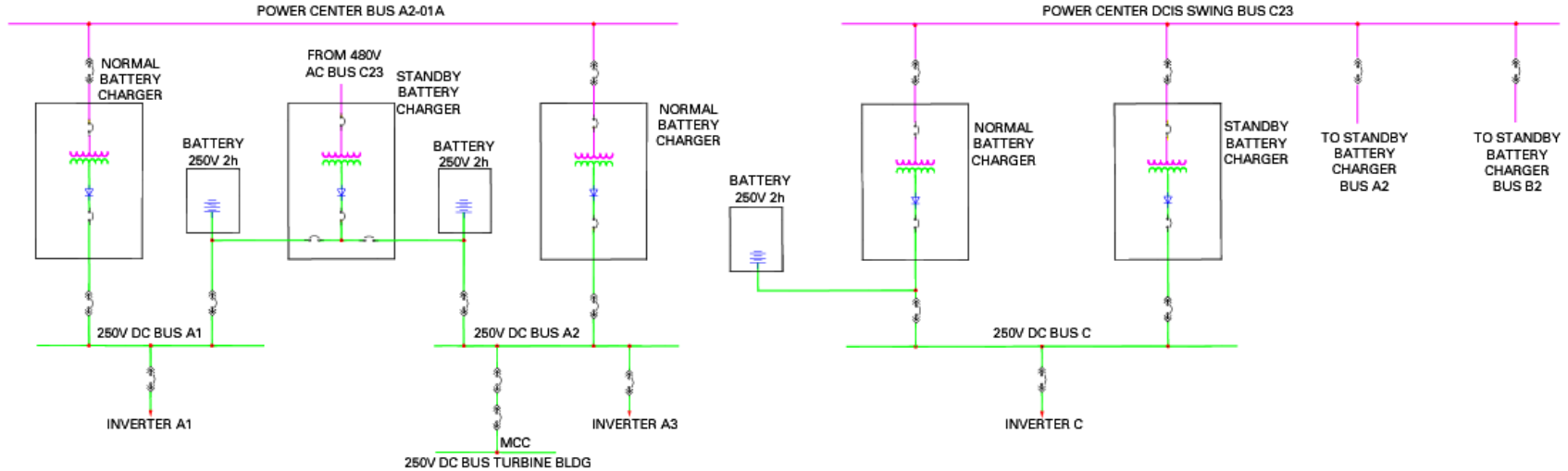


NON CLASS 1E UNINTERRUPTABLE POWER SUPPLY (SWING BUS)



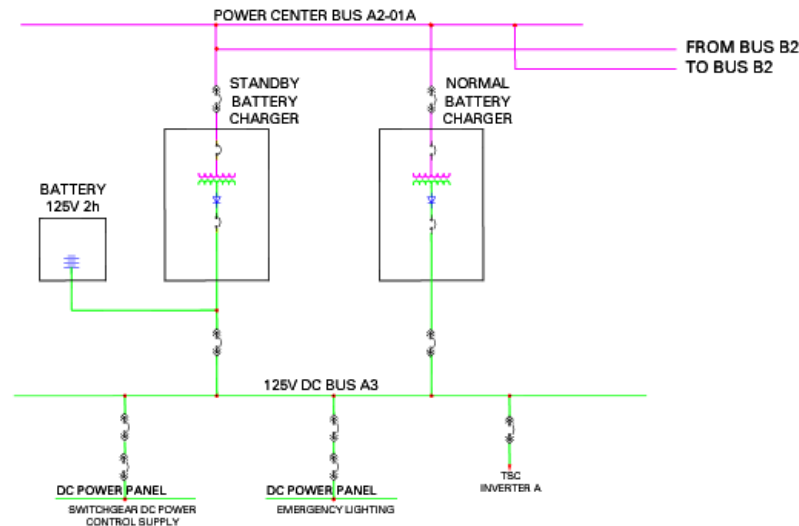
NON CLASS 1E UNINTERRUPTABLE TSC SYSTEM (TYP OF A2 AND B2)

ESBWR Non-Class 1E DC Power



NON-CLASS 1E 250V DC POWER SYSTEM (TYP OF BUS A2 & B2)

NON-CLASS 1E 250V DC POWER SYSTEM DCIS SWING BUS



NON-CLASS 1E 125V DC POWER SYSTEM(TYP OF BUS A2 & B2)