NSTD Introductory Course

New Gen III+ Reactor
Power Plant Designs

Economic Simplified Boiling
Water Reactor (ESBWR)

Disclaimer

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ESBWR

Key Design Features

Nuclear Power Plant (NPP) Development

Gen II

Large Commercial NPPs Currently in Operation Throughout U.S.

Gen III

Advanced LWRs

AP 600(W)

ABWR (GE)

System 80+ (CE)

Nuclear Power Plant (NPP) Development (cont.)

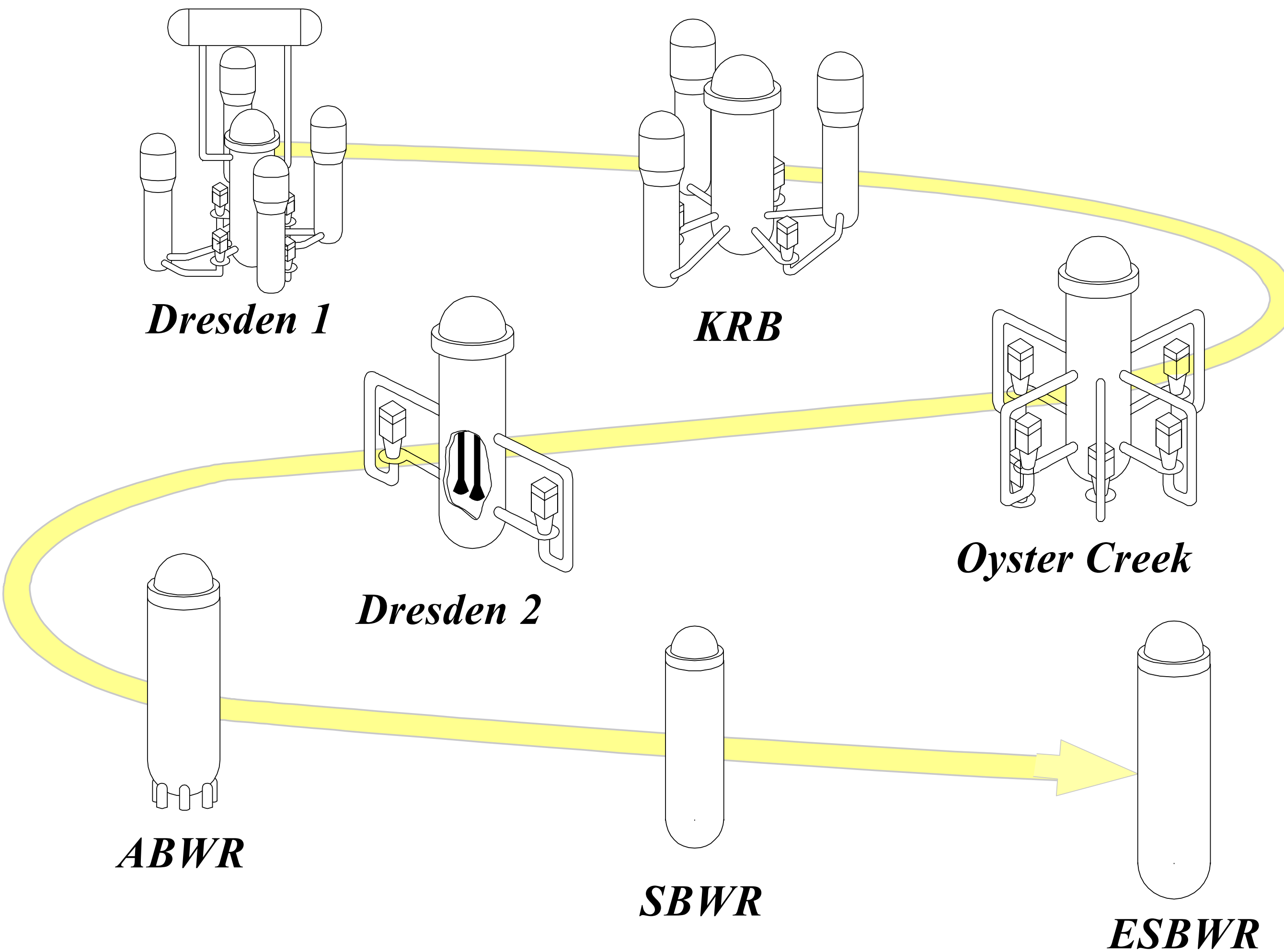
Transition

Probably Could Be Classed as Gen III+	SBWR

Gen III+

Evolutionary Designs	ESBWR (GE)
Improved Economics	AP 1000 (W)
Advanced Safety Features	ACR 700 (AECL)
Some Passive Design Aspects	EPR (AREVA - Framatome ANP)
Advanced Containment Design	PBMR (South Africa, PBMR Pty. Ltd.)
Simplified System Designs	

BWR Evolution



BWR Design Progression

BWR 2-6 → ABWR → SBWR → ESBWR

- 35 Domestic (U.S.) operating BWRs
- 17 International operating BWRs
- 2 International (Japan) operating ABWRs
- Provide the current status of its design certification process with the NRC.

BWR Product Line 2/3/4

- Motor Generator Used for Recirculation System Flow Control
- High Pressure Coolant Injection (except early BWR 2s - Nine Mile Point 1 and Oyster Creek which used Feedwater Coolant Injection)

BWR Product Line 5/6

- Flow Control Valves for Recirculation System Control
- High Pressure Core Spray

Recirculation Systems

- 5 Loops - Nine Mile Point 1 and Oyster Creek
- 2 Loops - all others

BWR Design Progression (cont.)

Isolation Condenser Systems

- Dresden 2 & 3
- Nine Mile Point 1
- Oyster Creek

Natural Circulation

- Humboldt Bay

Containment

- Mark 1 (23) — BWR 2,3 and older BWR 4s
  inverted light bulb
  drywell and torus
  usually an inerted atmosphere
- Mark II (8) — Newer BWR 4s and BWR 5s
  frustum of cone
  called “over-under”
- Mark III (4) — BWR 6s
  pressure suppression

ABWR NPPs

Kashiwazaki Units 6 & 7 **Located in Japan**

Expected time to fuel load . . . . 39 months

Actual construction time. . . . . Unit 6 - 61 months

Actual construction time. . . . . Unit 6 - 61 months

Actual time to fuel load . . . . Unit 6 - 36.5 months

. . . . Unit 7 - 38.3 months

Broke ground September 17, 1991

Commercial operation . . . . Unit 6 - November 7, 1996

. . . . Unit 7 - July 2, 1997

ABWR NPPs (cont.)

Lungmen Units 1 & 2 **Located in Taiwan**

Expected construction time . . . . 48 months

Delayed up to 2005 at 57% complete

Reactor installed. . . . . .Unit 1 - March 2005

Expected operation . . . . .Unit 1 - July 2006

. . . . Unit 2 - July 2007

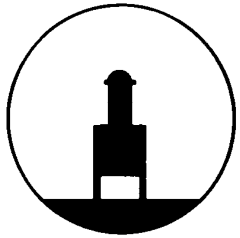
Optimized Parameters for ESBWR

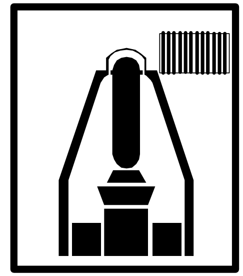
Parameter	BWR/4-Mk I (Browns Ferry 3)	BWR/6-Mk III (Grand Gulf)	ABWR	ESBWR
Power (MWt/GrossMWe)	3293/1098	3900/1360	3926/1350	4500/1580
Vessel height/dia. (m)	21.9/6.4	21.8/6.4	21.1/7.1	27.7/7.1
Fuel Bundles (number)	764	800	872	1132
Active Fuel Height (m)	3.7	3.7	3.7	3.0
Power density (kw/l)	50	54.2	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

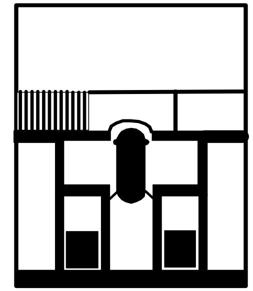
What's different about ESBWR

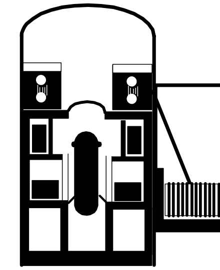
ABWR	ESBWR
Recirculation System + support systems	Eliminated
HPCF System (2 each)	Eliminated need for ECCS pumps
LPFL (3 each)	Utilize passive and stored energy
Residual Heat Removal (3 each)	Non-safety, combined with cleanup system
Safety Grade Diesel Generators (3 each)	Eliminated – only 2 non-safety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

BWR Containment Comparison

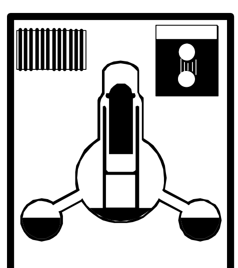


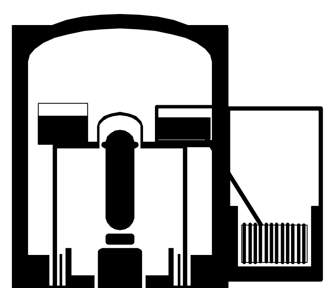


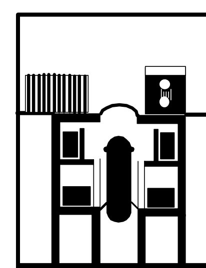




Characteristic	Dry	Mark I	Mark II	Mark III	ABWR	SBWR	ESBWR
Pressure Suppression	No	Yes	Yes	Yes	Yes	Yes	Yes
Drywell and wetwell volume (ft^3 X 10^6)	2.5	0.4	0.5	1.6	0.5	0.3	0.43
Design Pressure (psig)	50	62	45	15	45	55	40
LOCA Pressure (psig)	50	44	42	9	39	42	30







Plant Licensing Status

ESBWR

Design Certification

- Accepted for docketing by the NRC in December 2005.
- Final Design Approval (FDA) is expected in December 2009.
- Design Certification expected in December 2010.

Utility Activities

- The consortium, NuStart, is expected to apply for a construction/operating license (COL) for an ESBWR for Entergy Nuclear at its Grand Gulf Site in late 2007 or early 2008.
- Dominion will be ready to apply for a COL for an ESBWR at its North Anna Site in September 2007.
- Entergy Nuclear will apply for a COL for an ESBWR at its River Bend Site in the first half of 2008.

ESBWR

Plant Overview

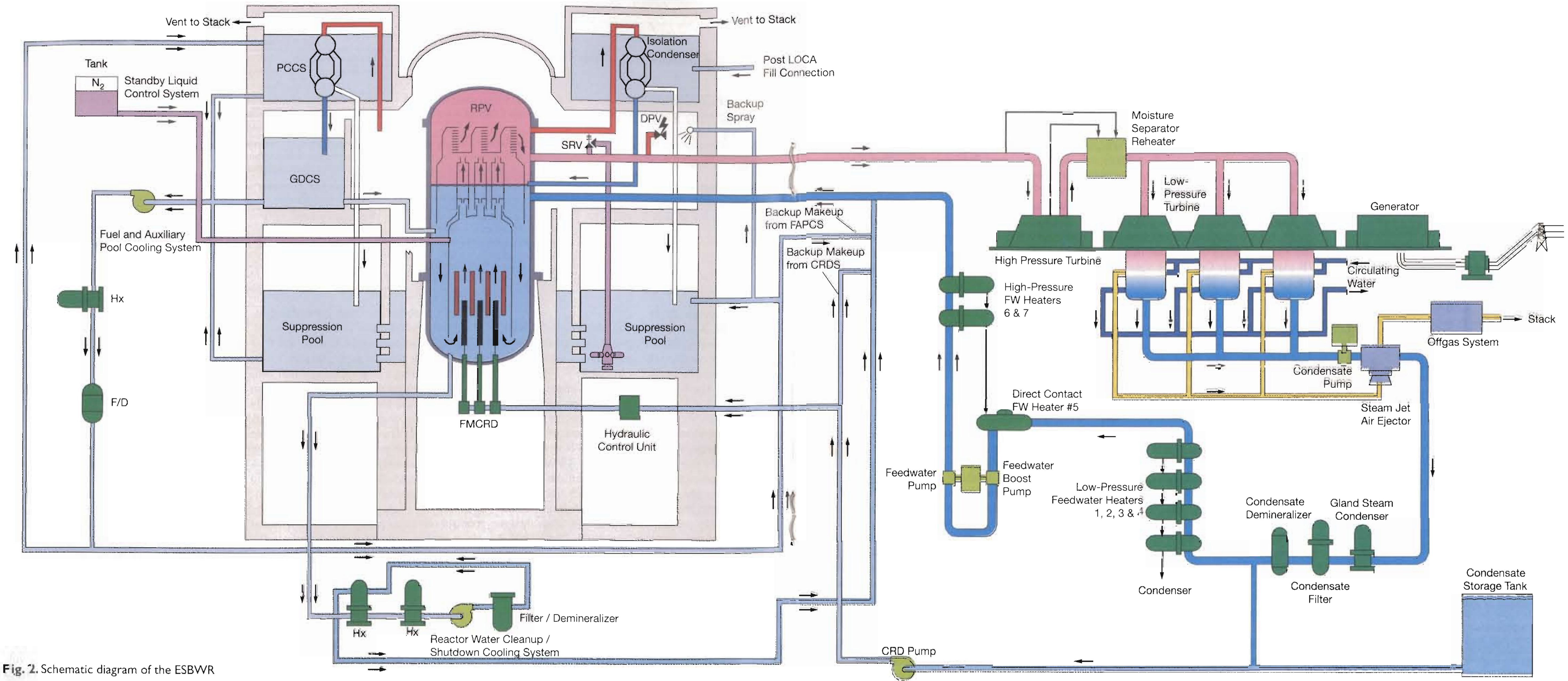
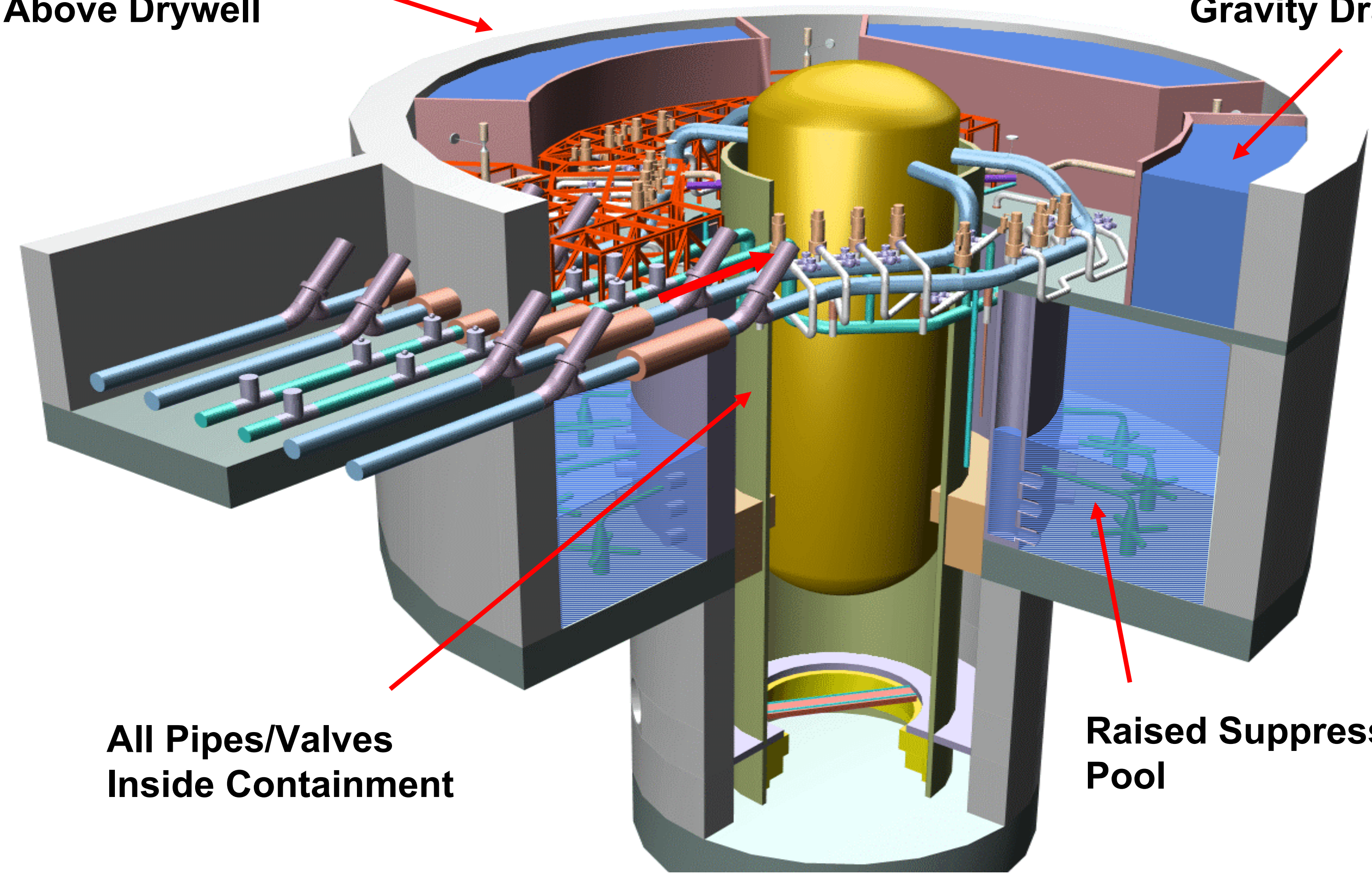


Fig. 2. Schematic diagram of the ESBWR

Safety Systems Inside Containment Envelope



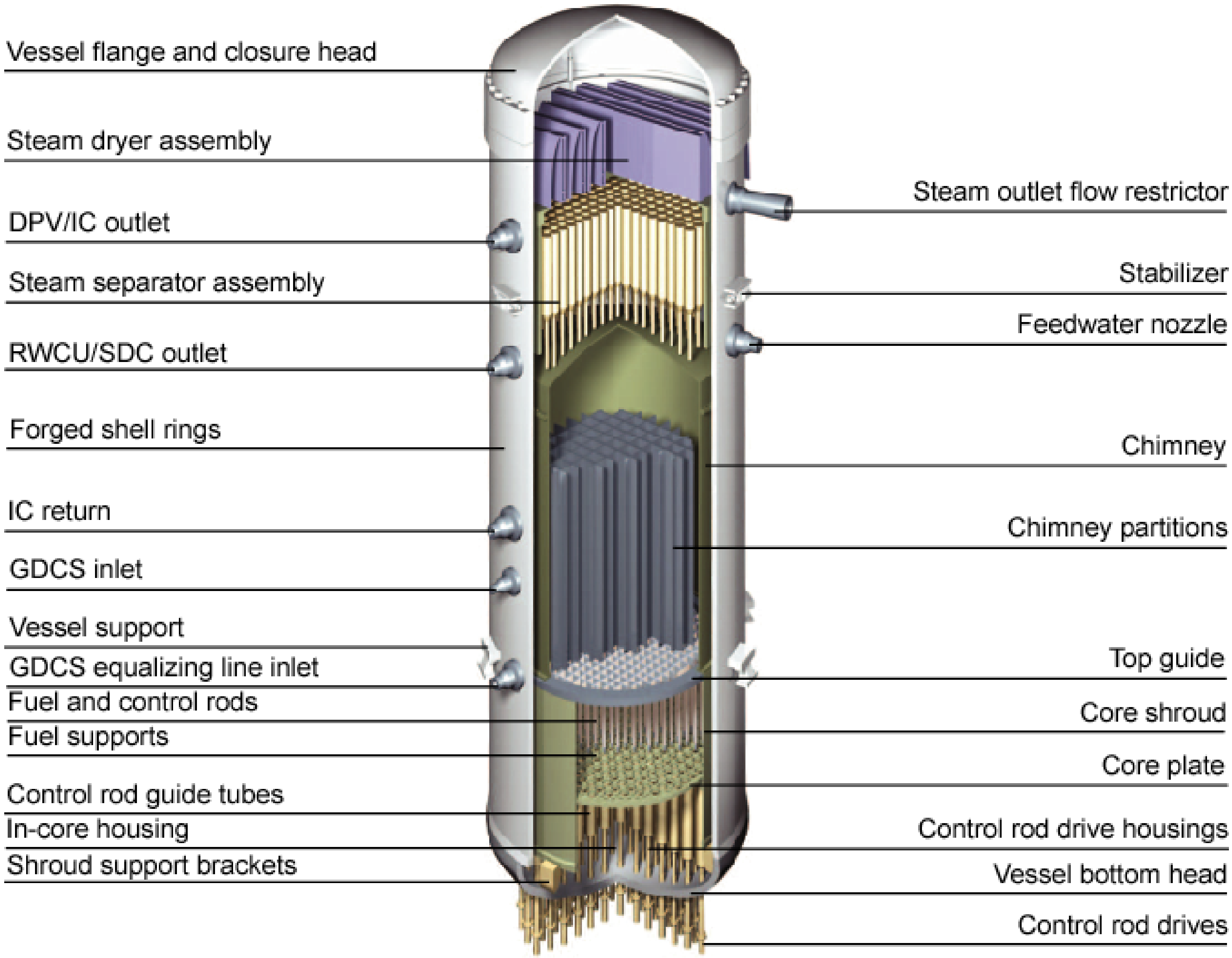
Decay Heat HX's Above Drywell

High Elevation Gravity Drain Pools

All Pipes/Valves Inside Containment

Raised Suppression Pool

Core and Vessel Design



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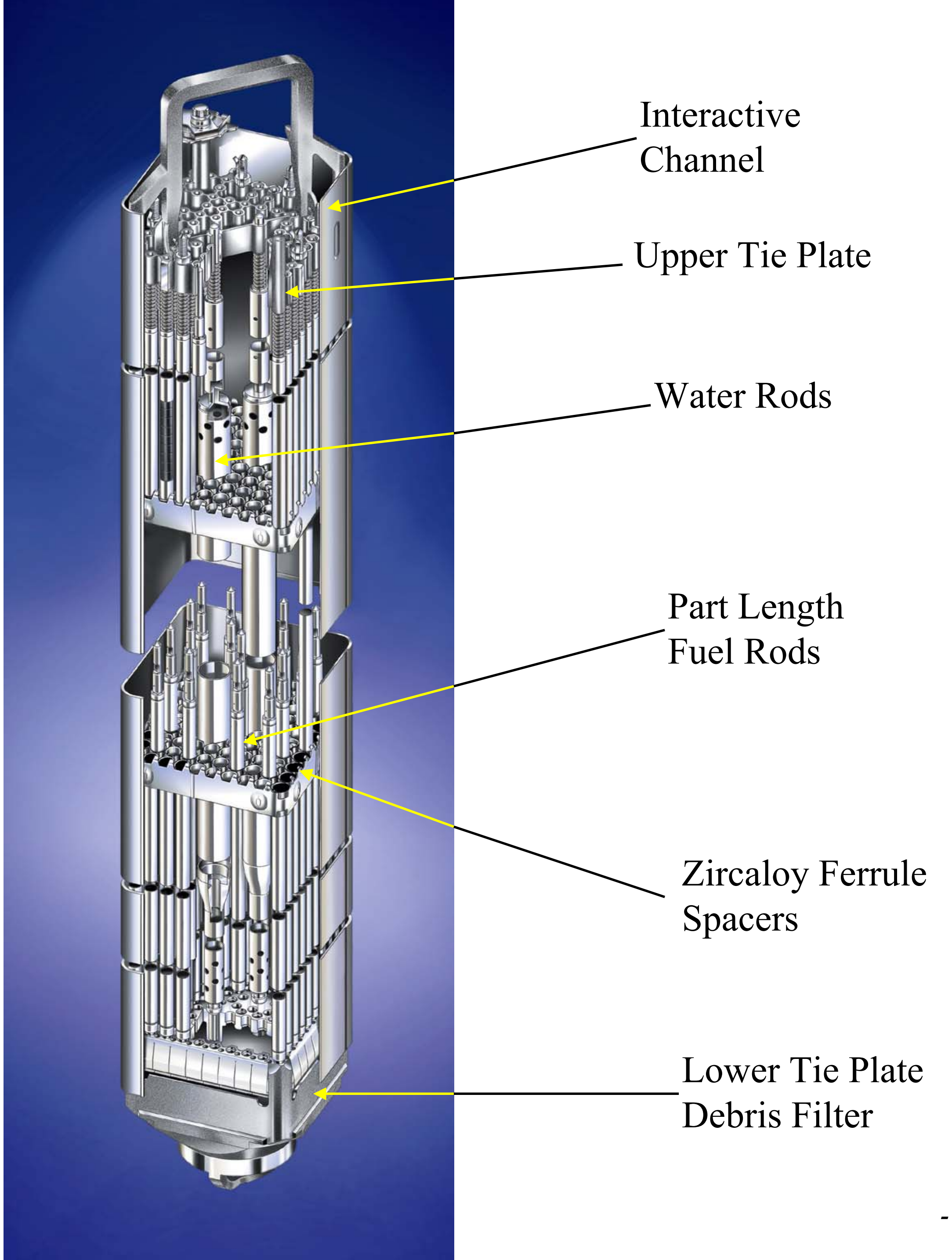
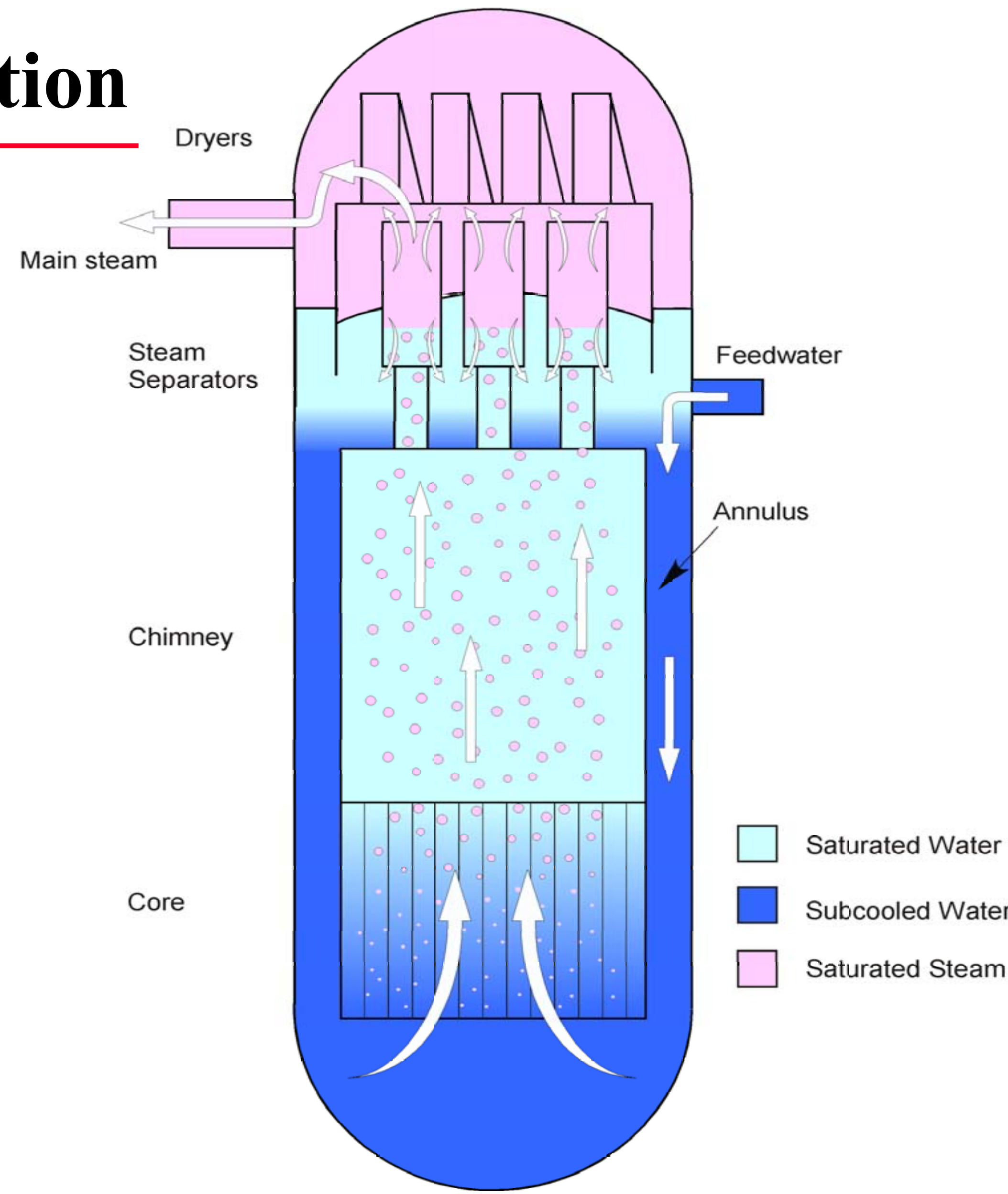
ESBWR Fuel Assembly

- **Same cross-sectional dimensions as ABWR**
- **Active Fuel Length:**
  ABWR = 144 inches
  ESBWR = 120 inches



ESBWR Normal Operation

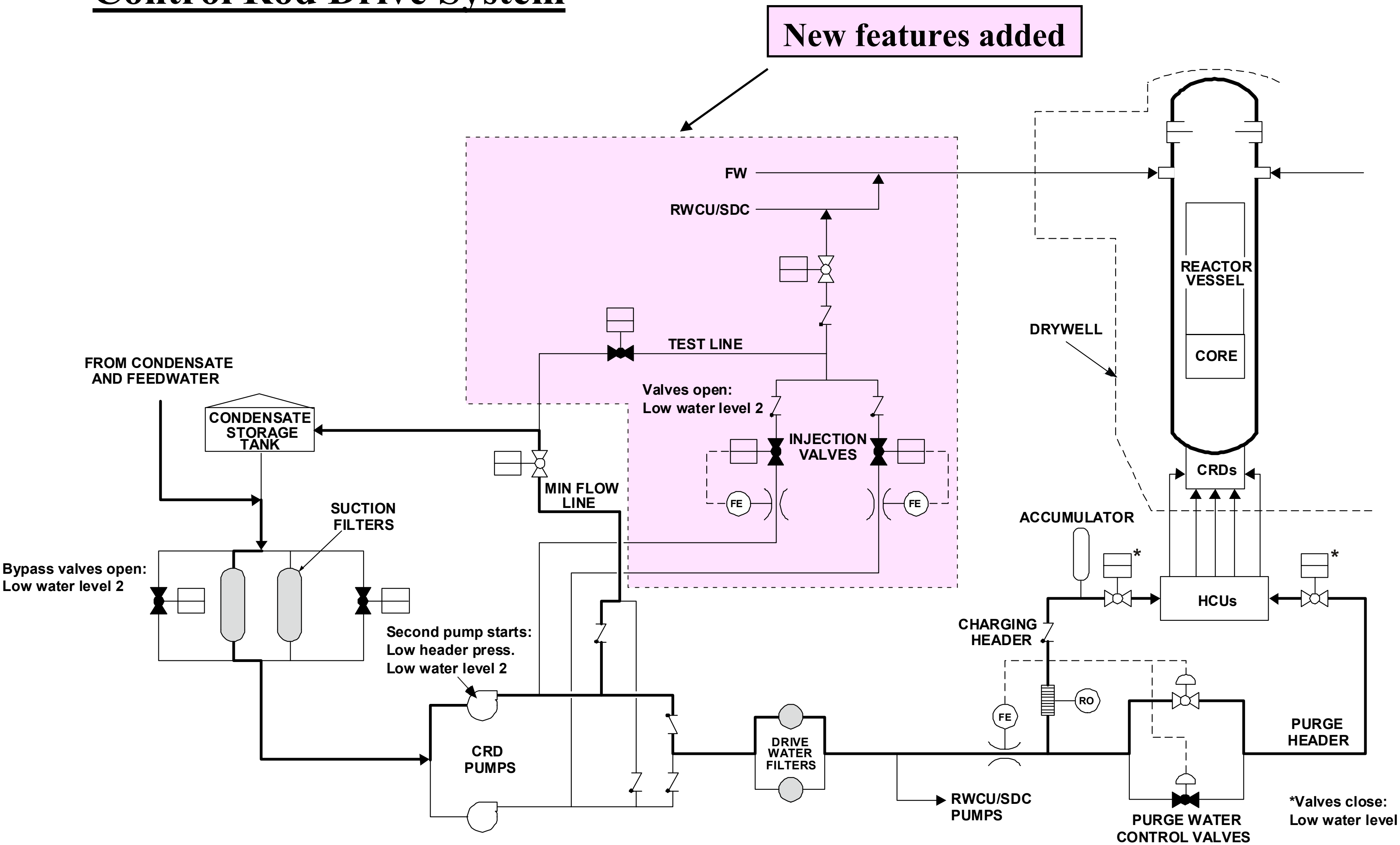
- No recirculation pumps – total reliance on natural circulation
- Significant natural circulation flow exists in all BWR's
- For a given core power, there is a corresponding natural circulation flow
- ESBWR uses enhanced design features to increase the flow compared to standard BWR's



Important Systems

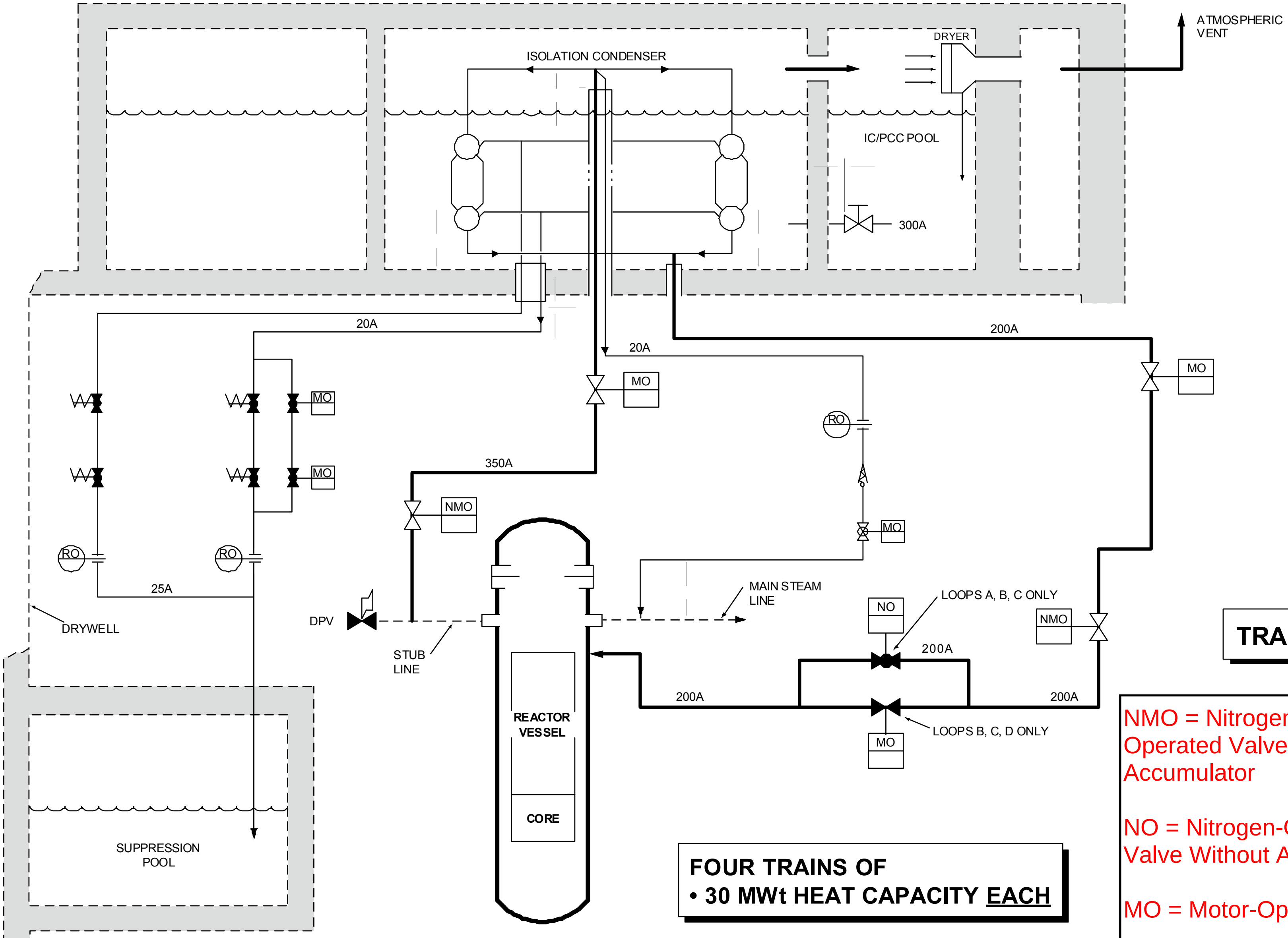
Control Rod Drive System (CRDS)

Control Rod Drive System



Isolation Condenser System (ICS)

ESBWR Isolation Condenser System - Schematic Diagram



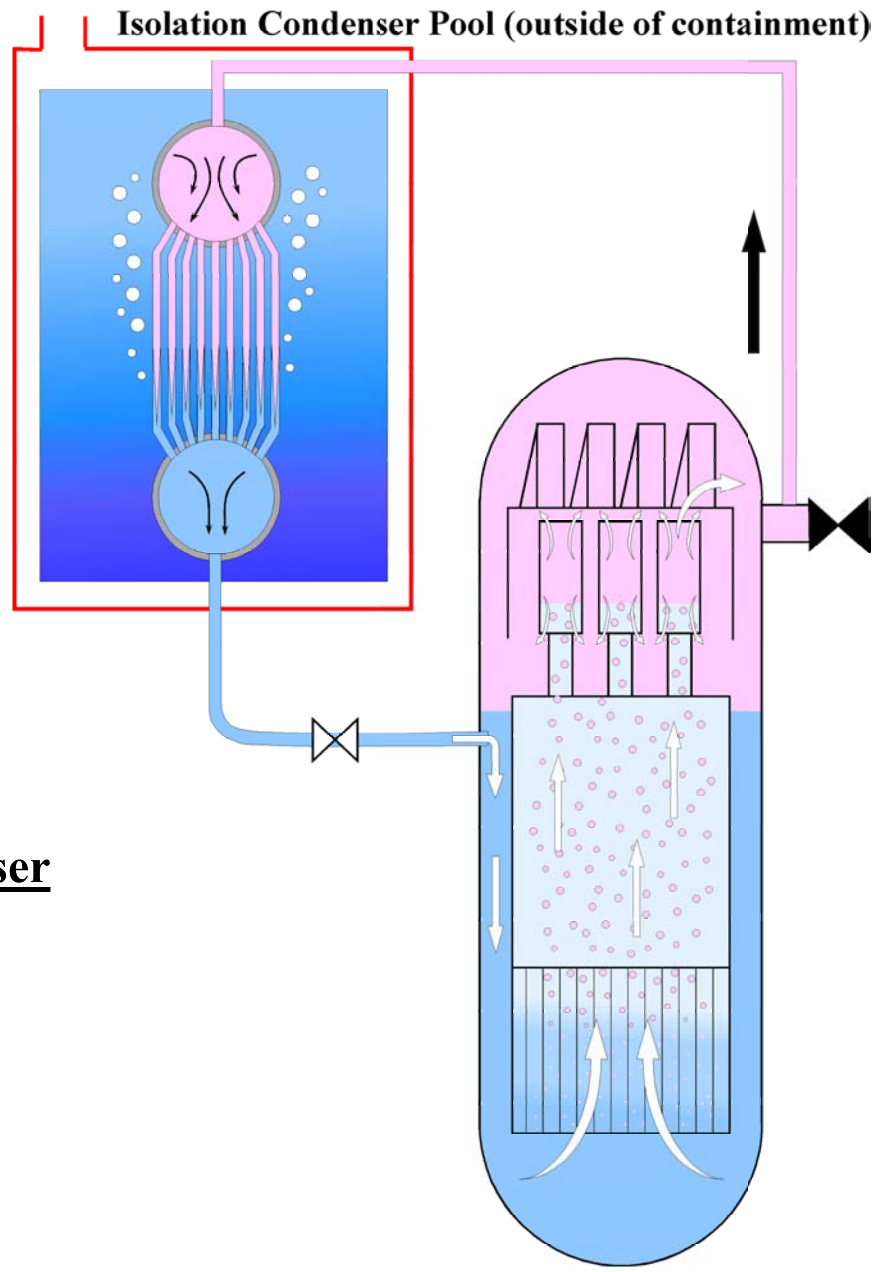
TRAIN A SHOWN

FOUR TRAINS OF
• 30 MWt HEAT CAPACITY EACH

NMO = Nitrogen-Motor Operated Valve Without Accumulator

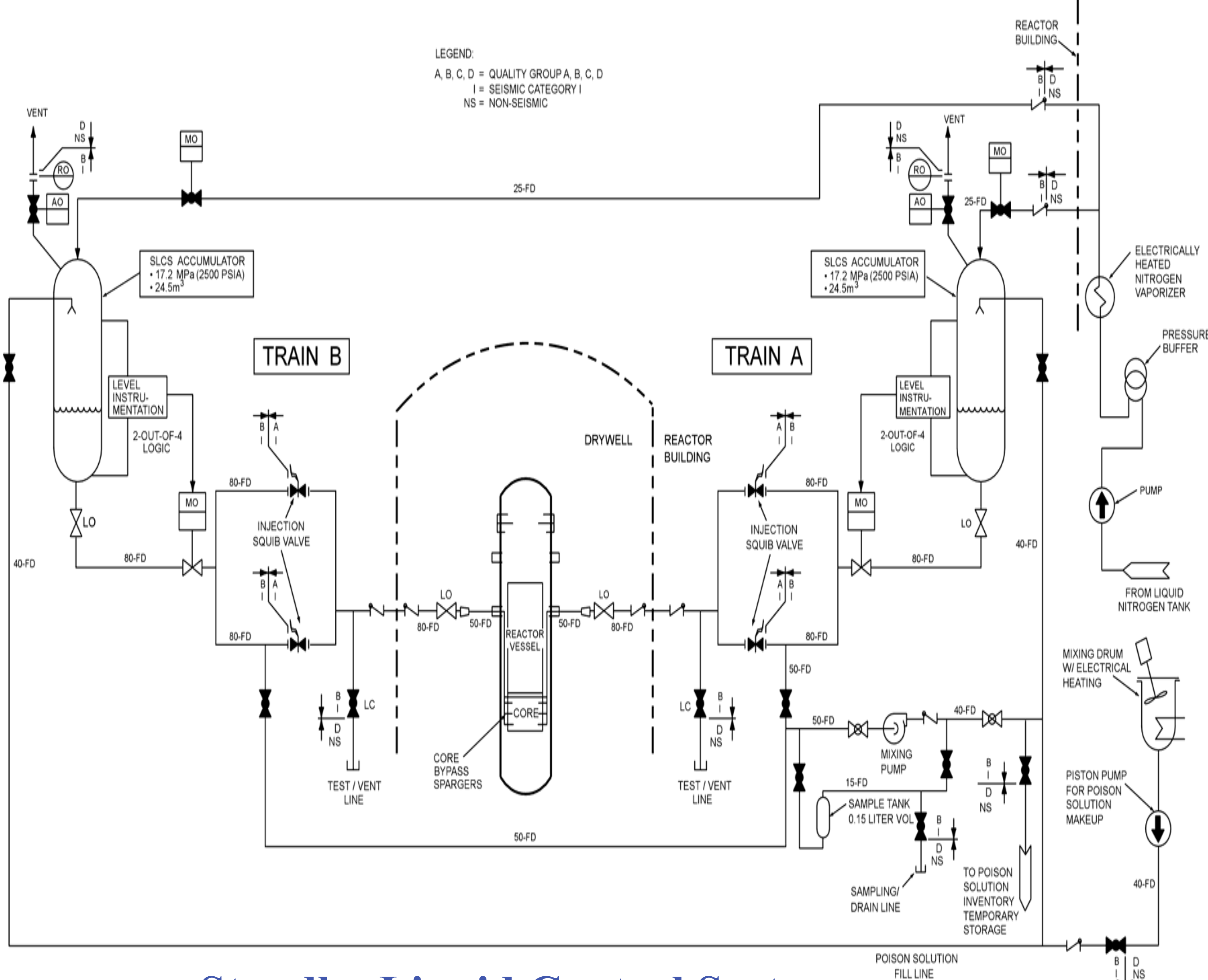
NO = Nitrogen-Operated Valve Without Accumulator

MO = Motor-Operated Valve



Isolation Condenser Simplified

Standby Liquid Control System (SLCS)

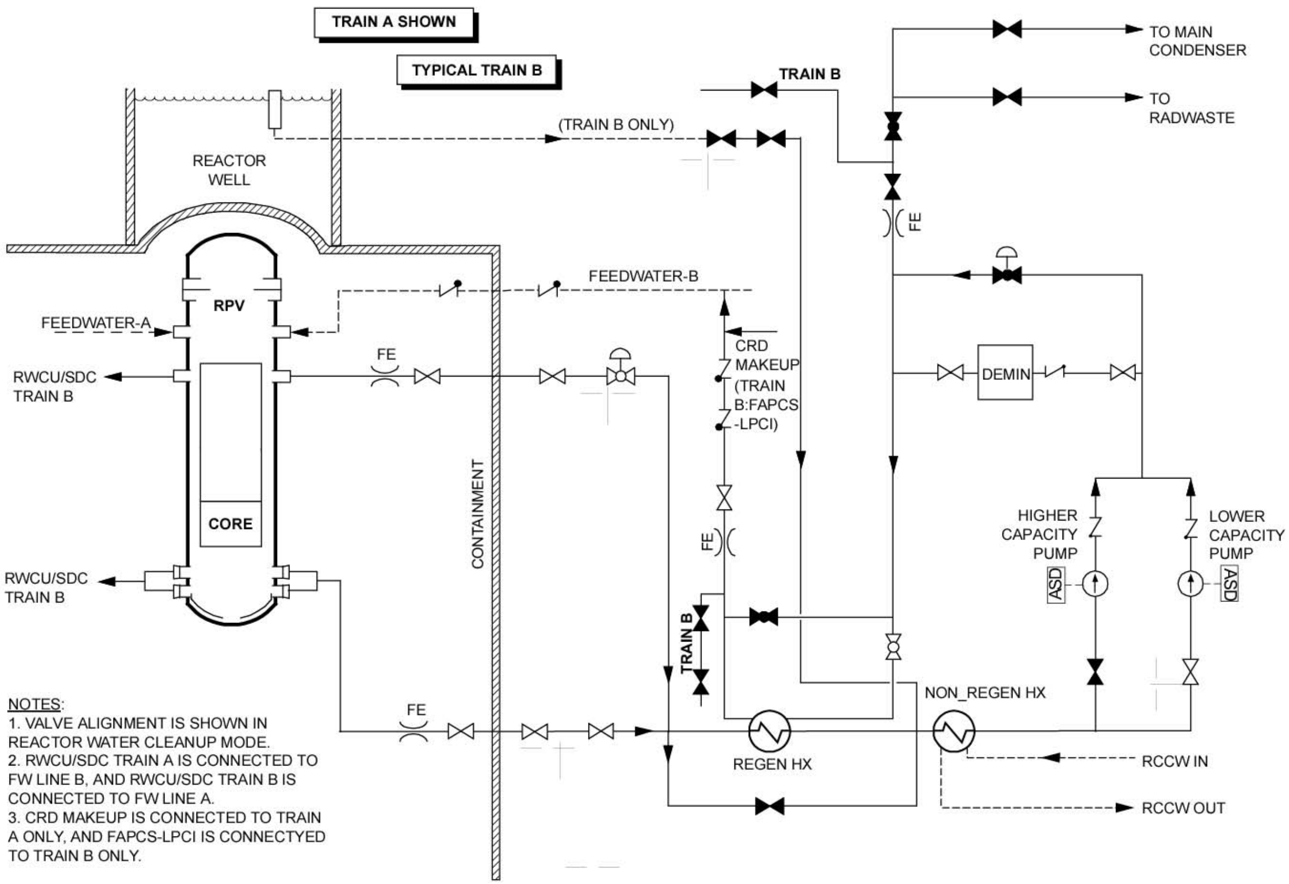


Standby Liquid Control System

ESBWR

Reactor Water Cleanup (RWCU) / Shutdown Cooling (SDC) System

Reactor Water Cleanup (RWCU)



NOTES:
1. VALVE ALIGNMENT IS SHOWN IN REACTOR WATER CLEANUP MODE.
2. RWCU/SDC TRAIN A IS CONNECTED TO FW LINE B, AND RWCU/SDC TRAIN B IS CONNECTED TO FW LINE A.
3. CRD MAKEUP IS CONNECTED TO TRAIN A ONLY, AND FAPCS-LPCI IS CONNECTYED TO TRAIN B ONLY.

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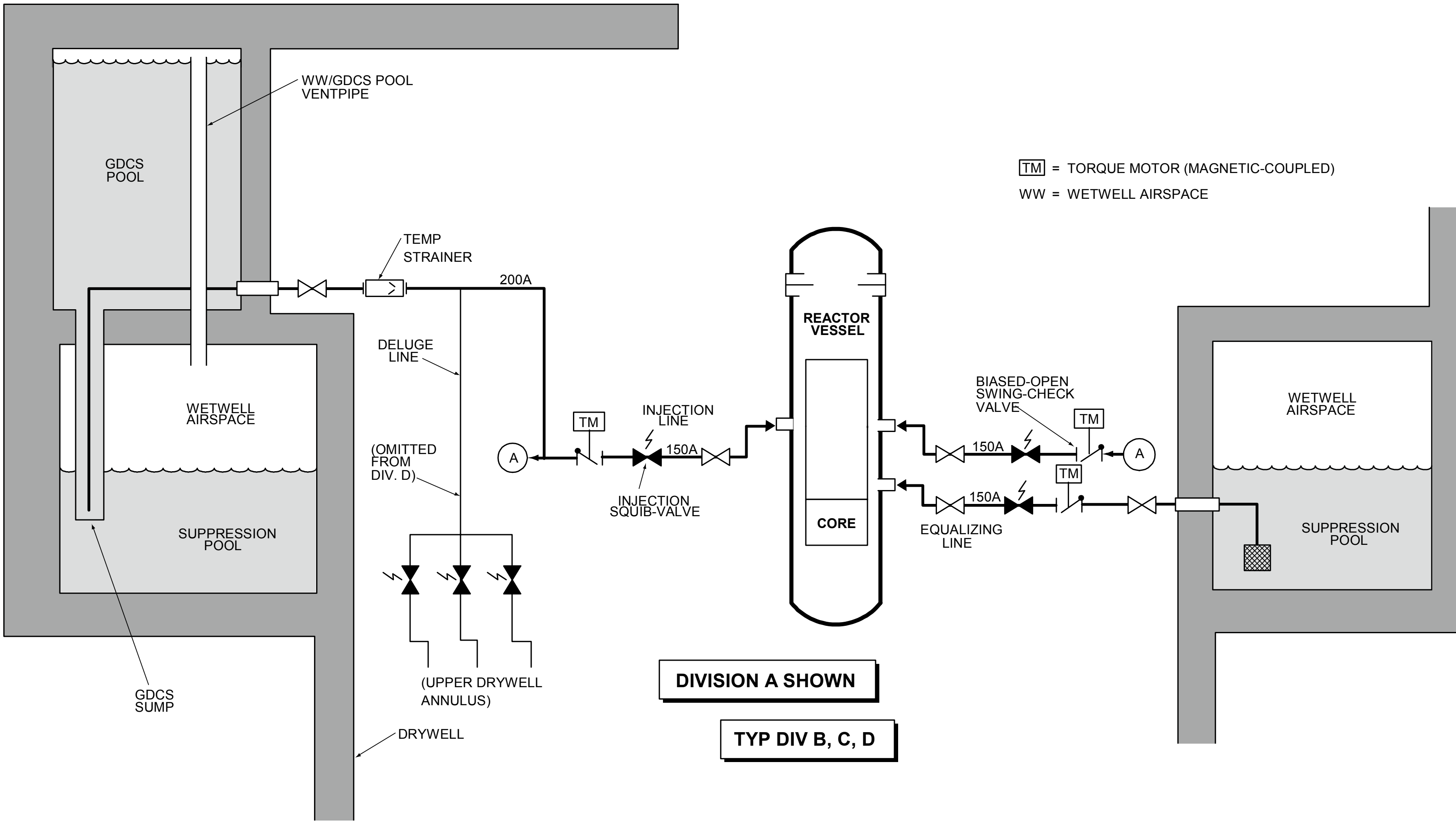
ESBWR

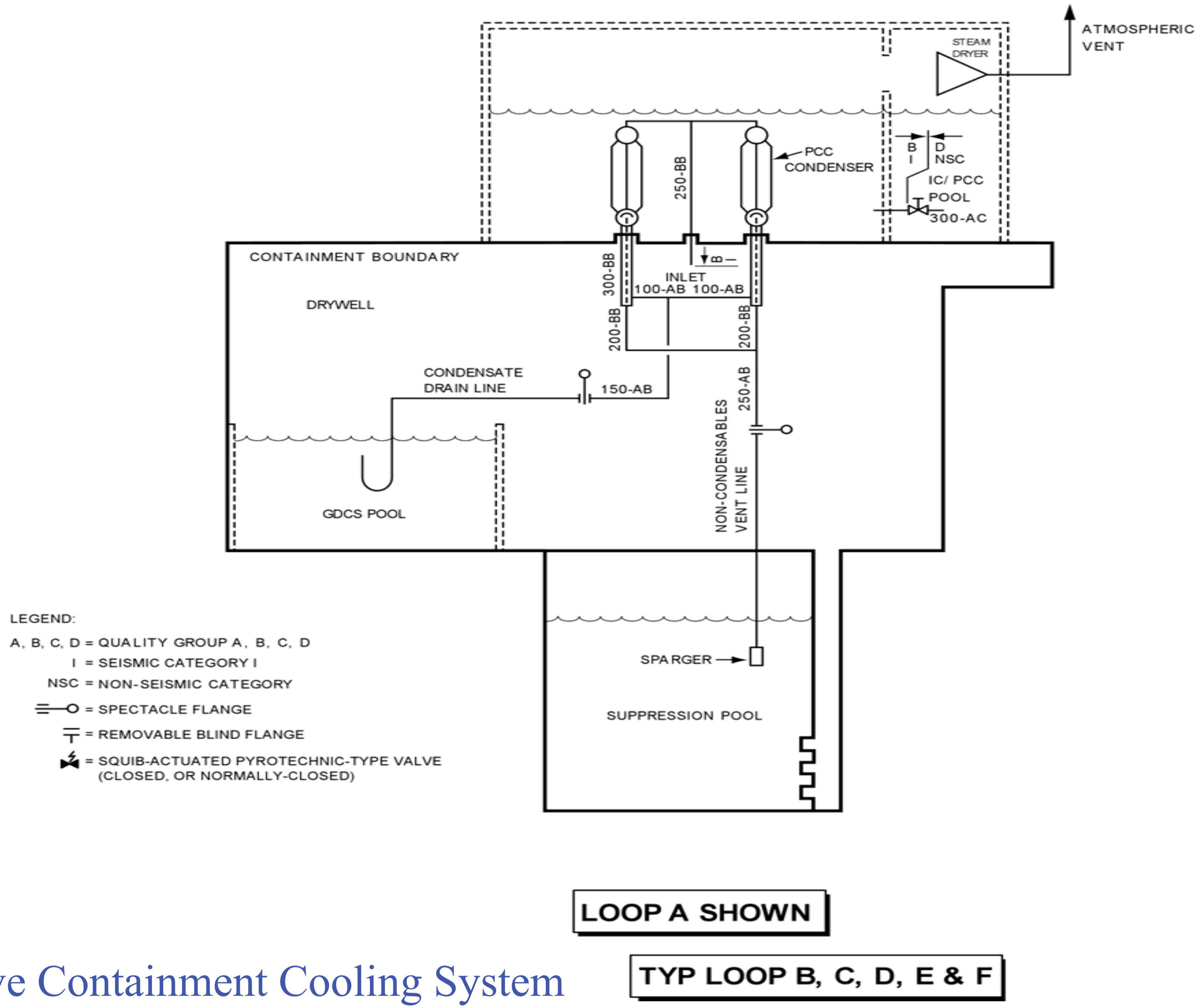
Safety Systems

Gravity-Driven Cooling System (GDCS)

ESBWR Gravity-Driven Cooling System - Schematic Diagram

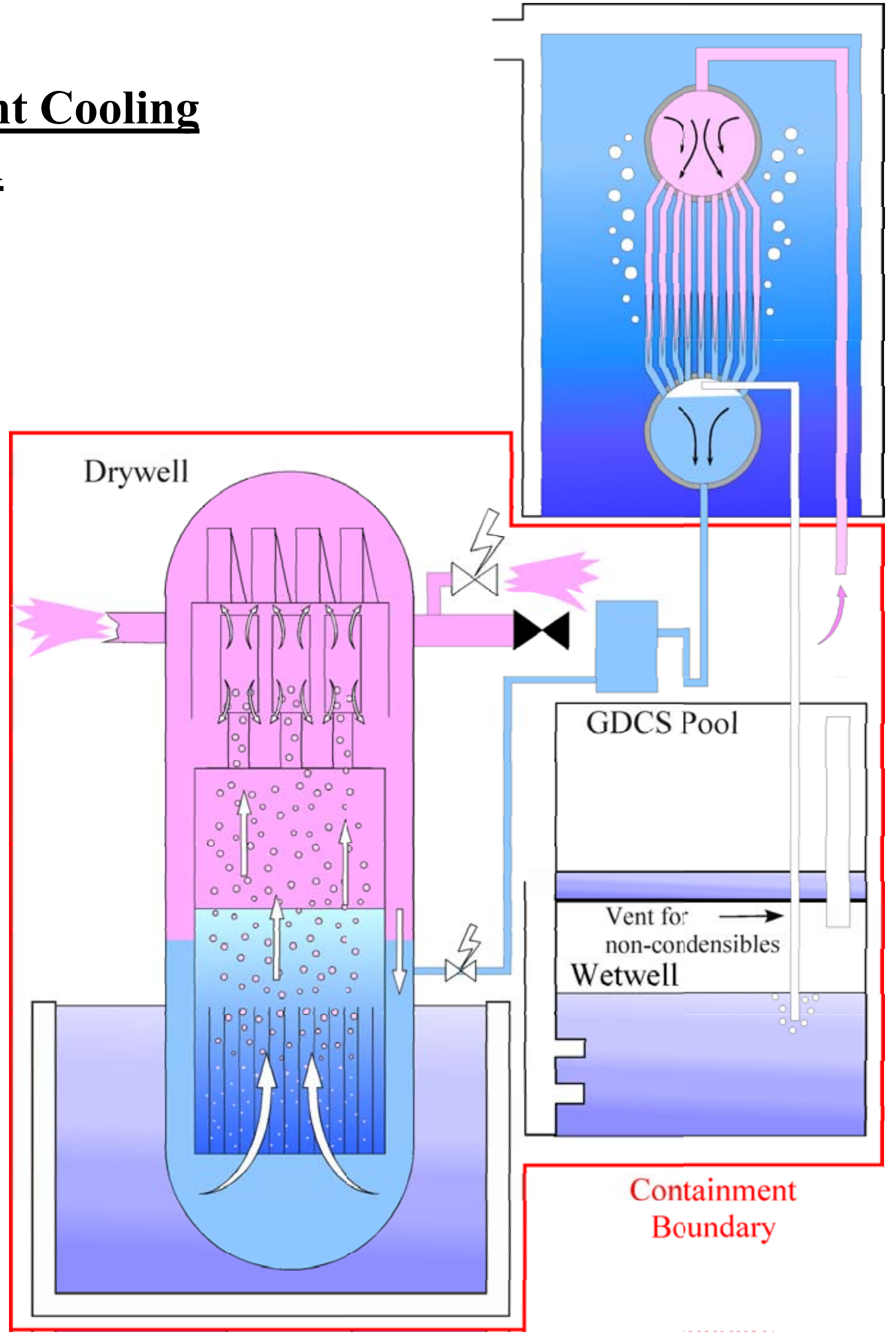


Passive Containment Cooling System (PCCS)



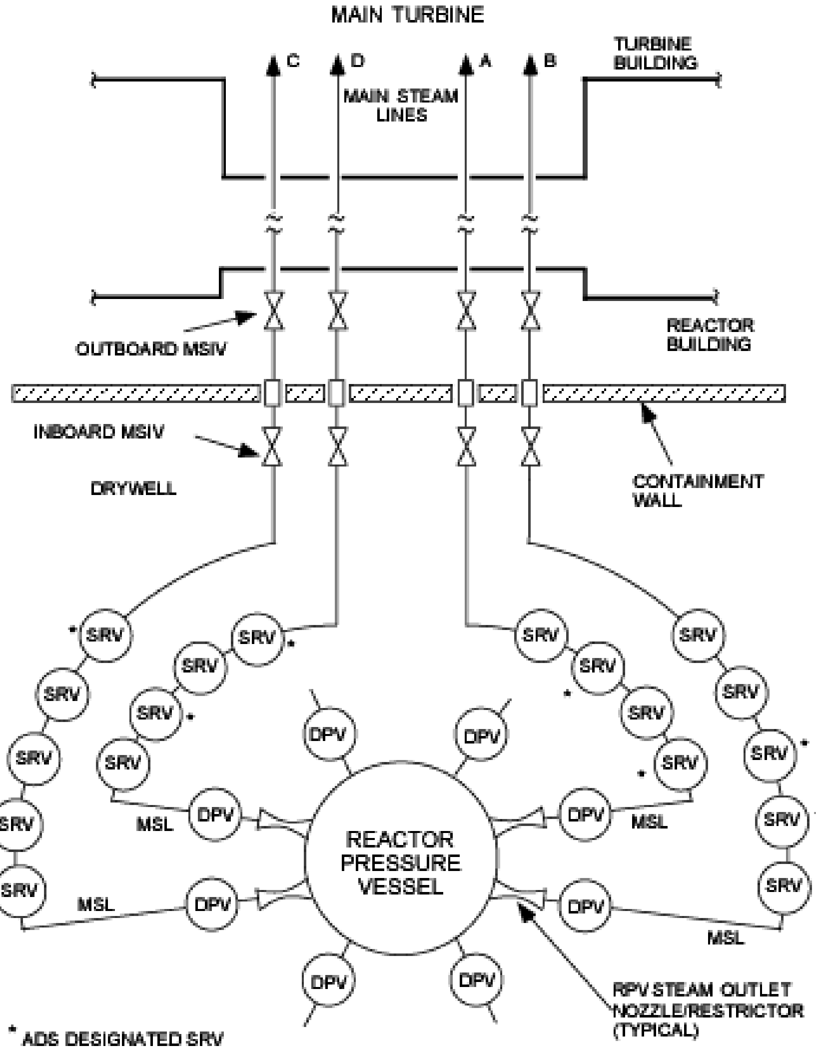
Passive Containment Cooling System

Passive Containment Cooling Simplified



Depressurization

MSIV, SRV and DPV Arrangement



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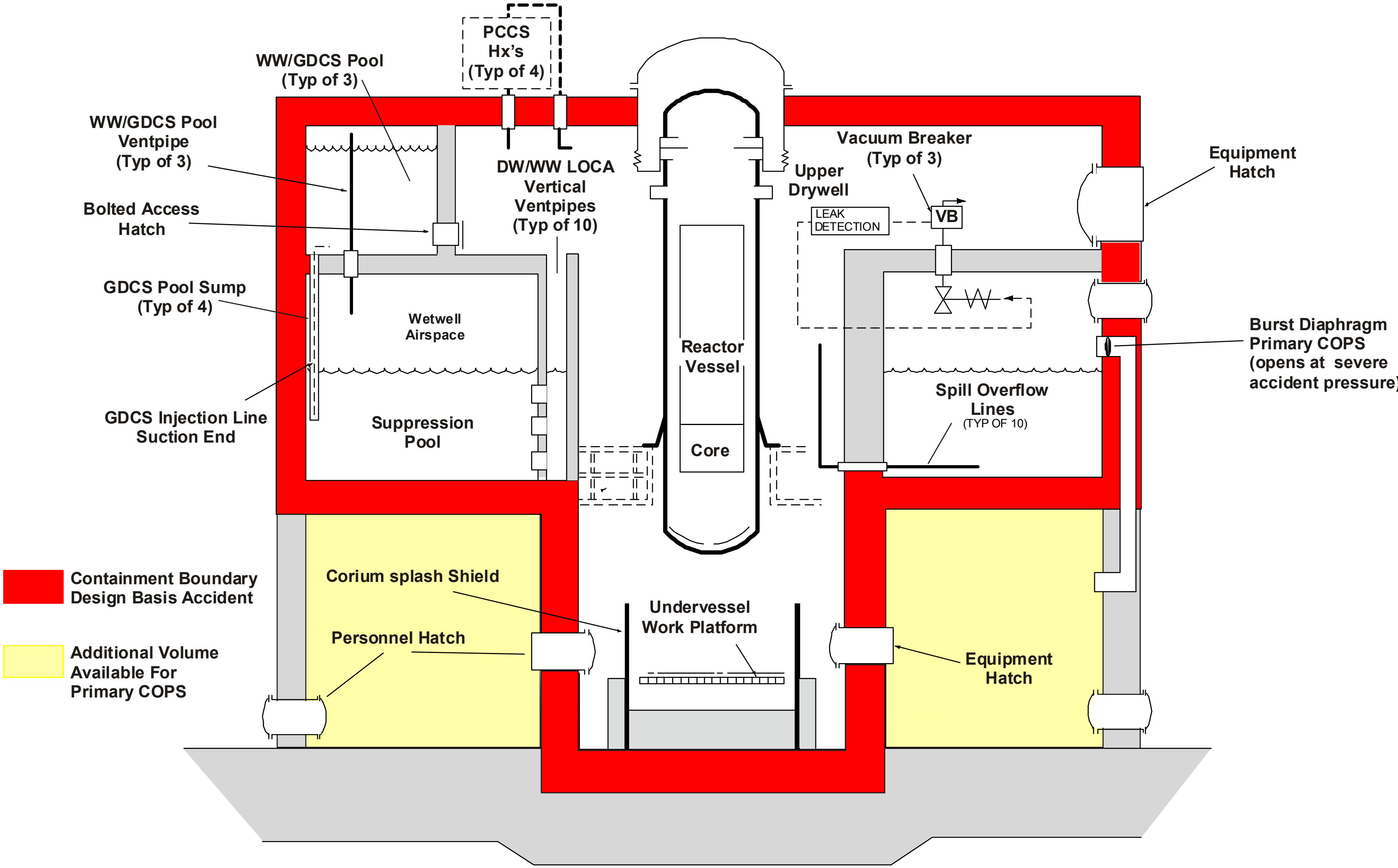
ESBWR

Containment Design

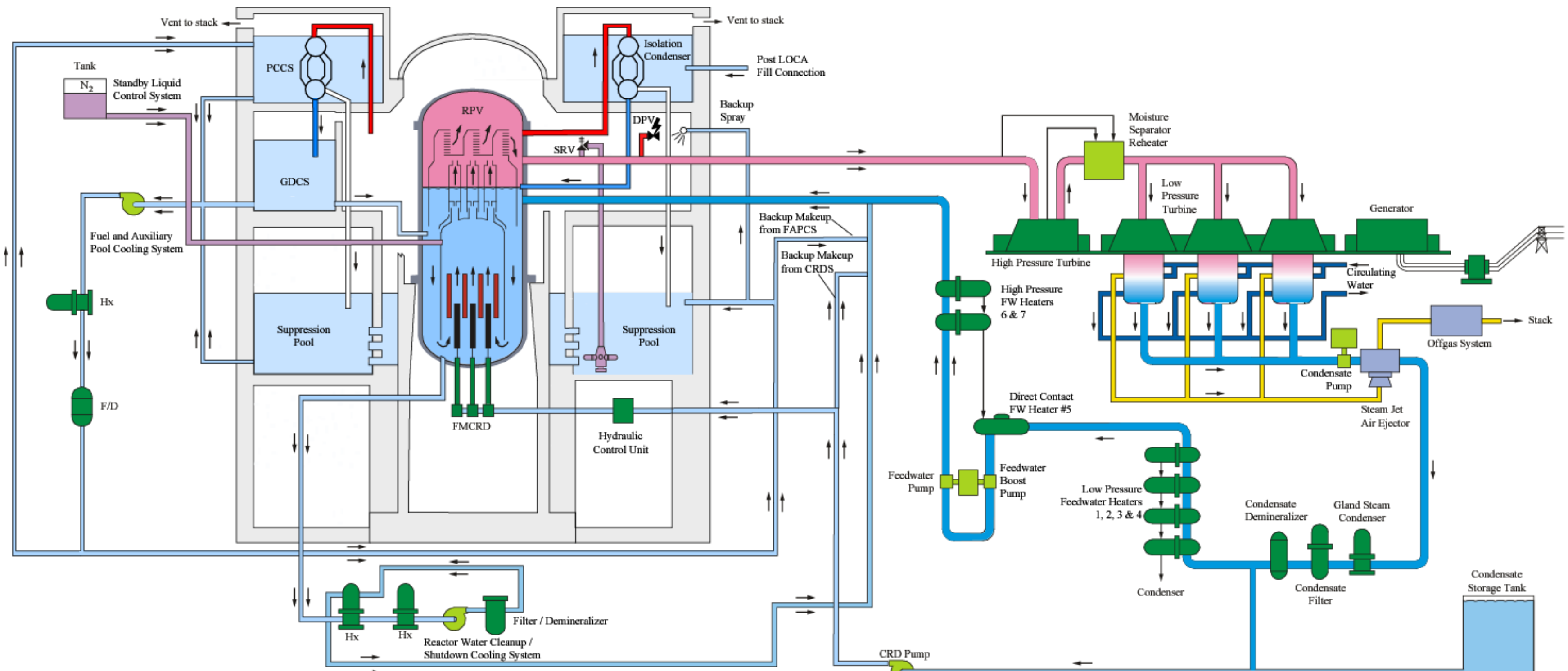
ESBWR Containment System - Schematic Diagram



Additional Systems

ESBWR

Power Conversion System (PCS)


Vent to stack
PCCS
Tank
N_2
Standby Liquid Control System
GDCS
Fuel and Auxiliary Pool Cooling System
Hx
F/D
Suppression Pool
RPV
SRV
DPV
Isolation Condenser
Vent to stack
Post LOCA Fill Connection
Backup Spray
Suppression Pool
FMCRD
Hydraulic Control Unit
Backup Makeup from FAPCS
Backup Makeup from CRDS
Hx
Hx
Filter / Demineralizer
Reactor Water Cleanup / Shutdown Cooling System
CRD Pump
Moisture Separator Reheater
Low Pressure Turbine
Generator
High Pressure Turbine
Circulating Water
High Pressure FW Heaters 6 & 7
Stack
Offgas System
Condensate Pump
Steam Jet Air Ejector
Direct Contact FW Heater #5
Feedwater Pump
Feedwater Boost Pump
Low Pressure Feedwater Heaters 1, 2, 3 & 4
Condensate Demineralizer
Gland Steam Condenser
Condenser
Condensate Filter
Condensate Storage Tank

ESBWR

Instrumentation and Control (I&C)

Summary of ESBWR I&C Characteristics

- ESBWR's digital I&C design is based on the same digital I&C framework, design, and hardware/software platforms of ABWR. The ABWR digital I&C design has been in operation and in construction (with hardware/software in fabrication/testing). – proven system and hardware/software designs.
- Automation implemented same as ABWR
- Minimized hardwired cables same as ABWR
- Digital Remote Shutdown System capable of full plant control and enhances EOP utilization
- Enhanced “diverse protection and actuation” capability in compliance to BTP HICB - 19
- Fixed in-core gamma thermometer AFIP to replace the TIP system
  – simplified operation and reduced personnel radiation dosage.
  - eliminated TIP containment penetrations
- The ESBWR I&C design will comply with updated or newly developed regulatory requirements such as BTP-14, BTP-19, as well as RG1.152.

Electrical Distribution

Standby On-site AC Power Supply

- Consists of two 15 MVA independent diesels coupled to 6.9 kV AC generators, the DG auxiliary systems, fuel storage and transfer systems and associated local instruments and controls.
- Each DG supplies non-safety AC power to it's associated PIP busses on loss of voltage for plant investment protection.
- On PIP bus undervoltage the DG starts, accelerates with in 1 minute.
- Major loads are tripped from the 6.9 kV PIP busses.
- DG will connect to the PIP busses when incoming preferred and alternate preferred source breakers have been tripped.
- Large motor loads are then reapplied sequentially and automatically after DG power source breaker closes.
- The DG is capable of being fully loaded within 600 seconds.
- DG operation is not required to ensure nuclear safety – only investment protection

PIP = Plant Investment Protection

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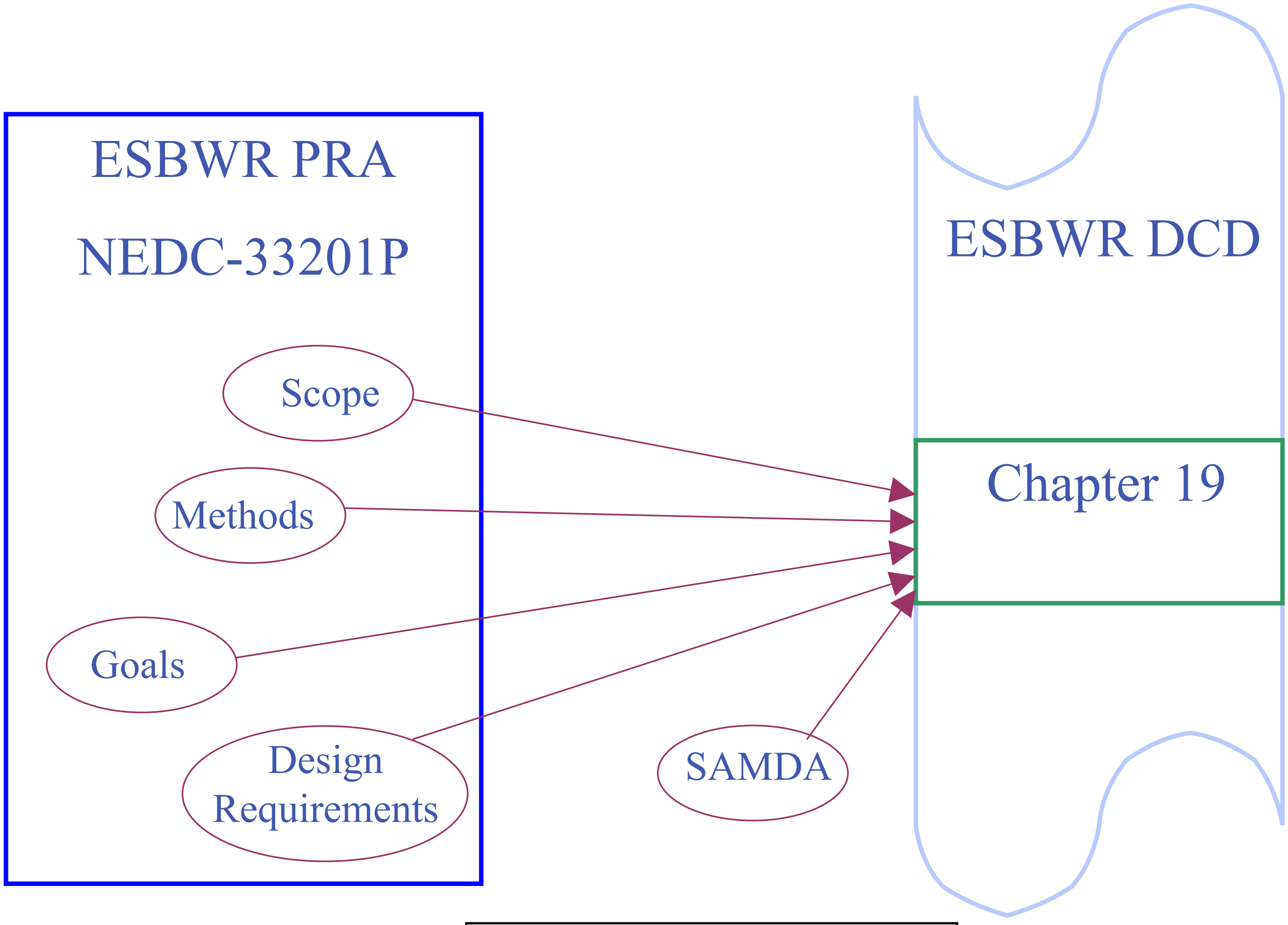
Accident Analysis

ESBWR

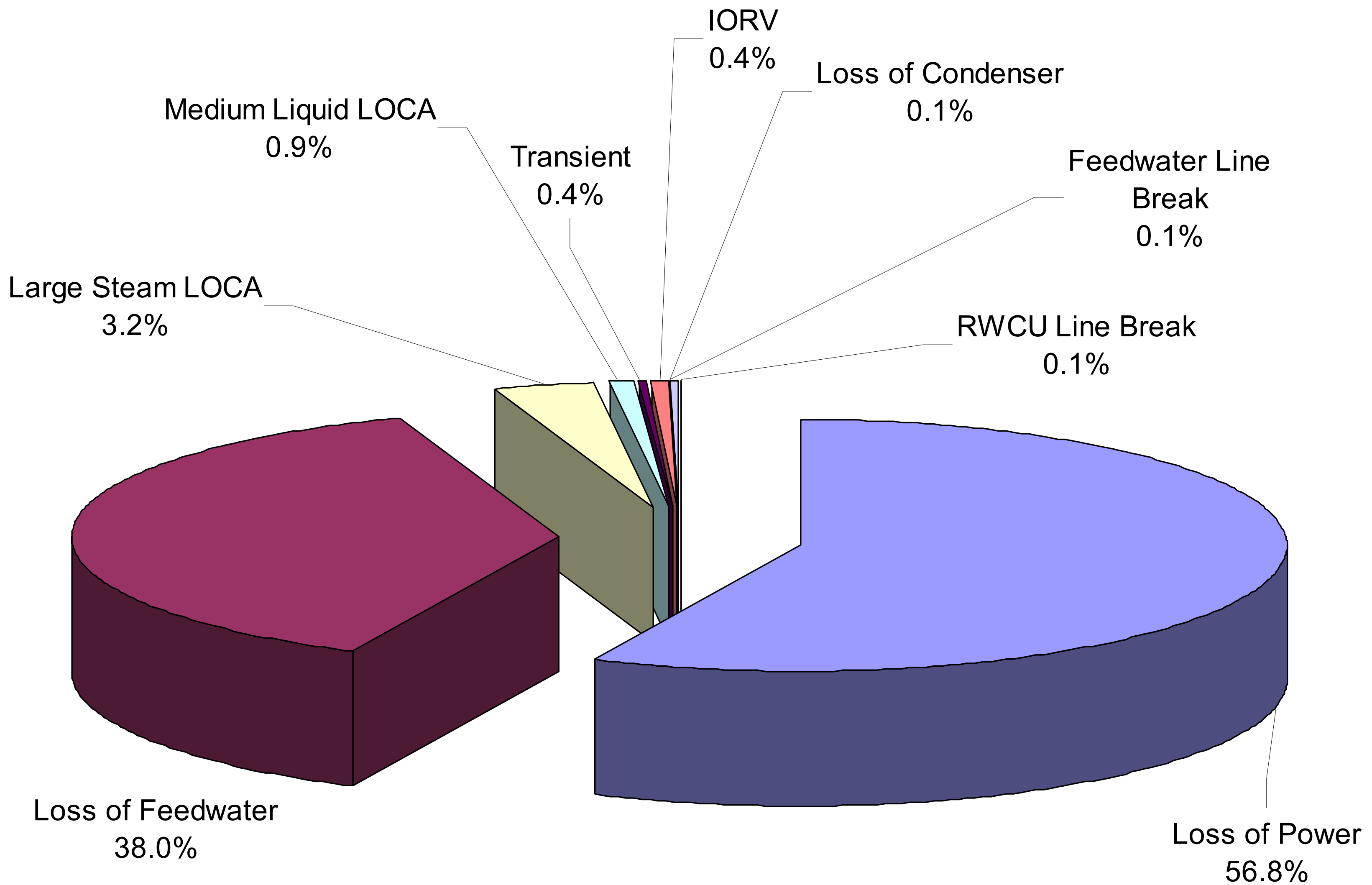
Probabilistic Risk Assessment (PRA)

Document Relationships



SAMDA = Severe Accident Mitigation Design Alternatives

Breakdown By Initiating Event



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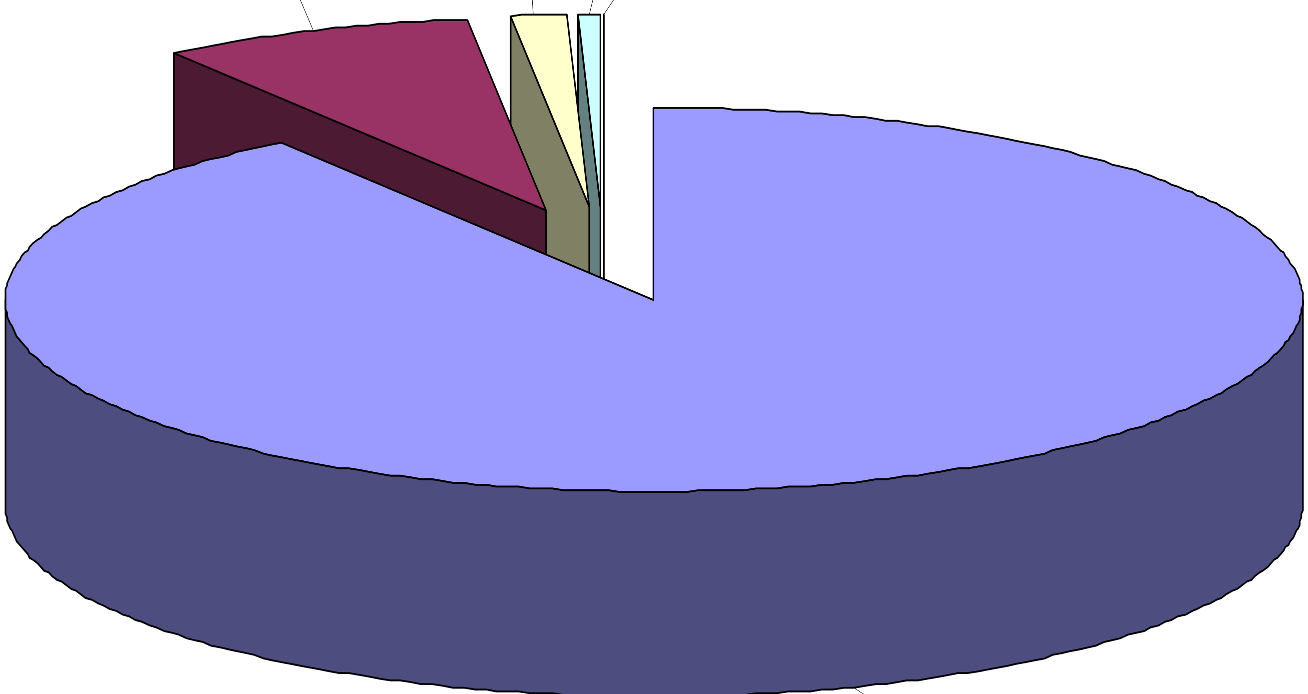
Breakdown By Accident Class



Design Control Document (DCD) Accident Analyses

ESBWR Severe Accident Treatment – Work Structure