GEH Safety Enhancement Services

2012 LAS/ANS SYMPOSIUM

July 5, 2012

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GE HITACHI

CURRENT US REGULATORY LANDSCAPE

NRC Orders and Request for Information
Issued March 12, 2012

NRC Orders:

- Mitigation Strategies for Beyond-Design-Basis External Events
- BWR Mark I and Mark II Hardened Containment Vents
- Spent Fuel Pool Instrumentation
  - February 2013 – Utilities to provide detail implementation schedule
  - Implementation by Dec. 31, 2016 (or 2 scheduled outages if earlier)

TIER 1: Items to be initiated in the near term or immediately

NRC Requests for Information:

- External hazards re-evaluation (flooding, seismic)
- Flooding & seismic walk downs and vulnerabilities
- Emergency preparedness - communications & staffing
  - November 2012 – Flooding & seismic walk downs completed
  - Possible follow up PRA and/or Margin Analysis

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NRC Longer Term Actions

TIER 2: Items which could not be initiated in the near term. These actions do not require long-term Study. NRC schedule expected mid-2012

- External hazards re-evaluation (all other external hazards excluding seismic and flooding)
- Spent Fuel Pool makeup capability
- Emergency preparedness regulatory actions

TIER 3: Items that require further staff study. Estimated 4-5 years before NRC guidance.

- Ten-year confirmation of seismic and flooding
- Potential enhancements to the capability to prevent or mitigate seismically-induced fires and floods
- Reliable hardened vents for other containment designs
- Hydrogen control and mitigation inside containment or in other buildings
- Emergency preparedness (EP) enhancements for prolonged SBO, multiunit events, radiation monitoring, and public education
- NRC Oversight Process modifications and staff training on severe accidents

GEH PORTFOLIO FOR: MITIGATION STRATEGIES FOR BEYOND DESIGN BASIS EVENTS

Clyde Union Turbine Pump

Product Description

The Clyde Union Turbine Pump or, Turbine Water Lubricated (TWL) is a component currently in use in the GE ABWR design and in many PWRs for emergency/aux feedwater. This component can be used to replace existing turbine and pumps.

The Clyde Union system does not need external power to operate as the water being pumped is the working fluid for the controls and is also the lubricating fluid for the bearings. The unit compact nominally 40"W x 70"L x 58" H.

Power devices only used for remote features:

- Remote trip...unit has on-board mechanical over-speed trip
- Kick Down...unit has 2 pump outputs (full output and ½ output)
- Instrumentation

Alternate Ultimate Heat Sink

Air Cooled Heat Exchangers

Product Description

Air Cooled Heat Exchangers can be added as a parallel system to the existing water cooled components to provide protection for critical systems that need an Ultimate Heat Sink to operate. Examples could be diesel generators, spent fuel pool, service water.

The Air Cooled Heat Exchanger System is scalable, modular, and easily installed into current plant configurations.

For reference a complete (incl pumps) 20 MWt system would be ~ 15ft x 60ft and require 500kWe portable DG to provide power

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Heat Recovery Generator

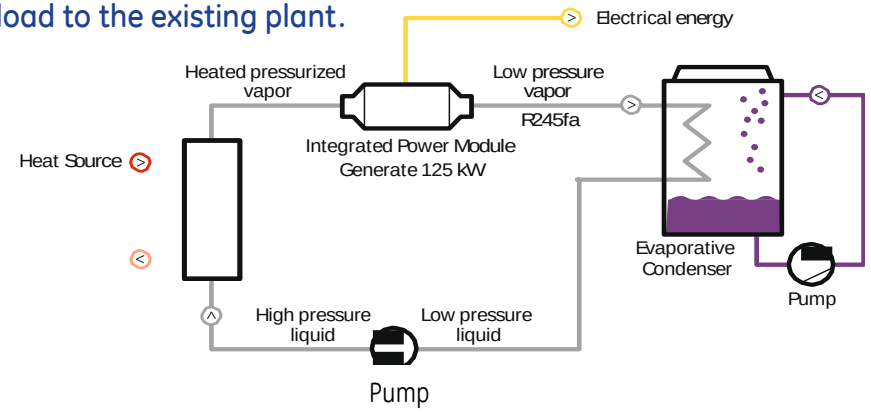
Product Description

The Heat Recovery Generator is a pre-packaged Organic Rankine Cycle Generator system that generates electricity through use of heat.

By coupling a "Clean Cycle 125" to a small diesel generator or slipstreaming onto main or aux steam supply lines, ~100 kWe can be produced to reduce battery load and/or increase AC availability for selected systems.

Larger Heat Recovery Generators can be applied to a diesel generator exhaust, extending existing system capacity and enhancing coping strategies.

The Heat Recovery Generator units are pre-packaged with self-contained air coolers for condenser and waste heat without adding load to the existing plant.



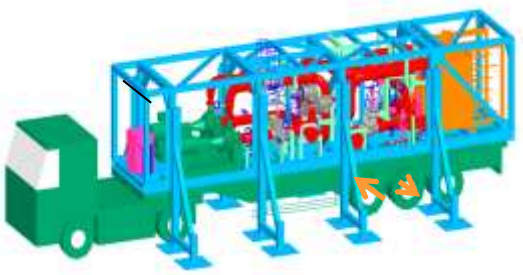
Skid Based Alternate Cooling

Product Description

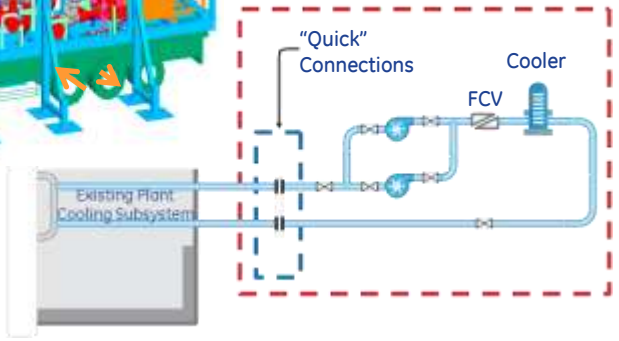
The GEH Skid Based Alternate Cooling System leverages existing GE products to provide a bolt on auxiliary cooling system to extend SBO coping time for core and spent fuel pool cooling.

Typical configuration is Dual Heat Exchanger Type with total heat load capacity ~19MW. Configuration can be enhanced with bolt on Air Cooled Heat Exchangers or an alternative Ultimate Heat Sink (pond, seawater, etc.)

The Skid Based Alternate Cooling System is scalable, modular, mobile and easily configurable to interface with a variety of plant systems and corresponding heat loads.



Example of Truck Mounted System



Skid Based, Modular, or Permanent Installation System Example

Alternate AC Power

Bus Load

Product Description

Alternate AC Power can be provided by a variety of diesel generator options.

GE Diesel Generators:

- GE has 100+ years of experience with diesel engines
- Range of power output from 1.5 MW up to 5 MW
- Weight: 1-2 MW = 10-15 tons; 3-5 MW = 40+ tons
- Footprint: ~ 14.5m x 4m
- Diesel powered … black start capability
- Easily transported by land, air, sea

Site Load

Product Description

Alternate AC Power can be provided by a variety of gas turbine generator options.

GE Gas Turbine Generators:

- Natural gas or liquid fuel
- High energy, high efficiency output (37%+)
- TM2500+ Mobile Units….>97M hours of operation
  - Easily transported by land, air, sea
  - 23 MW – 31 MW output
  - 2 trailer design…78'x21' footprint
- Larger stationary units…18 MW up to 103 MW

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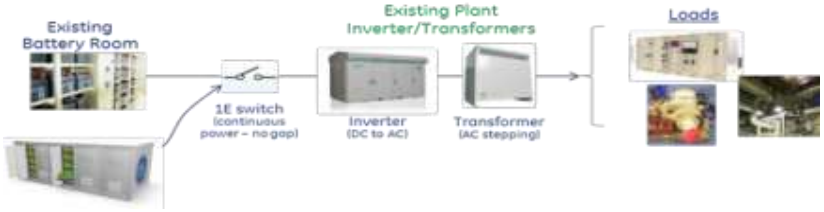
Station Battery Augmentation

Product Description

Self-contained battery modules provide a passive bridge from current battery backup to AC reinforcements (generators, off-site power delivery, etc).

Two options:

1. Lead-selenium battery modules
   - Can be stored on or off-site
   - Fully hardened - seismic, flood, high wind
   - Backup power management equipment included
   - Mobile…40' module = 1350kW hours total stored energy
   - Constant power output…output/hour=total stored energy/#hours
2. High-energy sodium metal halide battery modules
   - Lower cost for 24 hour application
   - Batteries only…must utilize site power management equipment
   - Must be kept on-site…Not seismic/flood hardened
   - ~12'x8'x8' module = 1MW…consumes ~5kW/hour to maintain operating temperature.



Mobile Water Filtration and Deionization

Product Description

GE has readily available mobile filtration/deionization/reverse osmosis capabilities. These capabilities are modular, scalable, and provide the fastest trailer deployment in the industry. Deployment options include 24/7/365 dispatch, operations, and communication centers.

Typical filtration is 650 gpm, deionization is 350 gpm, reverse osmosis is 220 gpm. Required 110/20 amp power supply.

Systems can be deployed as an Emergency Response or under standard service contracts.

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GEH PORTFOLIO FOR:
BWR MARK I AND MARK II
RELIABLE CONTAINMENT VENTS

ABWR COPS Retrofit

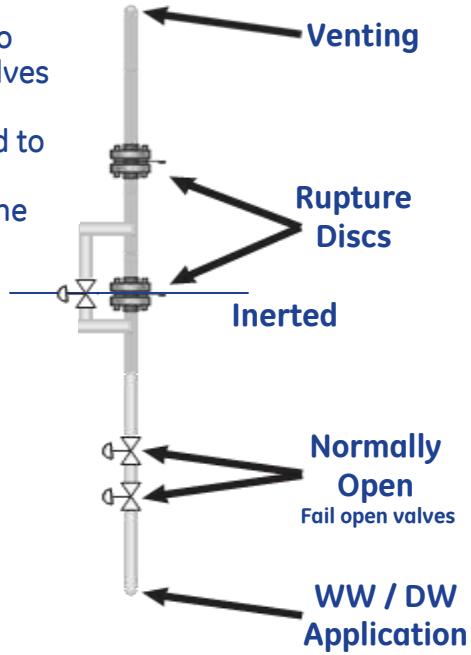
Product Description

The ABWR Containment Overpressure Protection System (COPS), which is part of the Certified ABWR design and currently installed in ABWRs in Asia, is a passive system requiring no operator action.

Use of this concept in existing BWR Mark II containments as a hardened containment vent per Tier 1 5.1 NTTF recommendation

The system consist of normally open valves with rupture discs to protect containment, bypass valves can be fitted to permit early venting. System can be designed to use existing containment penetrations and junction into the existing vent system.

For illustration purposes only



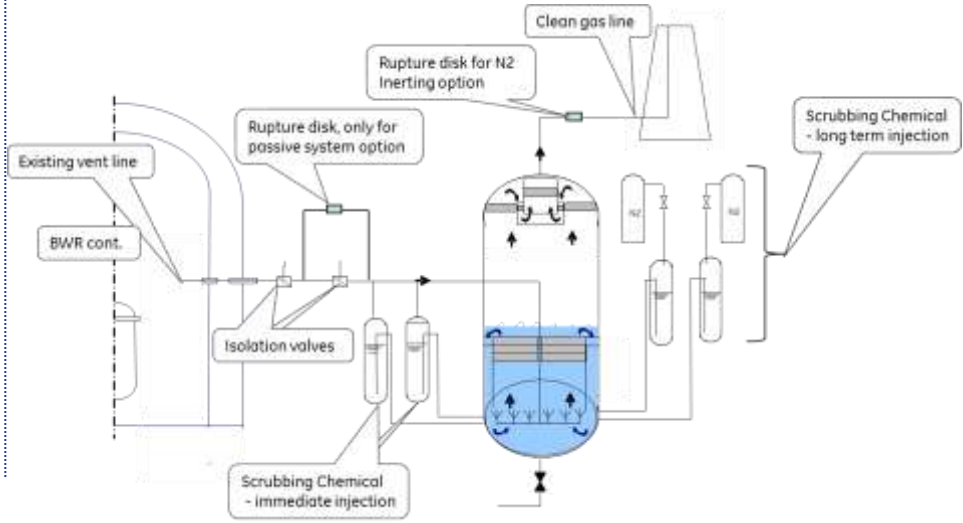
Containment Vent Filter System

Product Description

A 2nd Generation Containment Vent Filter system consisting of a tank with efficient first stage Nozzle Scrubber, a second stage co-current scrubber/recirculation zone with chemical scrubbing of Iodine species, and a third stage separator and filter.

System is installed in the containment vent system with two modes of operation, automatic (via rupture disc) and manual through isolation valves (to support early venting).

System is designed to meet required flow, decontamination factors, and containment response criteria. Compatible with Hardened Containment Vent



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GEH PORTFOLIO FOR: SPENT FUEL POOL INSTRUMENTATION

Spent Fuel Pool Instrumentation

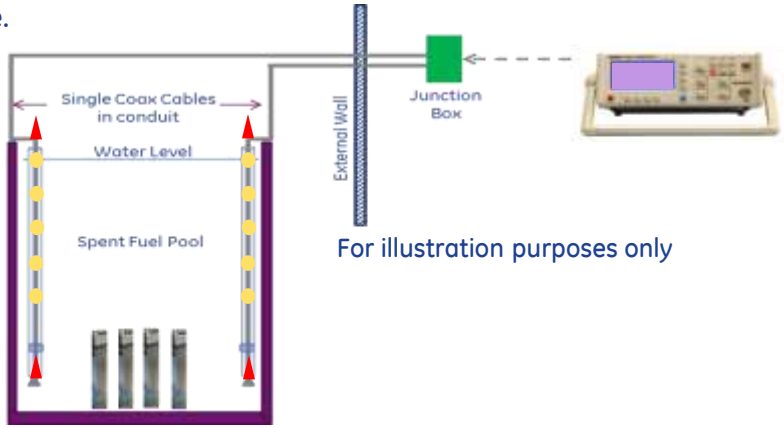
Product Description

Spent Fuel Pool (SFP) monitoring system to ensure trained personnel have the information needed about spent fuel pool water levels during loss of AC power to avoid fuel damage.

Parameters to monitor:

- Level Sensors
- Temperature

(Optional: Level Redundancy)



For illustration purposes only

Features:

- Instruments: Primary and portable accessibility
- Arrangement: Placed in corners of SFP structure
- Mounting: Exceeds seismic rating of SFP structure
- Qualification: Extended reliability at temperature, humidity, and radiation levels consistent with SFP saturation
- Power Supplies: Independent and portable augmentation
- Display: Control room, alternate shutdown panel, remote panel/other
- Diversity / Redundancy: Determined by plant

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GEH PORTFOLIO FOR: REQUEST FOR INFORMATION

Seismic / Flood Analysis Services - BWR

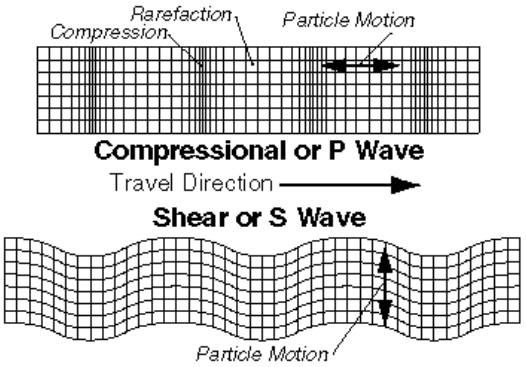
Product Description

GEH uses a methodology for Seismic Margin Analysis which was developed for the certification of the ABWR standard design and NRC approved. This methodology uses both a convolution of fragilities, and the min-max method to

- Generate the plant response model including seismic event trees and fault trees
- Develop new fragility curves for each important structure, system, and component (SSC) based on current design margins
- Determine plant and equipment capability to withstand a large earthquake

The Seismic PRA utilizes a similar generation of a plant response model, fragility curves for each important SSC, and then quantifies the model using the site-specific hazard curve.

GEH has previously evaluated the flooding hazards in support of the ESBWR design certification process. GEH also performed similar flooding hazard evaluation as part of the South Texas ABWR project. GEH has the experience in the risk evaluation associated with probable maximum flood, storm surge, dam failure, ice effects.



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GEH PORTFOLIO ADDITIONAL ITEMS

Prolonged SBO Safety Enhancement Analysis - BWR

Product Description

Utilities planning to modify their plant configurations in response to the NRC NTTF recommendations and the plant-specific INPO IER 11-4 results will benefit from GEH's experiences in previous containment and SBO analyses performed for their respective plants, such as under the power uprate projects.

GEH will use our proprietary NRC-approved methodologies, including the state-of-the-art TRACG model for containment to provide the following necessary plant-specific analyses for licensing submittal and/or to develop the required specifications for the hardware design, procurement and implementation:

- Containment pressure / temperature response during extended SBO
- Impact of containment response on system performance
- Reactor pressure vessel simulation…water level, pressure, temperature

Extended SBO Training Simulator - BWR

Product Description

Use of approved industry codes for severe accident analyses as part of the plant simulator software to enhance the current table-top simulation process.

Provides the capability to run severe accident simulations in real time providing the flexibility to change inputs for a more realistic simulation and, eliminate the snap-shot approach of the table-top exercise.

Enhances the current simulator software:

- Reactor pressure vessel accident simulation with TRACG code
  - Front-end of the SBO scenario, up to core dislocation stage
  - Seamless interface to MAAP / MELCOR for degraded core condition
  - Multi-dimensional model for high fidelity responses…reactor water level, RPV pressure / temperature
- Leverages current ABWR and ESBWR simulator software

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Passive Hydrogen Recombiners

Product Description

Passive Autocatalytic Recombiner (PAR) units are non-powered devices that reduce hydrogen by combining hydrogen with oxygen to make water. These units begin working at a lower hydrogen concentration (~1%) than igniters and are natural draft units. The PAR units are the technology of choice in the GEH ESBWR design.

GEH can provide the design, procurement, and installation of passive hydrogen control solutions.

The design phase includes input from GEH NRC approved codes, coupled with plant specific drawings, resulting in a detailed system specifications. Output of the design phase provides the customer with details on number, size, and placement of PARs to provide primary or backup hydrogen control.

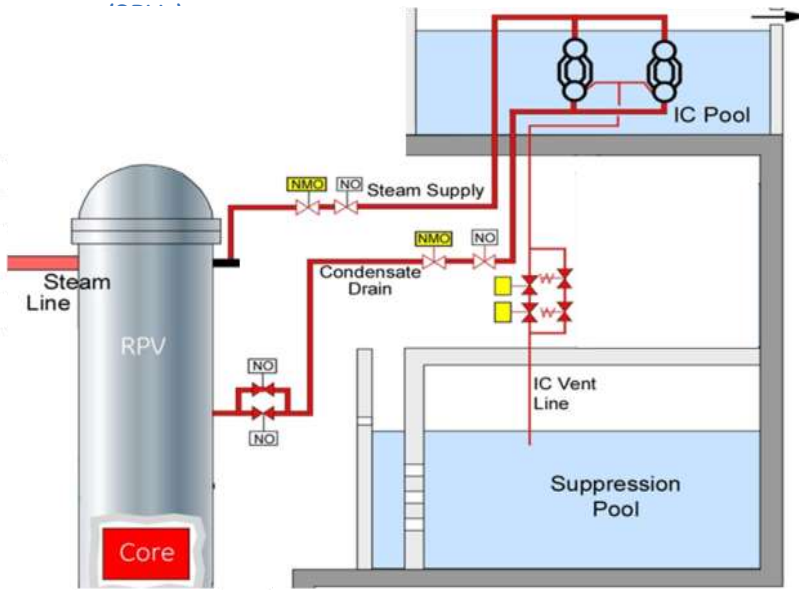
Isolation Condenser Retrofit BWR

Product Description

The Iso-Condenser Retrofit concept consist of using the Equipment Pool cavity, e.g. Dryer Separator Pit (DSP), to create an isolation condenser.

This concept represents a closed loop, gravity driven system.

- Utilizing the large volume in the DSP translates to a large operation time without make-up
- Decay heat removed by condensing steam is returned to the reactor
- Minimizes need for make-up to the Reactor Vessel…only replace what is blown down via the Safety Relief Valves



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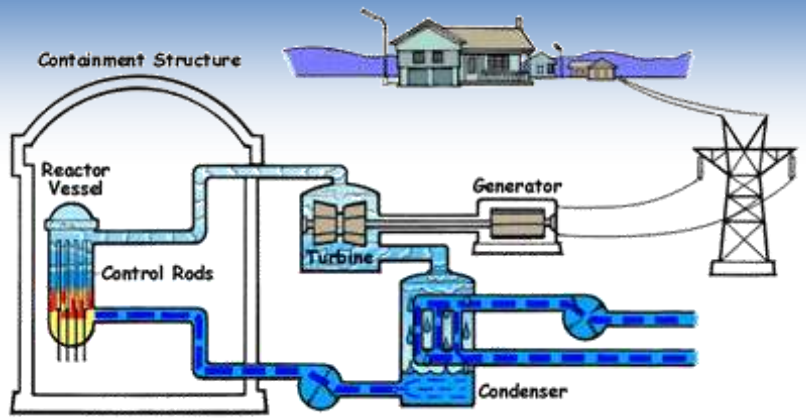
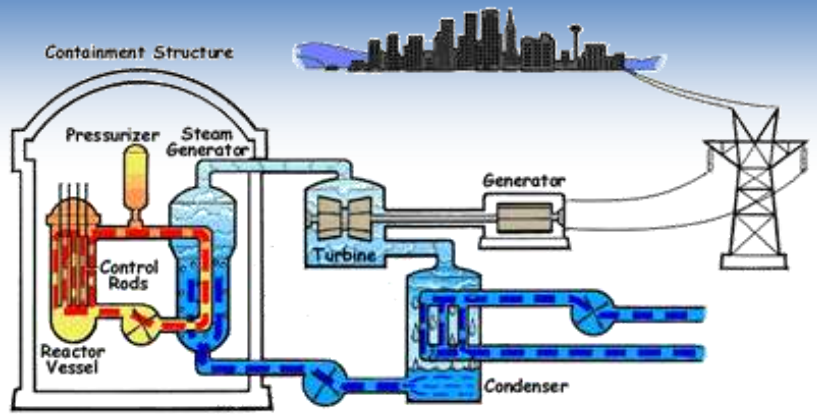
Basic Principles of Steam Generation





BWR

- Direct Cycle
- RPV Pressure ~7 MPa (1020 psig)
- RPV Temperature 288 °C (550 °F)
- Steam Generated in RPV (with Separator & Dryer)
- Bulk Boiling Allowed in RPV

PWR

- Indirect Cycle
- RPV Pressure ~15 MPa (~2240 psig)
- RPV Temperature 326 °C (~618 °F)
- Steam Generated in Steam Generator (via Second Loop)
- No Bulk Boiling in RPV

BWR … Lower RPV Pressure & Simplified Steam Cycle

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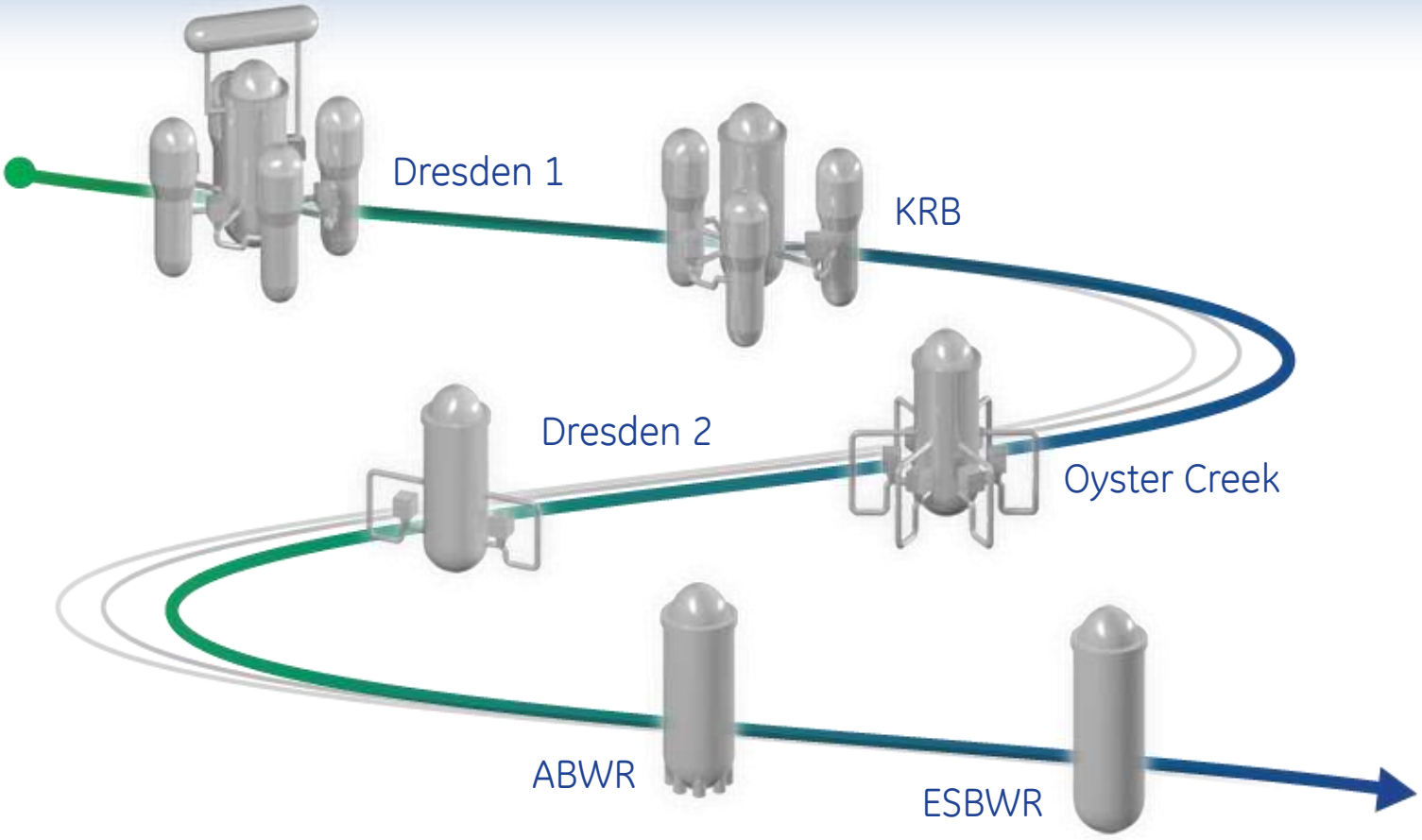
Simplicity



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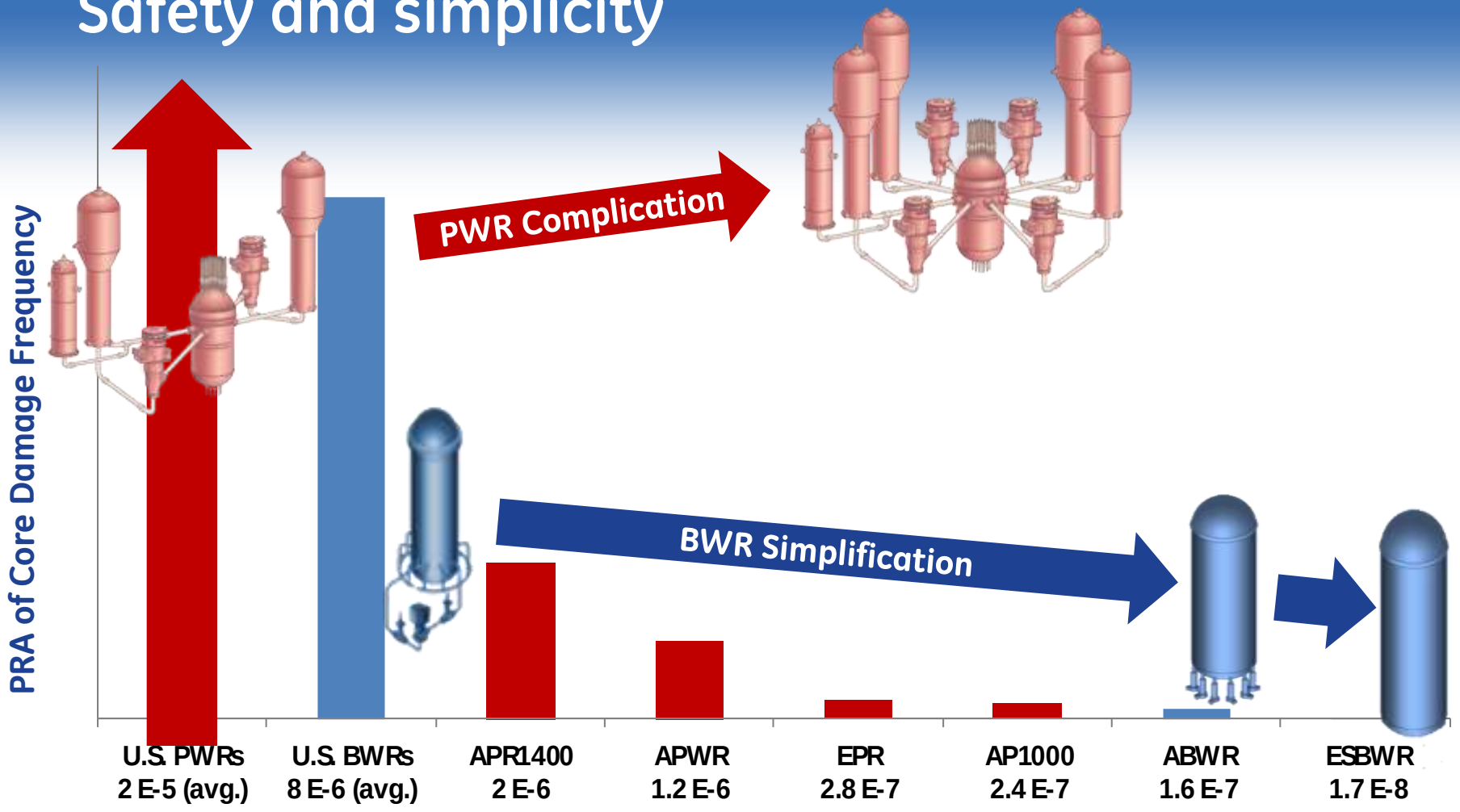
Safety and simplicity



References: Plant licensing DCDs and publically available information
Note: PRA of CDF is represented in at-power internal events (per year)
Note: NSSS diagrams are for visualization purposes only

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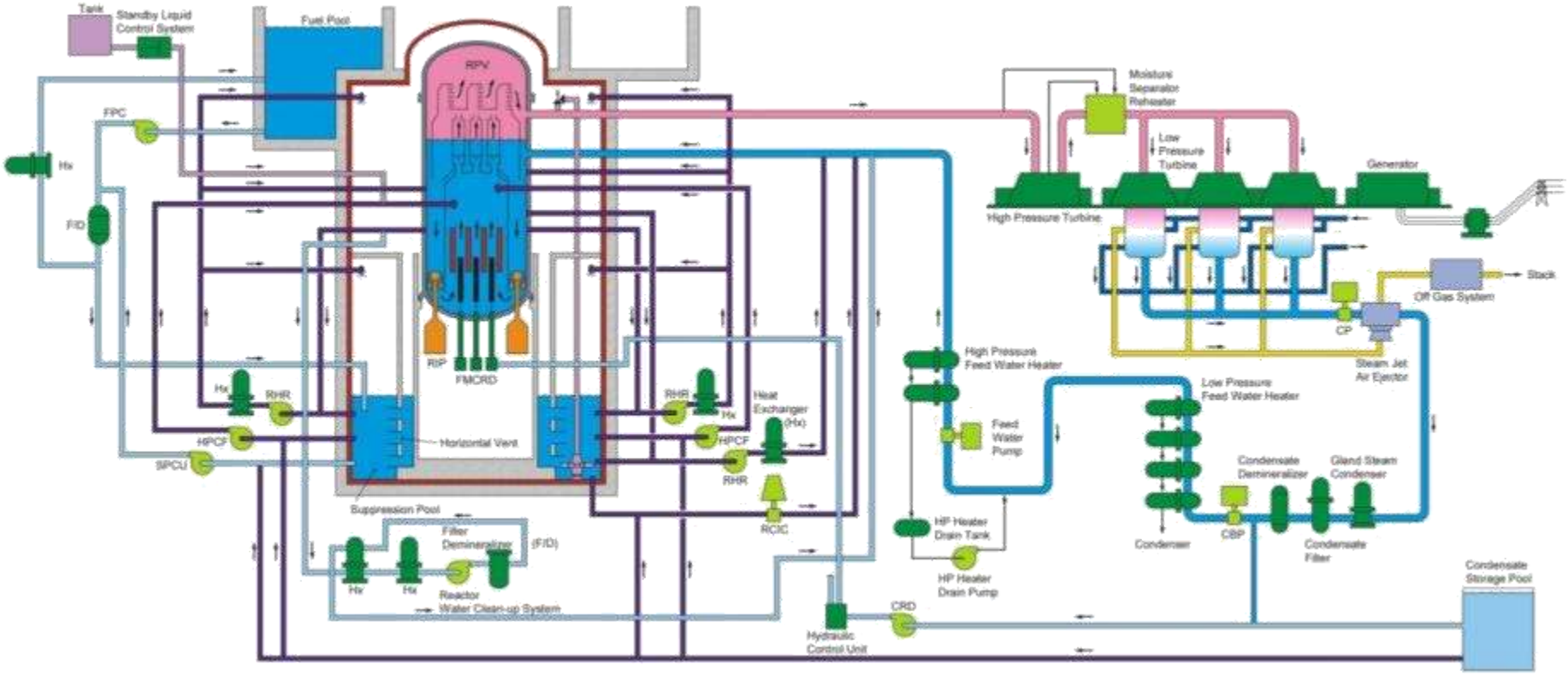
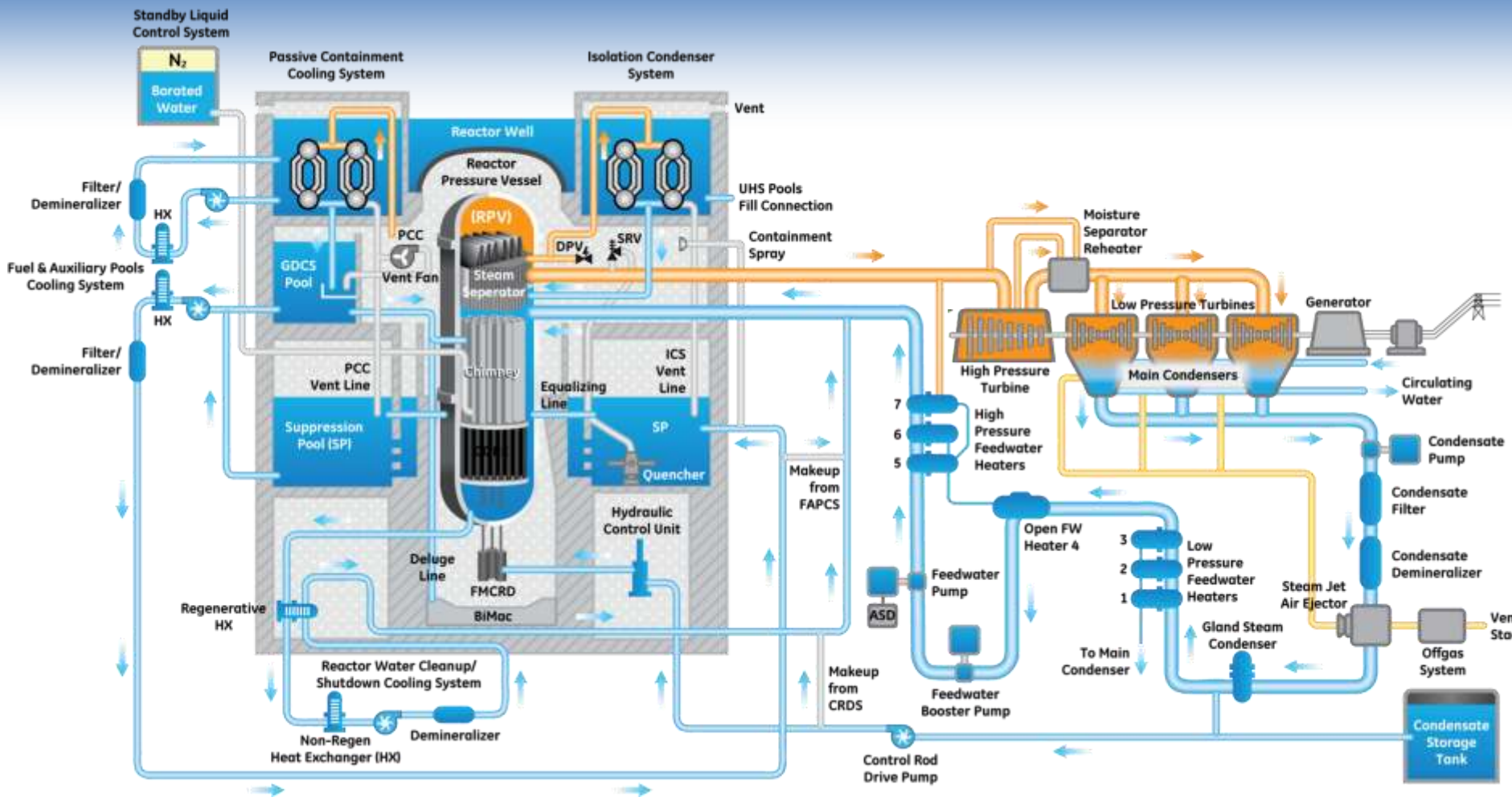
ABWR Overall Flowchart



Notice the simplification to ESBWR on next slide…

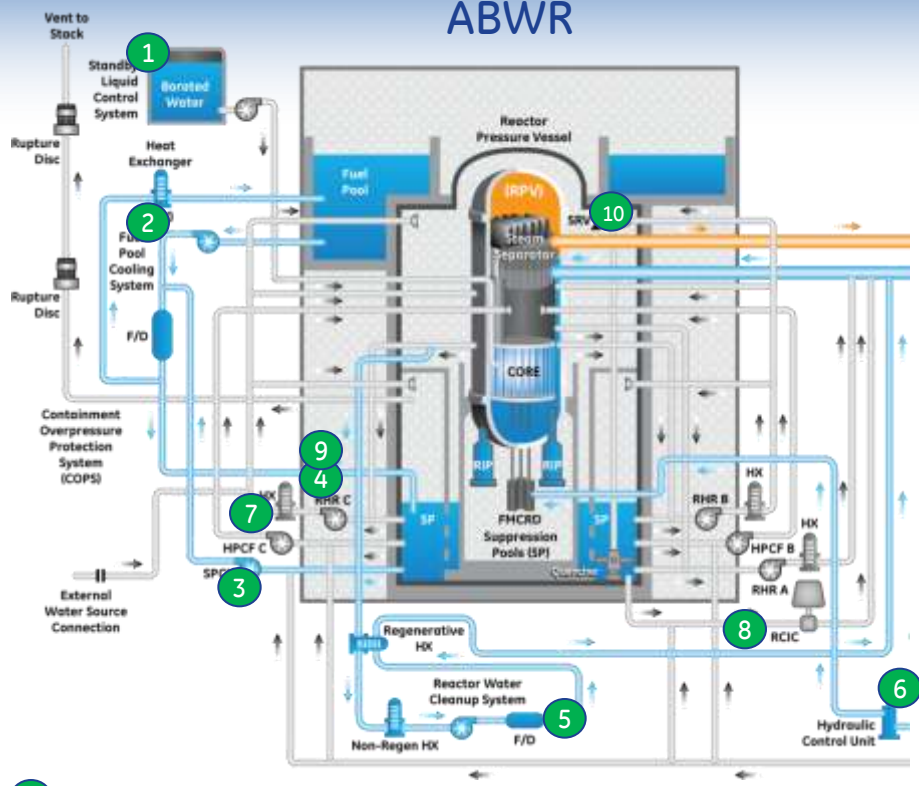
ESBWR Overall Flowchart



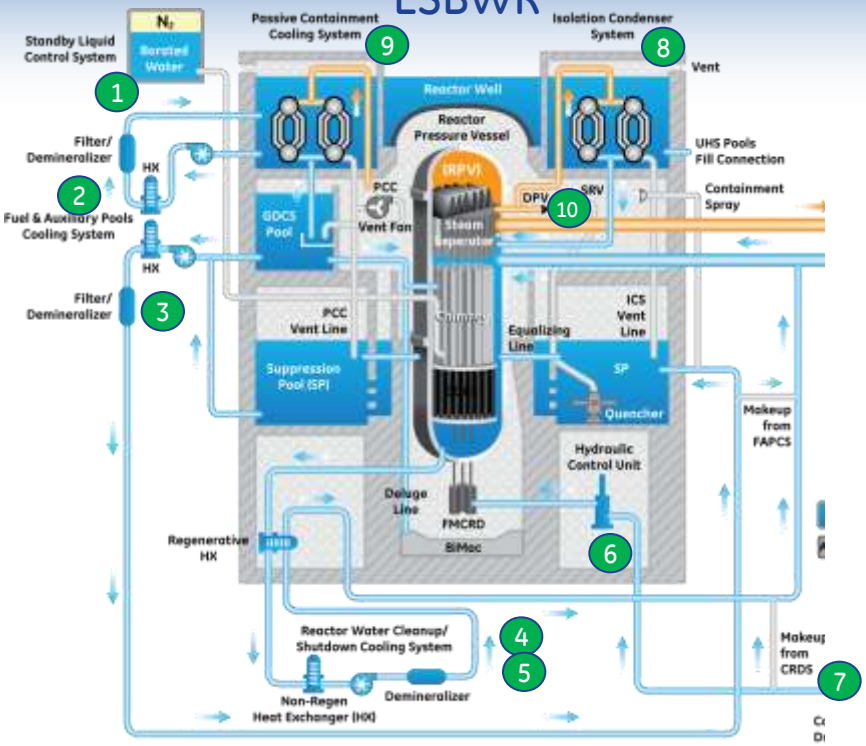
11 less major systems
25% less components

ABWR to ESBWR Evolution: Nuclear Island

ABWR



ESBWR



1. Standby Liquid Control System – **simplified** design
2. Fuel and Aux Pool Cooling – **equivalent** designs
3. Suppression Pool Cooling & Cleanup System – **equivalent** capability
4. Residual Heat Removal System – **equivalent** for shutdown cooling
5. Reactor Water Cleanup System – **equivalent** designs
6. Hydraulic Control Unit – **equivalent** design
7. High Pressure Core Flooder – replaced by HP CRD makeup
8. Reactor Core Isolation Cooling – replaced by Isolation Condenser
9. Residual Heat Removal Containment Spray – replaced by PCCS
10. Safety Relief Valves – Diversified by Depressurization Valves

Systems are Equivalent or Simplified

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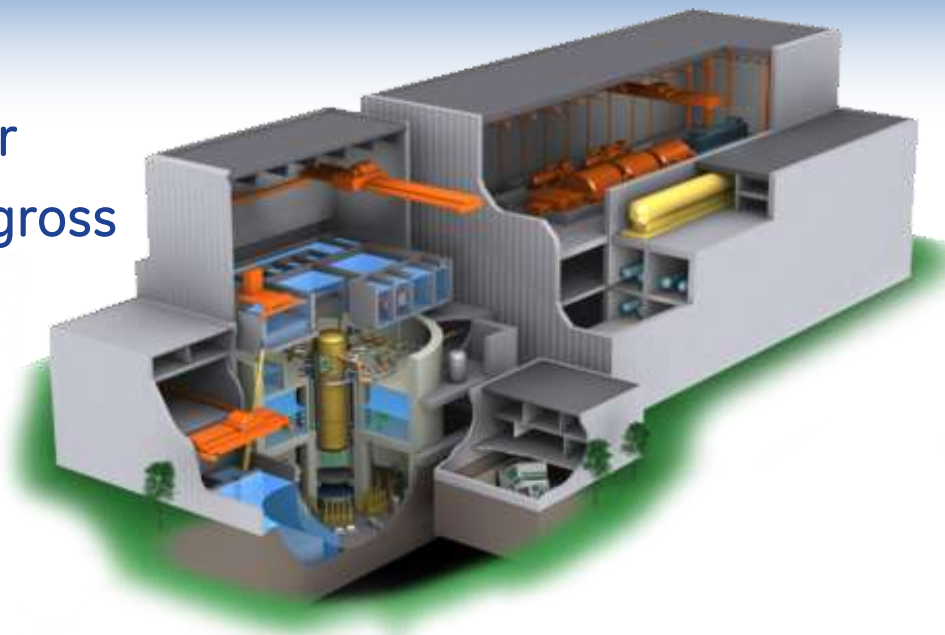
ESBWR Basic Parameters



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

- 7+ days passive capability
- No operator action or electricity during this time period

Operating Cycle length of 12 to 24 months

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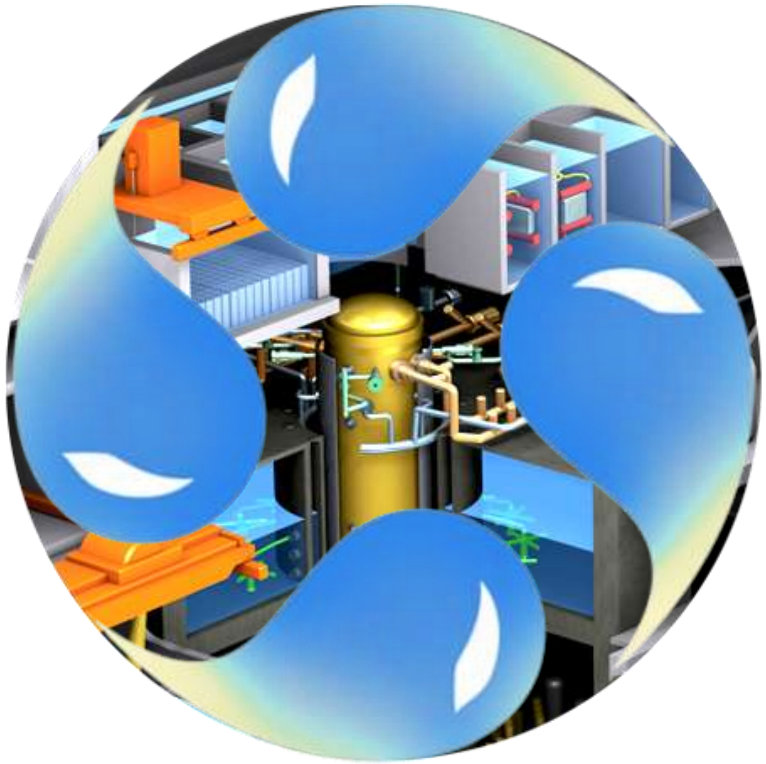
ESBWR Passive Safety Design

Natural circulation - Why reinvent the wheel?

Steam

Boiling



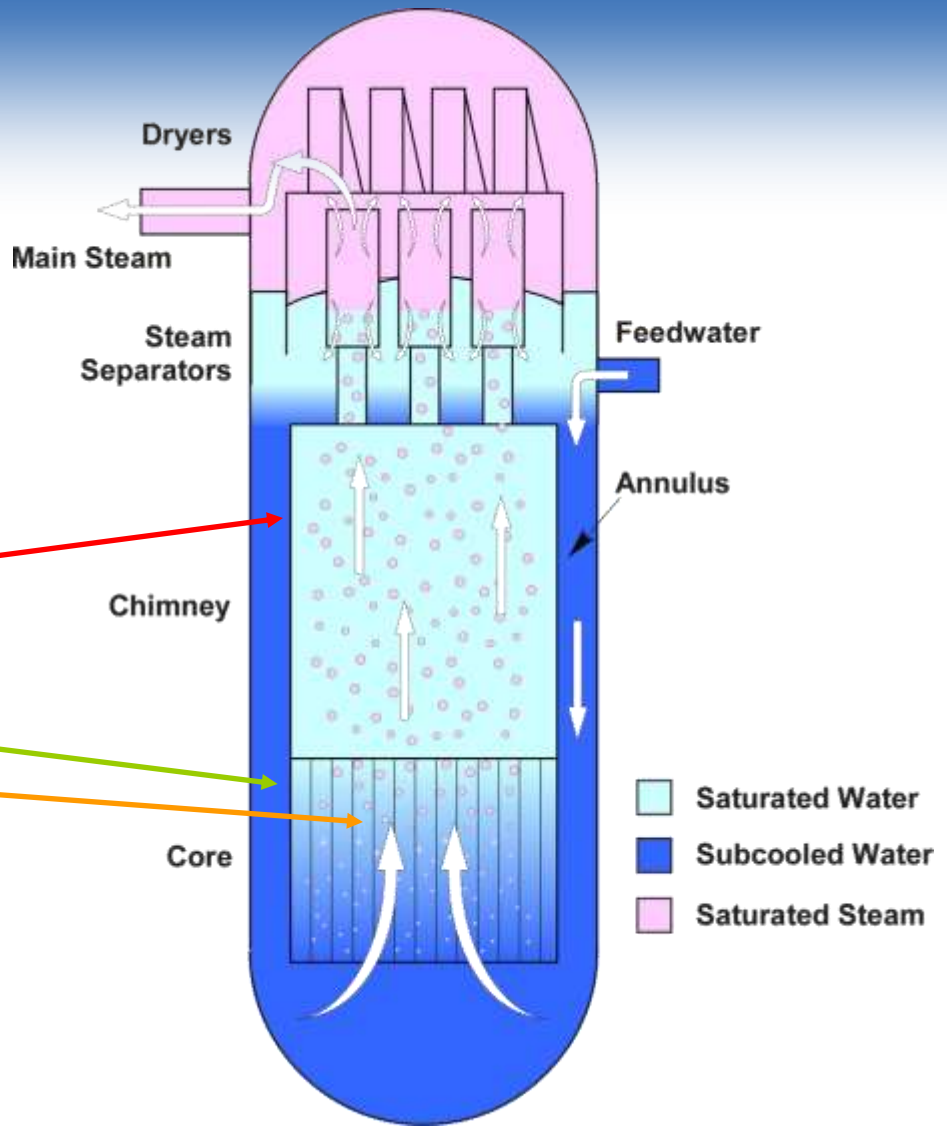
Condensation

Liquid

Natural Circulation

Simplification without performance loss …

- Passive safety/natural circulation
  - Increase the volume of water in the vessel
  - Increase driving head
    - Chimney, taller vessel
  - Reduce flow restrictions
    - Open downcomer
    - Shorter core
- Significant reduction in components
  - Pumps, motors, controls, Heat Exchangers
- **Power Changes with Feedwater Temperature and Control Rod Drives**
  - Minimal impact on maintenance



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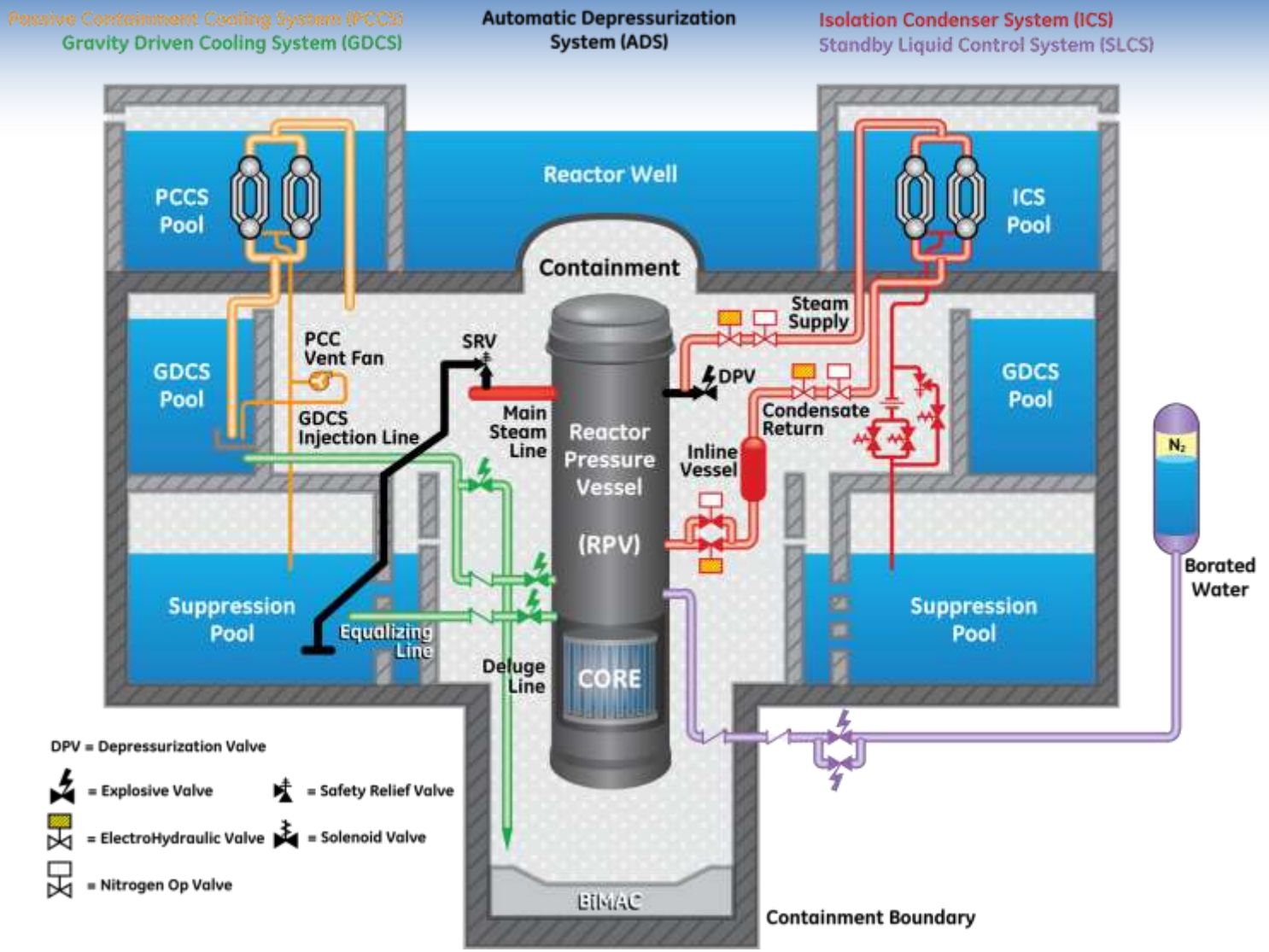
ESBWR passive safety systems



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Isolation Condenser System

- Fully passive – only requires gravity to function and starts automatically (fails in-service if DC power is lost)
- 4 separate systems housed in reinforced concrete vaults
- Limits reactor pressure (no SRV lifts) and temperature and conserves reactor water inventory following containment isolation
- Steam (heat) rises from reactor to the condenser pool, condenses, then gravity pulls the cool water down into the reactor (closed-loop)

Core cooling

Removes heat from containment

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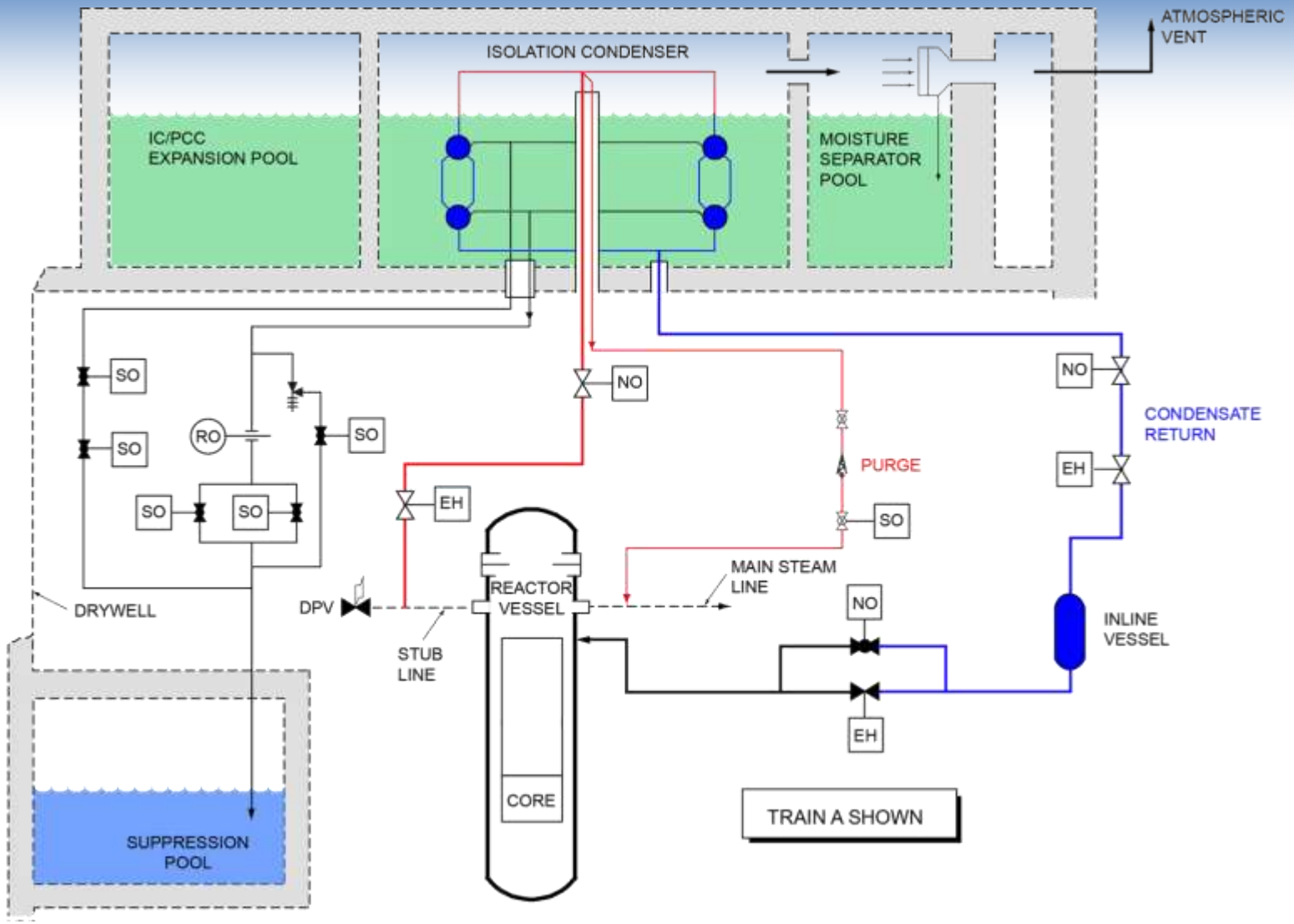
Isolation Condenser System - Standby



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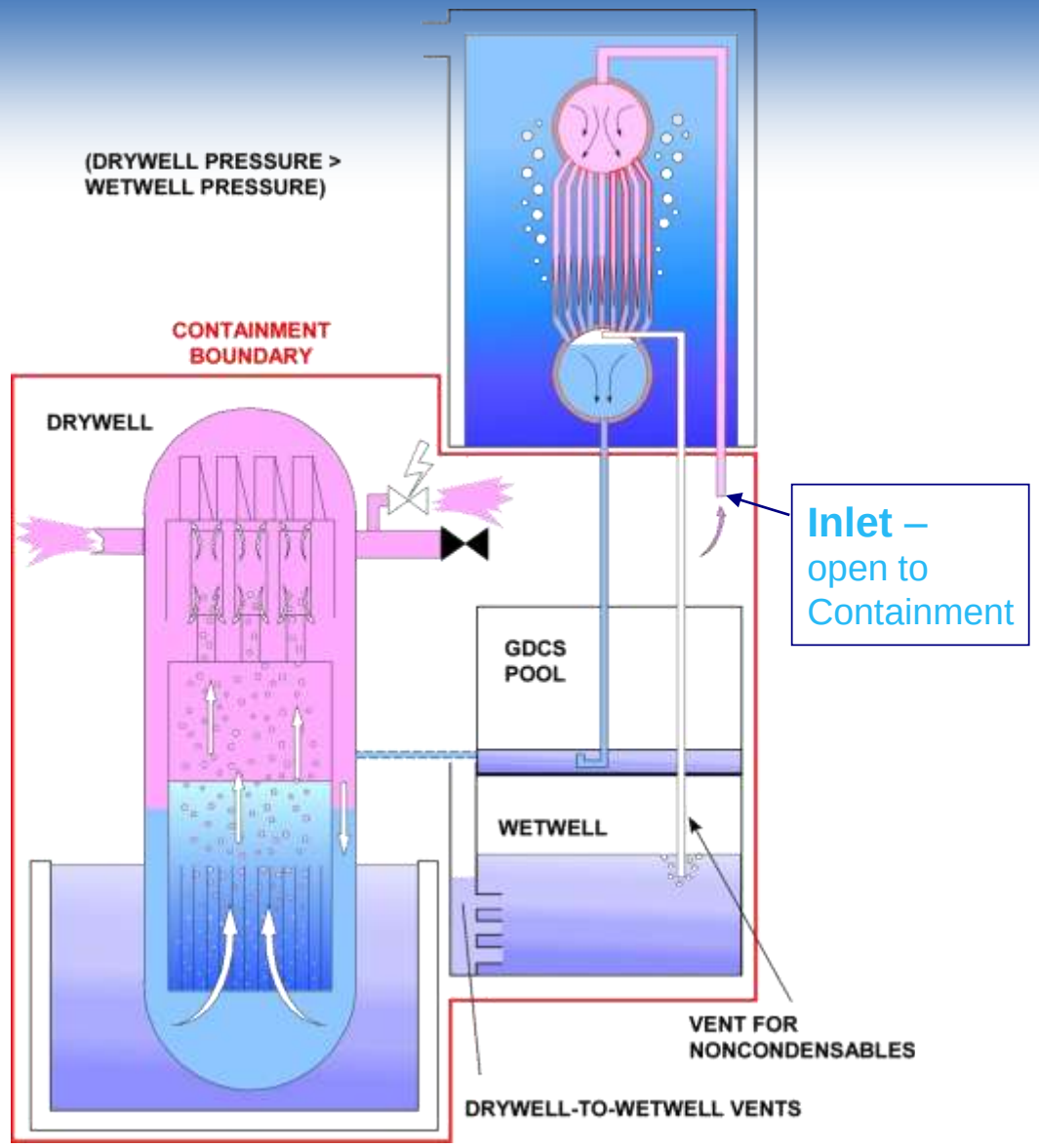
PCCS Thermal Hydraulics

PCCS loops - part of Containment boundary

Uses Natural Circulation



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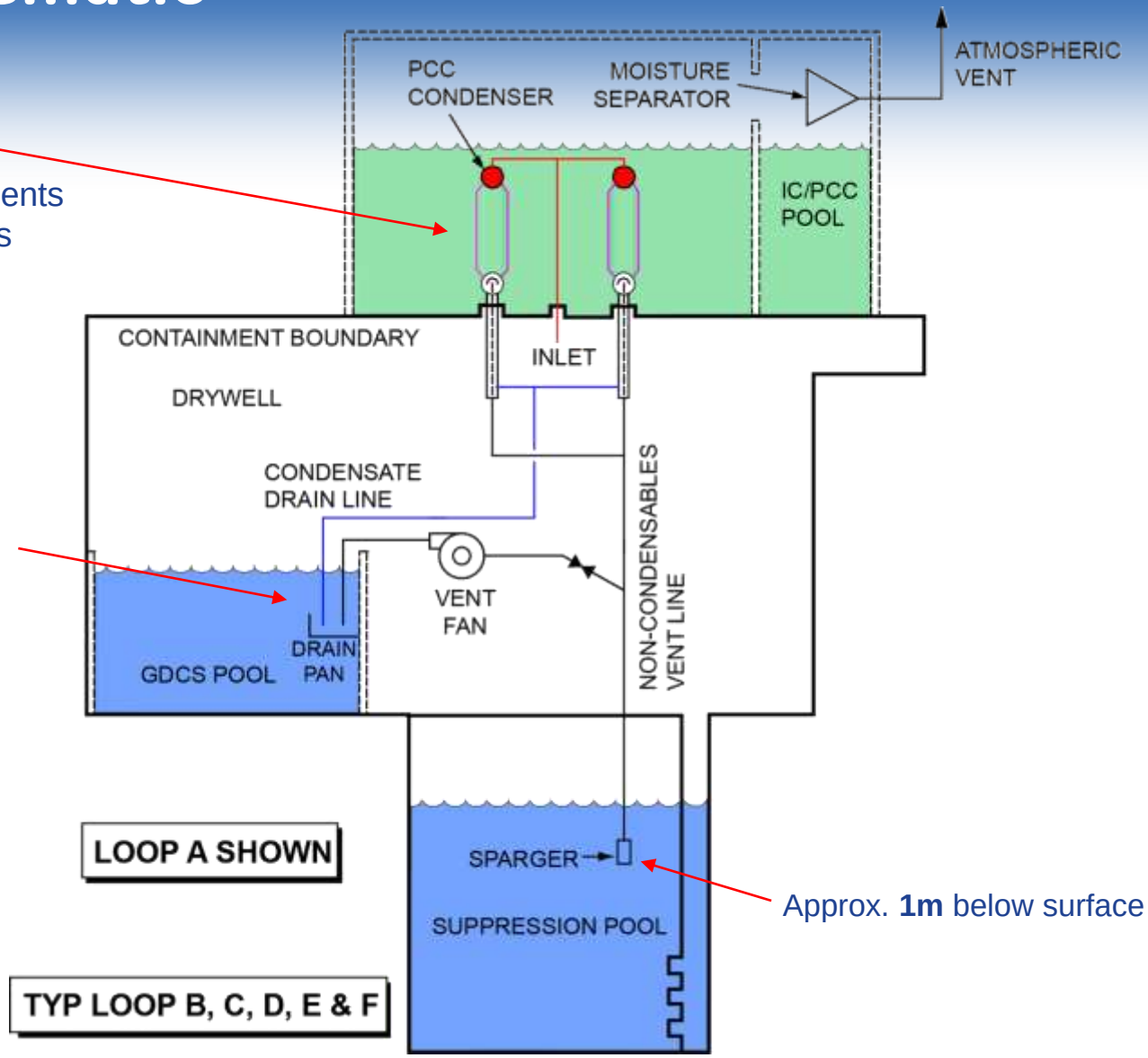
PCCS Schematic

6 HXs total

In sub-compartments of IC / PCC Pools

Loop Seal



Approx. **1m** below surface

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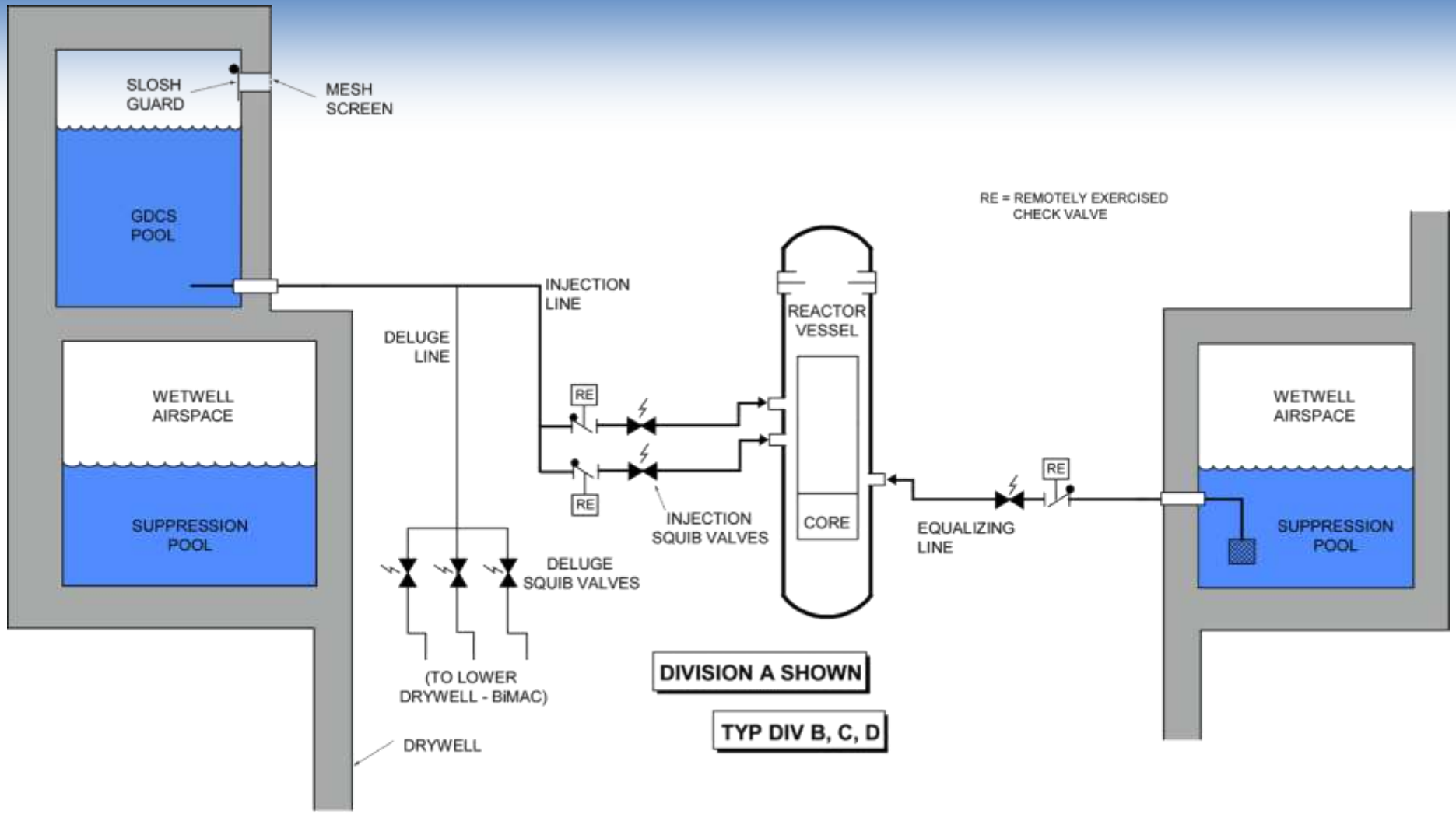
GDCS Schematic



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Evolution is natural











Dresden 1 Oyster Creek Dresden 2 ABWR ESBWR

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QUESTIONS