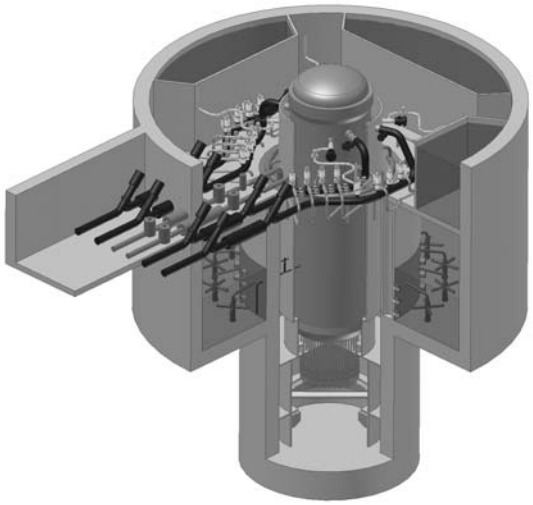
ESBWR Overview



August 30, 2005

imagination at work

ESBWR DCD Submittal

Comprehensive DCD Submitted

- Reg Guide 1.70 format
- Built on experience of SBWR & ABWR
- Incorporated lessons learned from AP-1000 review

High Level Overview Today

> Design Overview

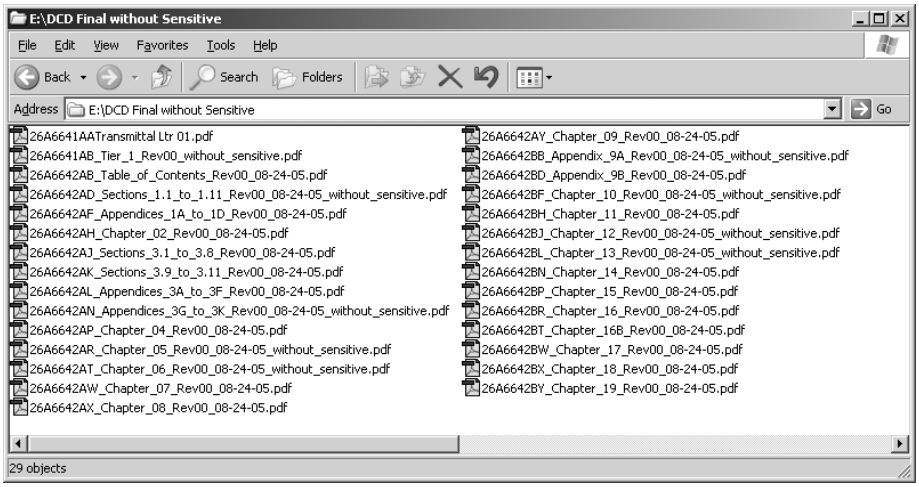
> PRA Summary

Detailed two day session planned in September 27-28

ESBWR DCD Submittal

3 CD's – 5 copies each

- 1) DCD without sensitive information
  - Tier 1 + Tier 2
- 2) DCD with sensitive information included
  - Tier 1 + Tier 2
- 3) NEDC- 33201P: PRA Report
  - 21 Chapters
  - Contains complete PRA and Severe Accident analyses
  - Contains GE proprietary information
- Each CD contains copy of submittal cover letter



Additional Copies Arriving Today

80 CDs of DCD with sensitive information

20 CDs of PRA

One hard copy of DCD & PRA

Presentation Content

- BWR Design Evolution
- ESBWR Primary Characteristics
- ESBWR Passive Systems
  - > Changes since start of pre-application
- ESBWR Active Systems
  - > Differences from previous BWRs
- Digital Control and Instrumentation
- Probabilistic Risk Assessment (PRA)
- Summary

ESBWR What's the E?

Eighth

Economic

Appendix E

Entergy's

It's Just "E"

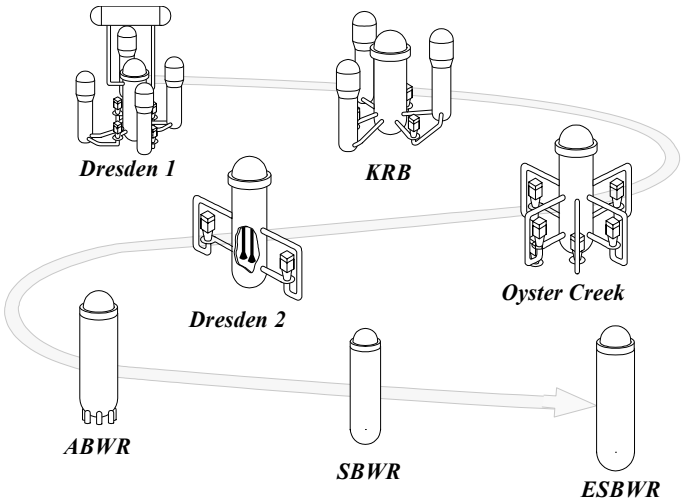
European

España

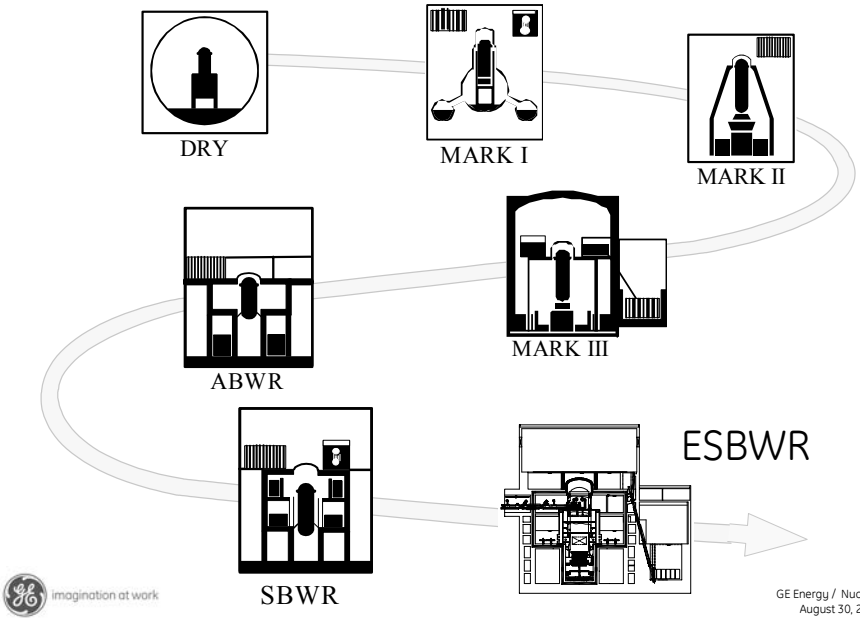
Excellent

Exelon's

BWR Evolution



Containment Evolution



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Site Parameters

- EPRI Utility Requirements Document Plus
  - > Tornado
    - – 330 mph
  - > Extreme Winds
    - – 140 mph for safety-related
  - > Temperatures
    - – Bound the 3 ESP sites
  - > Seismic
    - – Reg Guide 1.60 plus a CEUS hard rock site

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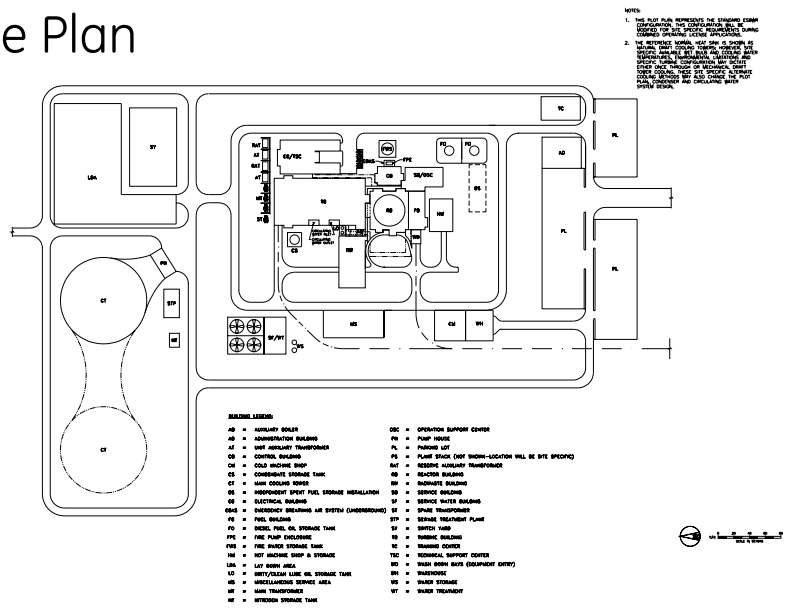
Site Plan



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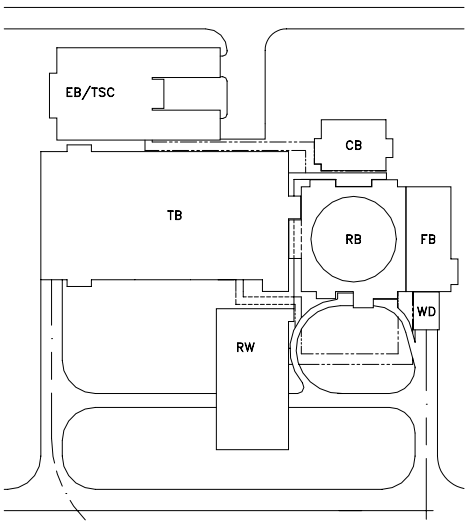
Power Block Arrangement



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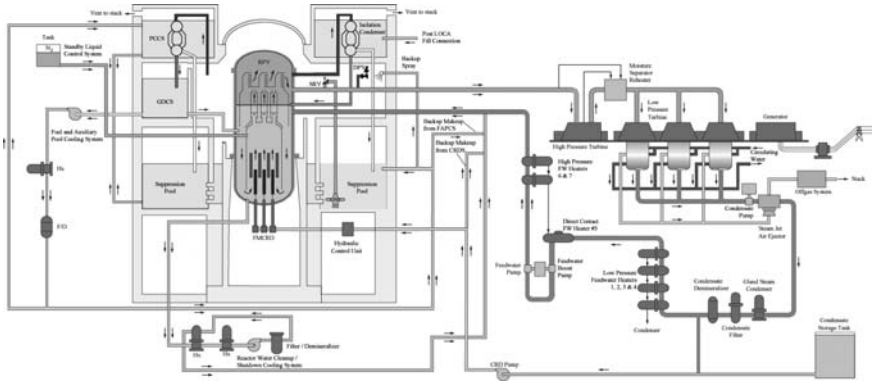
ESBWR Basic Parameters

- 4,500 Megawatt Core Thermal Power
- ~1,550 Megawatt Electric Gross
- Natural Circulation
- Passive Safety Systems

  > 72 hours passive capability

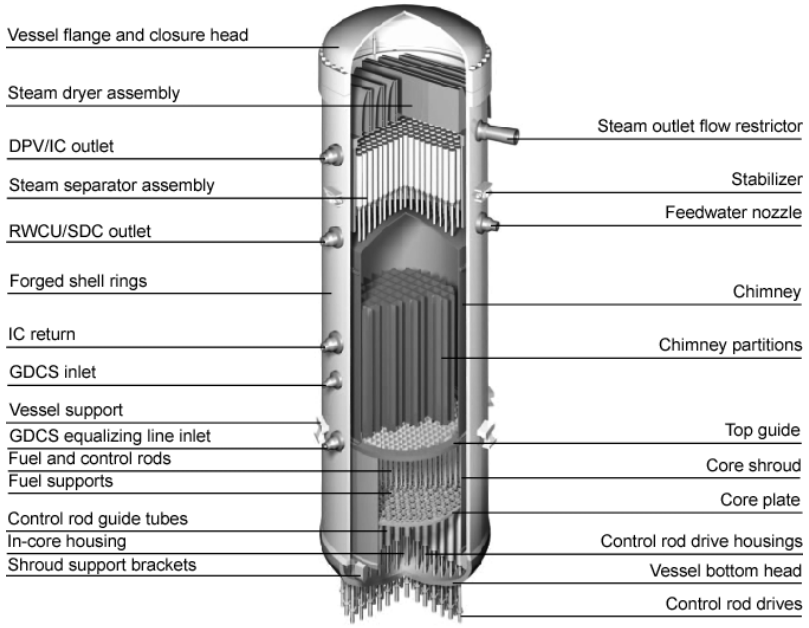


What's different about ESBWR

ABWR	ESBWR
Recirculation System + support systems	Eliminated
HPCF System (2 each)	Eliminated need for ECCS pumps
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

Optimized Parameters for ESBWR

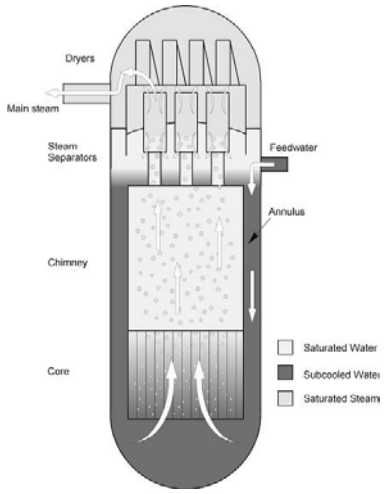
Parameter	BWR/4-Mk I(Browns Ferry 3)	BWR/6-Mk III (Grand Gulf)	ABWR	ESBWR
Power (MWt/MWe)	3293/1098	3900/1360	3926/1350	4500/1550
Vessel height/dia. (m)	21.9/6.4	21.8/6.4	21.1/7.1	27.7/7.1
Fuel Bundles (number)	764	800	872	1132
Active Fuel Height (m)	3.7	3.7	3.7	3.0
Power density (kw/l)	50	54.2	51	54
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	< 120



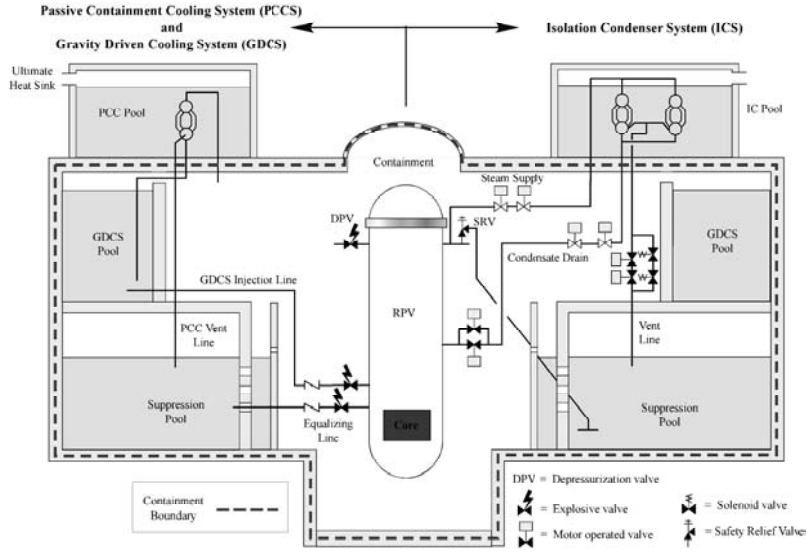
Natural Circulation

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



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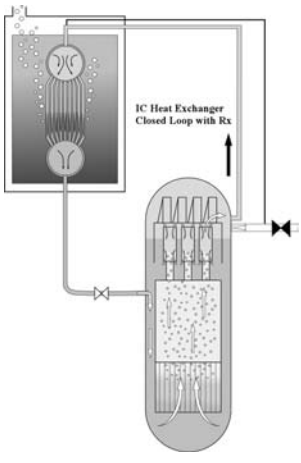
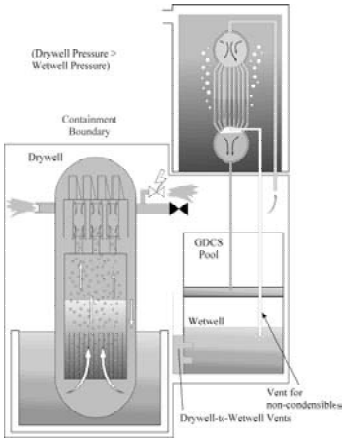
Passive Safety Systems …

Isolation Condenser System



Passive Containment Cooling



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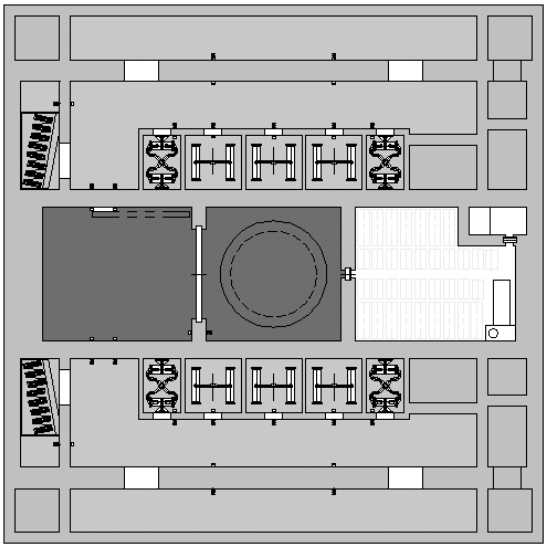
72 Hours Passive Capability



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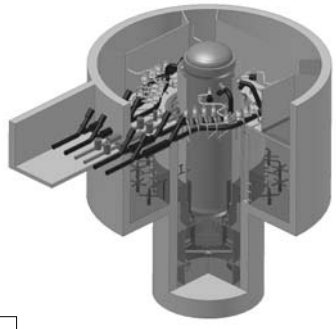
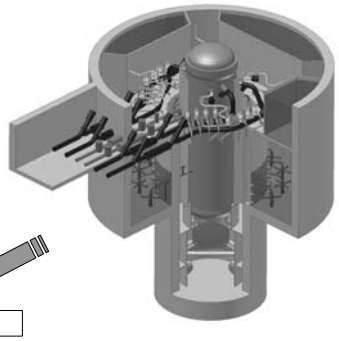
Gravity Driven Cooling System …

Simple design
Simple analyses

Extensive testing
Large safety margins





Gravity driven flow keeps core covered

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Anticipated Operational Occurrences

- Reliable controls eliminate most limiting AOOs
- Large steam volume in reactor mitigates pressure increases
  - > No pressure overshoot in any AOO
- IC prevents SRV opening in all AOOs
- CPR change lower than forced circ. BWRs
  - > Loss of FW Heating is Limiting CPR, slow quasi-static response
- Loss of Coolant Accidents (LOCA)
  - > Large margin to fuel uncovery in all pipe breaks
    - – Only Passive systems credited
    - – Designed for 72 hrs w/o external AC power or operator action

AOO Without Scram (ATWS)

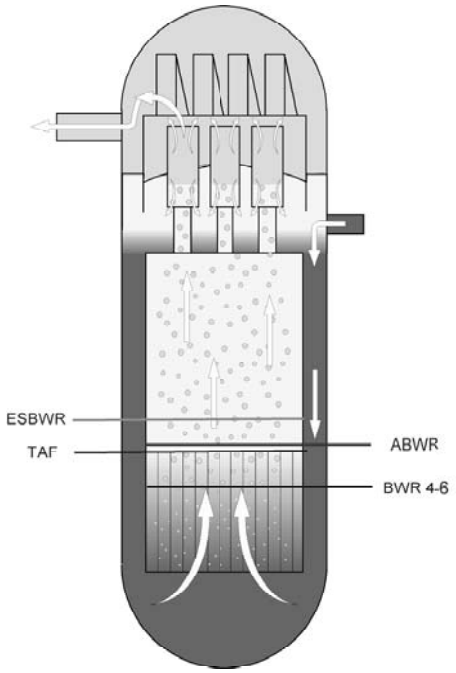
- Scram discharge volume eliminated

  Eliminates common mode failure
- Electric Control Blade insertion diverse from hydraulic scram
- FW runback results in decreased water level, core flow, & power reduction; automated and diverse from scram logic
- Boron Injection is direct to core bypass

  Eliminates lower plenum boron stratification
- Boron accumulator initial flowrate exceeds10CFR50 requirement

  Shutdown achieved quickly w/o depressurizing
- After shutdown IC terminates steam flow to suppression pool and pool heatup

LOCA Water Level Response



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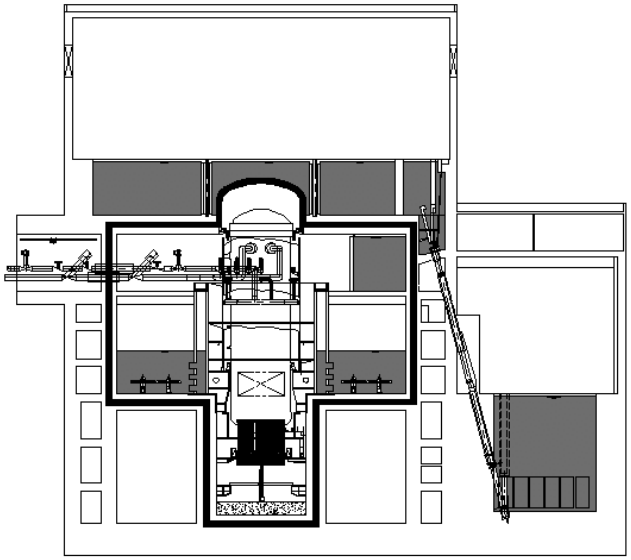
Reactor and Fuel Building



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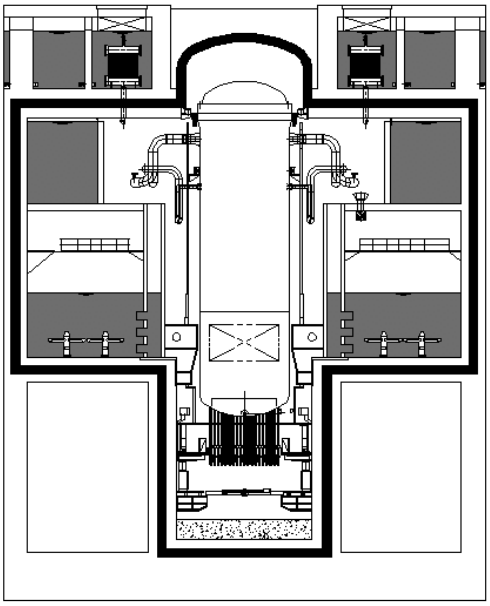
Containment



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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

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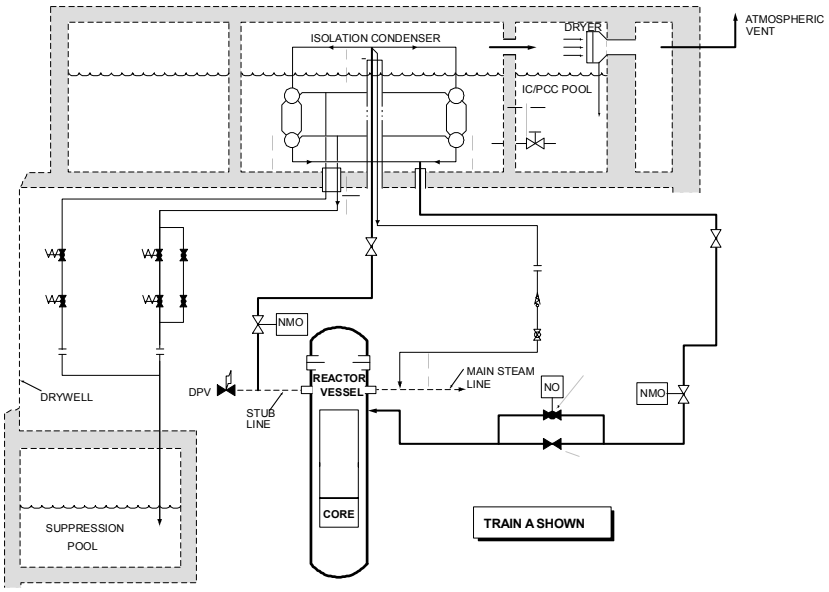
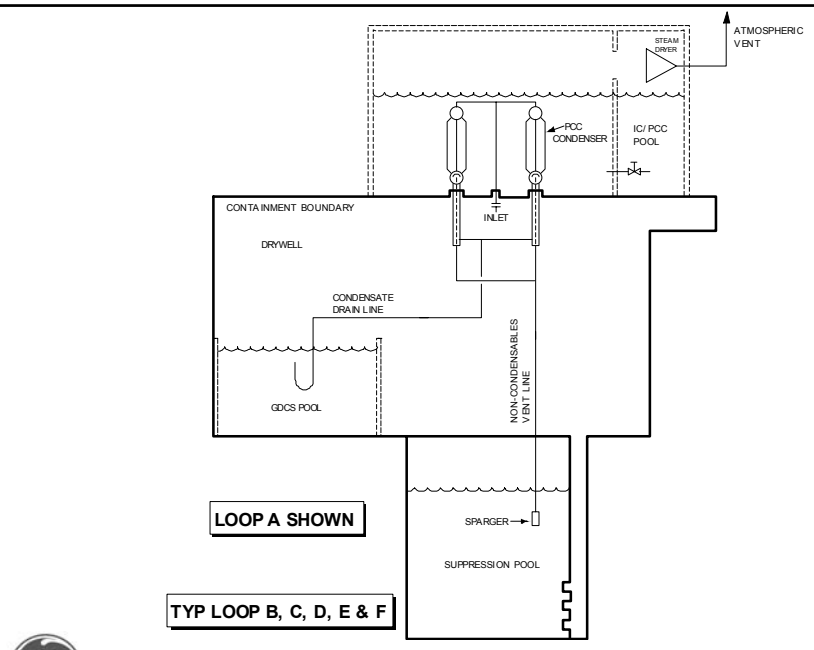


Passive Containment Cooling

- 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
  - > PCCs transport decay heat direct from Primary Containment to the Ultimate Heat Sink



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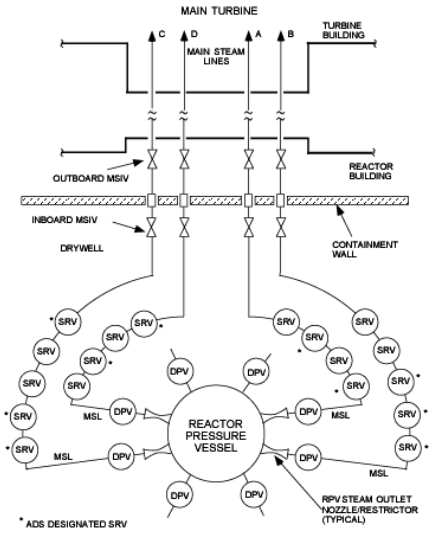
Emergency Core Cooling (ECC)

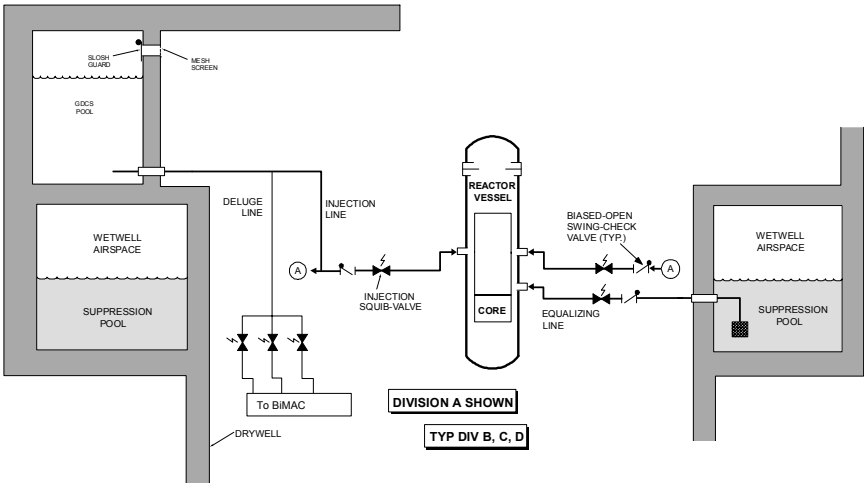
- Gravity Driven Cooling System (GDCS)
  - Three Pools
  - Four Trains
- Automatic Depressurization System (ADS)
  - 10 of 18 Safety Relief Valves (SRV)
    - Pneumatic actuation
  - 8 Depressurization Valves (DPV)
    - Squib actuated

Emergency Core Cooling (cont)

- 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 to above the top of fuel

MSIV, SRV and DPV Arrangement





Gravity-Driven Cooling System

imagination at work

Other Safety-Related Passive Systems

- DC Power Supplies
  - > Battery banks
  - > Inverters
  - > Battery Chargers
- Emergency Breathing Air System
  - > Main Control Room Habitability
- Standby Liquid Control (SLC)
  - > Two Pressurized Tanks of Boron

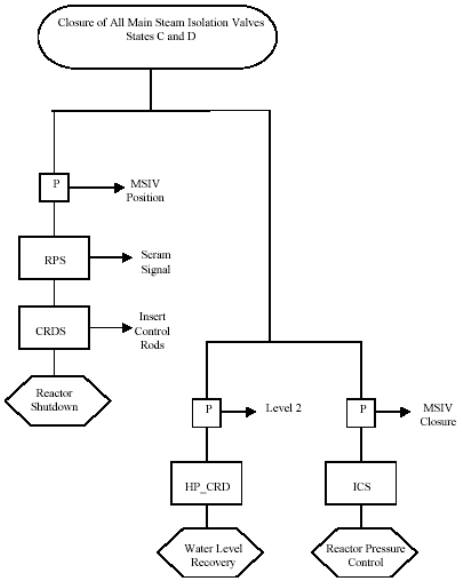
Safety-Related Electrical

- Four Divisions
- DC Backed
  - > Inverted power for AC loads
  - > 4 Divisions with 24 hours Capability
    - – Monitor
    - – Control
  - > 2 divisions with 72 hours Capability
    - – Monitor

Regulatory Treatment of Non-Safety Systems (RTNSS)

- Enhanced QA will be imposed on some systems
  - – Based on PSA insights
  - – Post 72 hours through 7 days
- Fire Protection Systems
  - > IC/PCC pool fill
  - > Spent Fuel Pool makeup

Nuclear Safety Operational Analysis



Plant Investment Protection (PIP)

- Non-safety systems provide for defense in depth
  - Significant contributors to plant availability
  - Asset Protection

> On-Site AC Power (Diesel Generators)

> Electrical Distribution

> CRD Hydraulics

> Reactor Water Cleanup

> Fuel and Auxiliary Pool Cooling and Cleanup

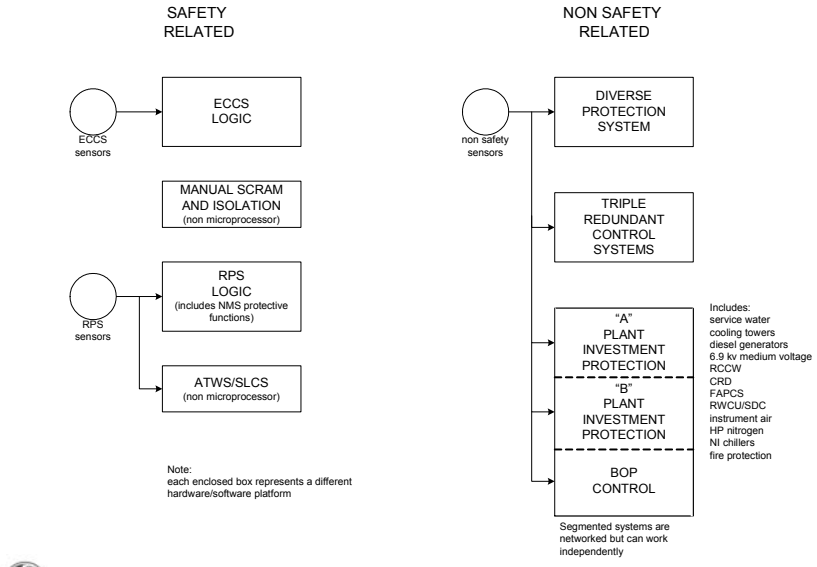
Instrumentation & Control Systems

- **Key Design Features**
  - > Digital data network for plant-wide control & display
  - > Intelligent multiplexing system & fiber optics
  - > Standardized I&C equipment and components
  - > Plant Computer System supports extensive plant automation
  - > Online diagnostics
  - > Advanced control room design

Digital Control and Instrumentation

- Diversity
  - > Manual scram, isolation
  - > Four divisions of RPS
  - > Four divisions on non microprocessor based ATWS/SLCS
  - > Four divisions of ECCS
  - > Triple redundant controller for diverse RPS and ECCS
  - > Triple redundant controllers for major nuclear control functions
  - > Redundant controllers for investment protection and BOP control

Digital Control and Instrumentation

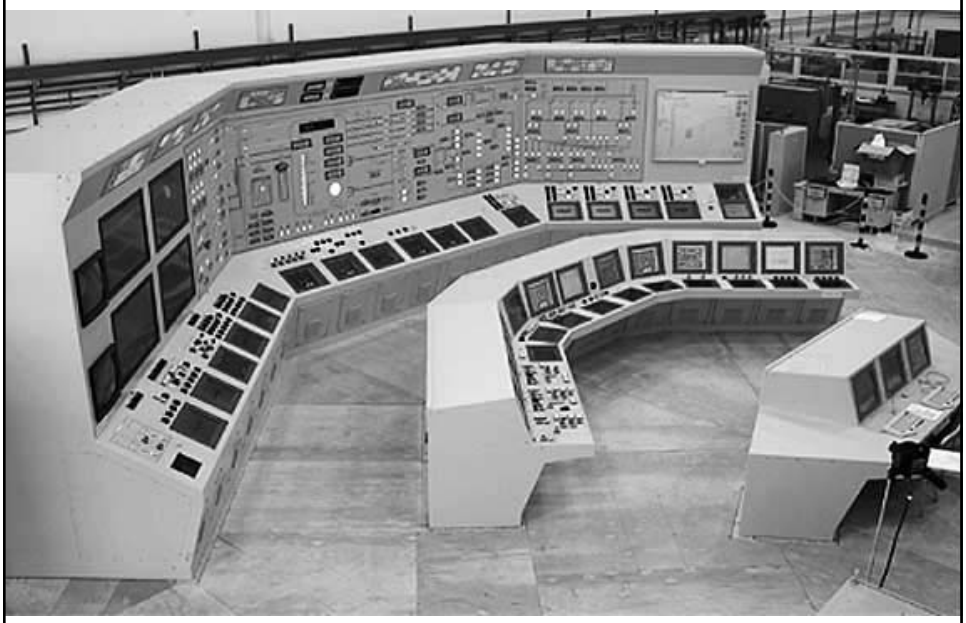


Reactor Protection

- Based on ABWR design
  - > 2/4 logic
  - > Fail safe
  - > Deterministic
  - > Diverse from ECCS
- Any two unbypassed same parameters that exceed limits will always cause a scram with:
  - > Any single logic failure
  - > Any division of sensors bypass status
  - > Any division of logic bypass status
  - > Any single power failure
  - > Any possible main control room RPS control configuration

Engineered Safety Feature I&C

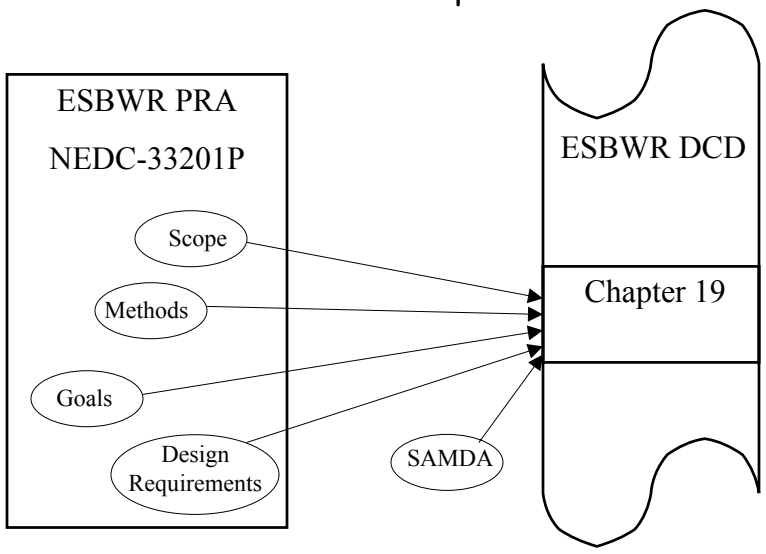
- Based on ABWR design
  - > 2/4 logic
  - > Fail As Is
  - > Deterministic
  - > Diverse from RPS
- Any two unbypassed same parameters that exceed limits will always initiate ECCS with:
  - > Any single logic failure
  - > Any division of sensors bypass status
  - > Any single power failure
  - > Any possible main control room ECCS control configuration



PRA Overview

Organization of the Documents
Attributes of the PRA
Summary of Results

Document Relationships



PRA Scope

Internal Events, Power Operation
- > Level 1, 2, and 3

Internal Events, Shutdown
- > Level 1
- > 99% SDCDF in mode 6, so no level 2 required

External Events (non-Seismic)
- > Screening shows no impact on risk

Seismic
- > Seismic margins analysis identified no outliers

PRA Quality

Follows ASME Standard Principles
- > Where applicable, meets capability category 3
- > Some plant specific information not available until COL or construction

Certification PRA Capability
- > Determine that ESBWR meets risk goals
- > Determine importance at a system level
- > Determine overall importance of operator action

Each Element Appropriate for Certification

Definitions

Core Damage	• PCT > 2200 ^{o}F (calculated by TRACG) • Core Uncovered (estimated by hand calc, MAAP, other)
Containment Failure	• Uncontrolled Release • Sensitivity Assessment for Venting Release

Comprehensive System Analysis

Detailed Fault Tree Model

> 24 systems modeled

> Major components included

> Fully linked support systems

> Intra-system common cause

> Inter-system common cause for squib valves

Containment Performance

Level 2 Linked Directly to Level 1

Phenomena Probabilities from ROAAM

> High confidence, rather than mean, values used

Shutdown

Detailed Model

> Loss of decay heat removal

> LOCA

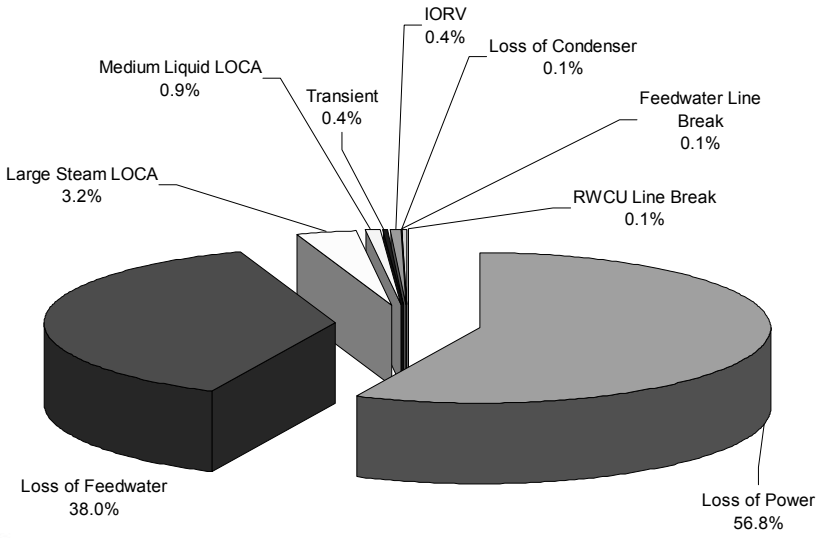
> Loss of Preferred Power

Includes Manual Shutdown for Refueling

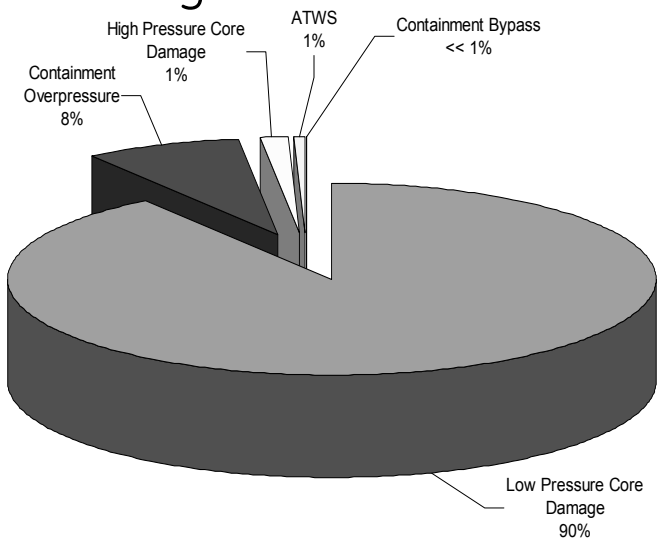
The Bottom Line

Internal Events CDF	3.2×10^{-8}
Internal Events LRF	1×10^{-9}
CCFP	0.025
Probability of Exceeding 25 Rem at 1/2 Mile	2×10^{-9}
External Events Contribution	negligible
Shutdown CDF	4×10^{-9}

Breakdown By Initiating Event



Breakdown By Accident Class



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Attributes of ESBWR Risk

Redundancy and Diversity!!

At Least 3 I&C Systems Need to Fail for Core Damage

Top Cutsets Involve

> CCF of Batteries

> CCF of Squib Valves

Loss of All Electric Power (AC & DC) Itself Does Not Cause Core Damage

Containment Failure Does Not Lead to Core Damage within 72 Hours

Containment Can Be Flooded Above Core Using Passive Systems

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Attributes Affecting Risk (continued)

High Containment Ultimate Strength

- > High confidence pressure 1.2 MPaG
- > Most scenarios well below 0.9 MPaG

Ex-Vessel Explosion

- > Does not occur if water in lower drywell less than 0.7 m. This is the likely case.
- > Containment survives EVE pressure pulse
- > Consideration for localized failures included

Attributes Affecting Risk (continued)

Direct Containment Heating

- > Containment survives initial pressurization
- > Long term high temperatures do not fail liner or penetrations
- > Lower to upper drywell configuration minimizes relocation of core debris
- > Containment spray added as defense-in-depth

Attributes Affecting Risk (continued)

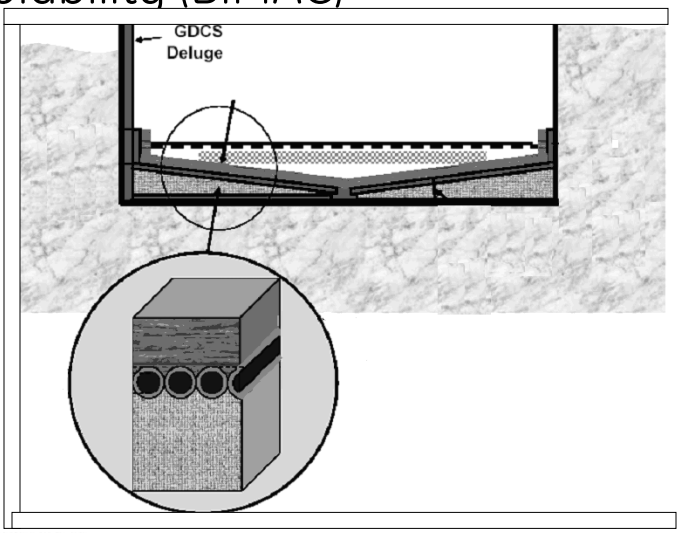
Basemat Melt Penetration

> Precluded by BiMAC (see next slide)

> Diverse actuation

> Cools debris from above, below, and on sides

Basemat Internal Melt Arrest and Coolability (BiMAC)



Regulatory Treatment of Non-Safety Systems

One System Identified

> Fire water refill of IC/PCC pools

Sensitivity Analysis Provides Basis

> Calculated CDF using only safety-related and special treatment systems

> CDF = 4.0×10^{-5}

> LRF = 2.6×10^{-7}

Other Sensitivities

Case	Core Damage Frequency (yr^{-1})	Large Release Frequency (yr^{-1})
Base	3.2×10^{-8}	8×10^{-10}
Safety + RTNSS	4.0×10^{-5}	2.6×10^{-7}
No Operator Credit	1.9×10^{-6}	4.0×10^{-7}
Squib Failure x 5	1.4×10^{-7}	2.4×10^{-9}
Squib Failure x 10	2.8×10^{-7}	4.2×10^{-9}
Truncation @ 10^{-14}	3.4×10^{-8}	9×10^{-10}

Conclusions

PRA Report Provides a Comprehensive Assessment of ESBWR Mitigation Capabilities

Incorporating Risk Insights During Design Drives Reliability

ESBWR Satisfies Risk Goals With Significant Margin

ESBWR DCD Submittal

Complete & comprehensive submittal

Simple design facilitates review

GE prepared to continue close cooperation to support review process

Utilities expecting accelerated schedule to meet COL plans

Accelerated schedule consistent with US government energy policy goals