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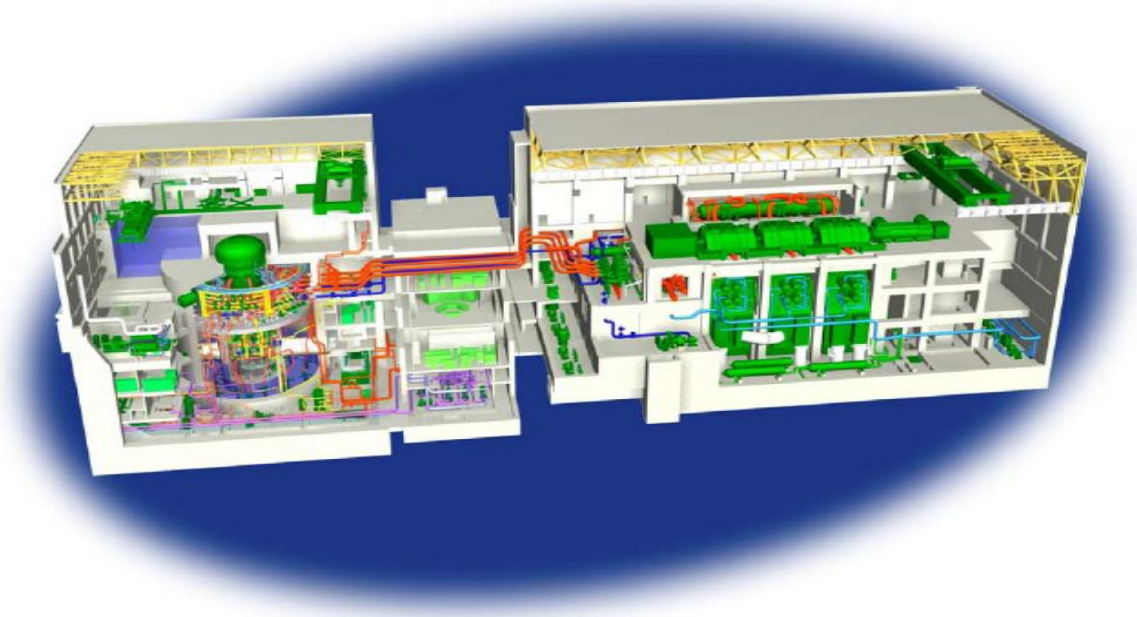
T12LIC0005 Rev.0

Fukushima Lessons-Learned and US-ABWR Capabilities for Beyond Design Basis Events



Toshiba Corporation
June 28, 2012

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Toshiba Attendees

Kenji Arai	*Toshiba Senior Fellow*
Fumihiko Ishibashi	*Toshiba Senior Manager, Nuclear Safety System Design & Engineering Department*
Hirohide Oikawa	*Toshiba Chief Specialist, Nuclear Safety System Design & Engineering Department*
Kazuo Hisajima	*Toshiba Chief Specialist, System Design & Engineering Department*
Yoshihiro Naruse	*TANE Senior Vice President Engineering, & Chief Technology Officer*
James J Powers III	*TANE Vice President Engineering*
Robert Schrauder	*TANE Vice President Licensing*
Dale Wuokko	*TANE Licensing Specialist*
Yuya Aoyagi	*TANE Licensing Engineer*
Daniel Stenger	*Attorney, Hogan Lovells*
Robert Quinn	*ABWR Project Manager, Westinghouse*
Caroline Schlaseman	*MPR, DCD Renewal Project Manager*

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Desired Outcomes

The Desired Outcomes of this Meeting are:

- The NRC to have an Understanding of:

- *How the US-ABWR design currently addresses Fukushima Lessons-Learned*
- *The current capability of the US-ABWR design to cope with beyond design basis events*
- *Plan for addressing SECY-12-0025 Issues*

- Receive NRC Feedback

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Agenda

- ***ABWR Operating Experience***
- ***Toshiba Role in US-ABWR Design Certification Rule***
- ***Toshiba Involvement and Activities Post Fukushima***
- ***US-ABWR Design for***

  - External Events

  - Beyond Design Basis External Events

  - Station Blackout

  Core Cooling

  Containment Overpressure Protection

  - Spent Fuel Pool Cooling

  - Spent Fuel Pool Instrumentation

- ***Alignment with Fukushima Tier 1 and 2 Activities***
- ***DC Renewal Application and Fukushima Related Matters***
- ***Conclusion***

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US-ABWR Abbreviations

ABWR	Advanced Boiling Water Reactor
ADS	Automatic Depressurization System
ACIWA	AC Independent Water Addition System
AFI	Alternate Feedwater Injection System (High Pressure Injection System)
AIA	Aircraft Impact Assessment
COPS	Containment Overpressure Protection System
CTG	Combustion Turbine Generator
DCD	Design Control Document
ECCS	Emergency Core Cooling System
EDG	Emergency Diesel Generator
FPC	Fuel Pool Cooling and Cleanup System
FPS	Fire Protection System
HPCF	High Pressure Core Flooder System
LPFL	Low Pressure Flooder System
SFP	Spent Fuel Pool
RCIC	Reactor Core Isolation Cooling System
RHR	Residual Heat Removal System
TWL	Turbine Water Lubricated Pump

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ABWR Operating Experience

- **The ABWR is a Proven Safe Design with Over 40 Reactor Years of Safe Reliable Operation**

- **Currently Four ABWRs in Japan**
  - *Kashiwazaki-Kariwa Nuclear Plant units 6 and 7, commercial operation 1996 and 1997 respectively*
  - *Hamaoka Nuclear Plant unit 5, commercial operation 2005*
  - *Shika Nuclear Plant unit 2 commercial operation 2006*

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Toshiba Role in US-ABWR Design Certification Rule

- ***US-ABWR Design Certification Rule would have expired June 2012***
- ***Toshiba submitted application to the NRC to renew the Rule by Letter Dated October 27, 2010***
- ***Application incorporated South Texas Project 3 & 4 departures***
- ***NRC accepted and docketed on Dec. 14, 2010***
- ***Toshiba will submit Revision 1 to the application including AIA amendment and PRA update in June 2012***
- ***Toshiba will incorporate Fukushima Lessons-Learned in a future revision***

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Toshiba Involvement Post Fukushima

- ***Contributed to Plant's Stabilization and Recovery***
  - *Led US-Japan Team (Toshiba, Westinghouse, B&W, Shaw)*
  - *Supported Japanese BWR Utilities for incorporating additional mitigation capability as required by the Nuclear and Industrial Safety Agency (NISA)*

- ***Japanese Utilities Plant Safety Enhancement***
  - *Proposed measures for plant safety enhancements*
  - *Proposed US SAMG Approach (Toshiba-Exelon-Westinghouse team)*

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Toshiba Involvement Post Fukushima

- ***Stress Tests at Japanese Utilities***

  - Supporting safety margin evaluation for earthquake and tsunami

- ***Fukushima Accident Investigation and Countermeasure Development***

  - Supported development of the Japan Nuclear Technology Institute (JANTI) report

- ***Interaction with US Leaders***

  - NRC Chairman visit to Toshiba – November, 2011

  - ACRS Chairman visit to Toshiba – March, 2012

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Toshiba Activities Post-Fukushima

Involvement in US Industry Forums

- *Member NEI New Plant Oversight Committee*
- *Member NEI New Plant Working Group*
- *Member EPRI*
- *Member of STP 3&4 Fukushima Response Team*
- *Providing input on Proposed Rulemaking*
- *Attending NRC/Industry Meetings on Orders and 10CFR50.54(f) Request for Information*
- *Developing concepts for US-Utilities to address NTTF recommendations with Westinghouse*
- *Howard Baker Forum for U.S.-Japan Roundtable on Nuclear Energy Cooperation*

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SECY-12-0025 Issues: Tier 1 Activities

2.1 – Seismic and flooding reevaluations

2.3 – Seismic and flooding walkdowns

4.1 – Station Blackout (SBO) regulatory actions

4.2 – Mitigating strategies for beyond design basis events

5.1 – Reliable hardened vents for Mark I and II containments

7.1 – Spent fuel pool instrumentation

8 – Strengthen & Integrate EOPs, SAMGs, & EDMGs

9.3 – Enhanced EP staffing and communications

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SECY-12-0025 Issues: Tier 2 Activities

2.1 – Other Natural External Hazards

7.2 – Provide safety-related AC power to the SFP makeup system

7.3 – Revise Tech Specs to address enhanced instrumentation and new AC power requirements

7.4 – Seismically qualified spray to SFP

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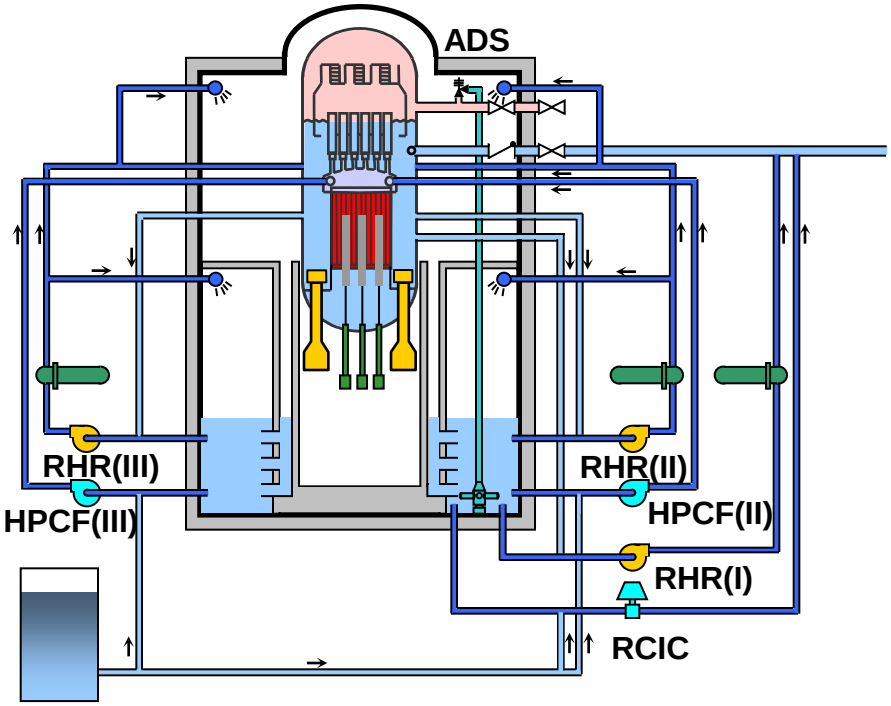
US-ABWR Design: Engineered Safety Features

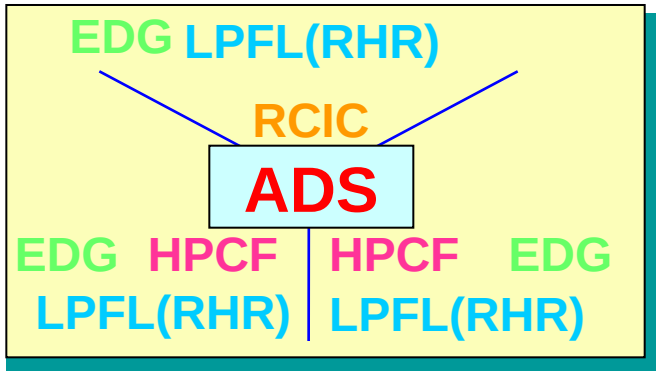


Safety Systems

- *Three Redundant and Independent divisions of ECCS*

- *ECCS*

HPCF: High Pressure Core Flooder
LPFL: Low Pressure Flooder
RCIC: Reactor Core Isolation Cooling
ADS: Automatic Depressurization System



LPFL: Low Pressure Flooder System
RHR: Residual Heat Removal System
HPCF: High Pressure Core Flooder System
RCIC: Reactor Core Isolation Cooling System
ADS: Automatic Depressurization System
EDG: Emergency Diesel Generator

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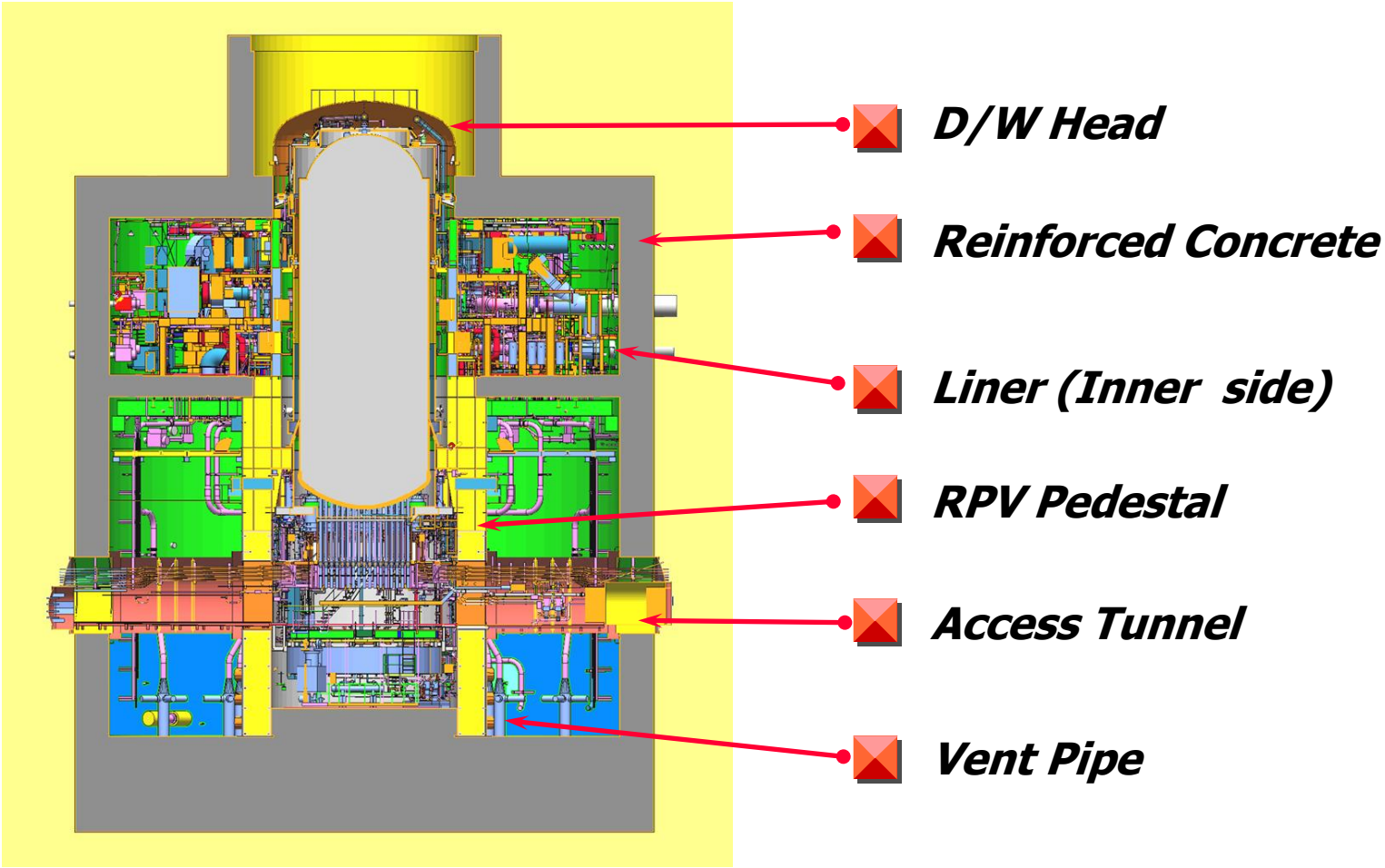
US-ABWR Design: Containment Design Feature

- Reinforced Concrete Containment
- Horizontal vent system
- Improve seismic performance by lower gravity center



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US-ABWR Design: Design Basis for External Events

- **The US-ABWR SSCs important to safety are designed to withstand the effects of External Events**

	US-ABWR	US Regulation
Earthquake	0.3g: Max. Horizontal ground acc. 0.3g: Max. Vertical ground acc.	GDC2 R.G.1.60
Flooding (including Tsunami)	1 ft (0.3 m) below grade	GDC2 R.G.1.59 R.G.1.102
Tornado	483 km/h (300mph)	GDC2 R.G.1.76 Rev 1
Hurricane	Addressed on site specific basis	GDC2 R.G.1.221
Extreme wind	177 km/h: Non-Safety Related 197 km/h: Safety Related	GDC2

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US-ABWR Design: Mitigation of External Events

- **The US-ABWR SSCs important to safety are designed to withstand the effects of External Events**

	US-ABWR	US Regulation
Backup Power Supply	EDG × 3 CTG × 1	GDC 17, 2, 4, 5 RG 1.6, 1.9, 1.32
Physical Separation	All Safety-Related SSC Separated	10 CFR 50.48, GDC 17 RG 1.189, 1.75
SBO Coping System (Core Cooling)	CTG + DC batteries RCIC ACIWA/RHR + FPS pump or Fire truck	10 CFR 50.63 RG 1.155
Aircraft Impact Coping	Addition of AFI Addition and upgrading of fire barriers and doors	10 CFR 50.150
Extensive Damage Mitigation	B.5.b equipment	10CFR50.54 (hh)(2) EA-02-026, Section B.5.b

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US-ABWR Capability For Beyond Design Basis Events

- ***US-ABWR design fully addresses NRC requirements for design basis events***

- ***US-ABWR design includes numerous design features that provide capabilities to cope with beyond design basis conditions***

  Examples:

  - *Combustion Turbine Generator (CTG) provided to cope with SBO*
  - *Alternate Feedwater Injection System (AFI) capable of injecting water directly to reactor*
  - *AC Independent Water Addition (ACIWA) mode for core cooling, spent fuel pool cooling, or containment overpressure protection using either diesel driven fire protection system pump, or fire truck*

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US-ABWR Consideration for Beyond Design Basis External Events

- **US-ABWR design includes consideration for beyond design basis external events**

Examples

- *Earthquake : HCLPF (High Confidence Low Probability of Failure) capacity at least equal to twice the SSE is demonstrated for all Standard Plant safety related SSCs.*
- *Flooding (including Tsunami) : Reactor and Control Building doors are protected with tornado missile barriers, which will limit leakage due to external flooding above the design basis level. Site specific evaluation can be performed by COL applicant to add additional flood protection as necessary.*
- *Tornado : The tornado wind speed and pressure drop in DCD are more conservative than those in R.G. 1.76 revision 1.*
- *Extreme Wind : The tornado wind provides substantial margin above the extreme wind. (See the previous table)*

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J-ABWR Experience of Beyond DB Earthquake

- *Kashiwazaki Kariwa (KK)6/7: Chuestu-Oki Earthquake: July 16, 2007*

  - Observed Peak Acceleration at Reactor Building Lowest Level

	Horizontal	Vertical
KK-6	0.33 g	0.50 g
KK-7	0.36 g	0.36 g

US-ABWR Design Basis Peak ground acc. =0.3 g for SSE

- KK-7 in Operation accomplished Major Safety Functions

- Fundamentally Same Seismic Design in US-ABWR

- *IAEA Mission Report (Feb. 26, 2008)*

'From the presentations made by TEPCO experts as well as reports by the regulatory authority NISA, and as was confirmed by plant walkdowns performed by IAEA experts, ***it is indicated that the safety related structures, systems and components of all seven units of the plant*** *(in operating, start-up and shut down conditions)* ***demonstrated exceptionally good apparent performance in ensuring the basic safety functions concerning control of reactivity, cooling and confinement.'***

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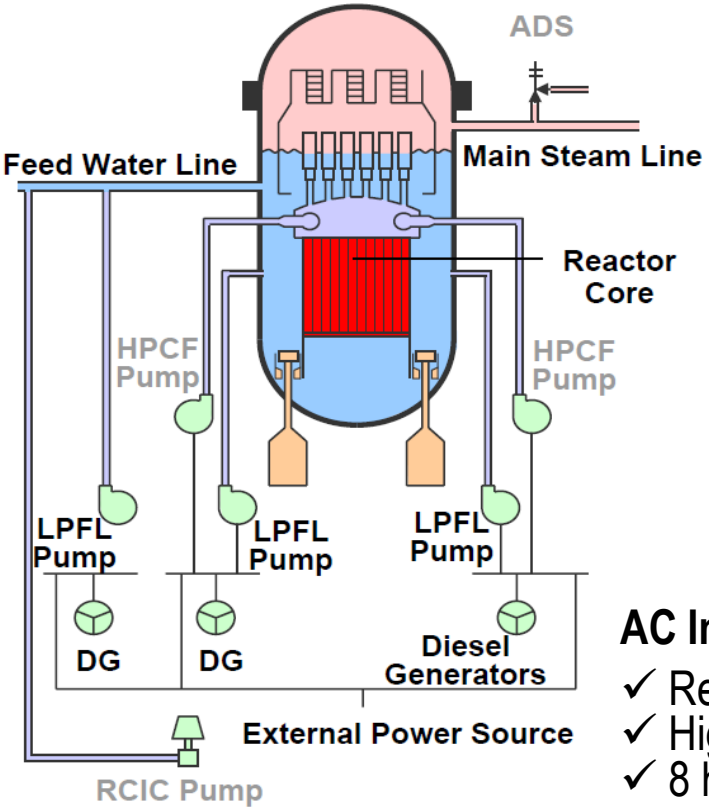
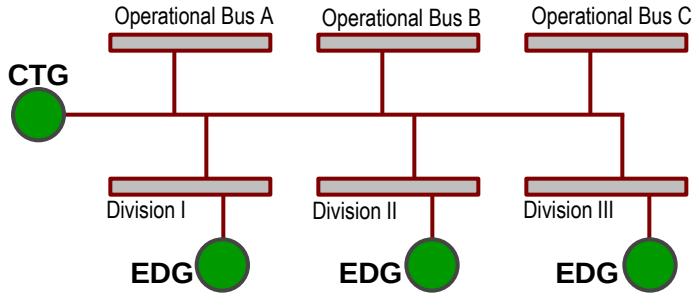
US-ABWR Coping Capability against SBO

US-ABWR ECCS Configuration & Power Supply Overview





Power Supply

- ✓ 3 redundant EDG
- ✓ Alternative AC power (CTG)
  - • Connection to Bus in 10 minutes
  - • 7 Day onsite fuel supply

AC Independent ECCS (RCIC)

- ✓ Reactor steam driven
- ✓ High pressure RPV coolant makeup
- ✓ 8 hours DC Battery for electrical operation

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US-ABWR Back-Up Power Supply

- **US-ABWR design includes Power Source Redundancy and Diversity**
  - *3 redundant Emergency Diesel Generators (separated physically and electrically)*
  - *8 hours of DC battery power (for SRV operation, RCIC controls, and other instrumentation)*
  - *Combustion Turbine Generator*
    - *Operates during SBO without external AC power*
    - *Has a 7 day on site fuel storage volume*
    - *Provides backup power to any one of three ECCS divisions*
    - *Housed above the design flood level and is in a building protected from adverse site related weather conditions*

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US-ABWR Core Cooling

- ***RCIC available for Core Cooling with availability of DC Control Power***
- ***Alternate Feedwater Injection System***
  - *With availability of CTG, system capable of injecting water directly to reactor*
  - *Evaluating AFI piping modification to accommodate temporary portable pump if CTG is unavailable*
- ***RHR AC Independent Water Addition (ACIWA) mode provides for core cooling using either diesel driven fire protection system pump, or fire truck***

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US-ABWR RCIC Design

Turbine Water Lubricated (TWL) Pump

- *TWL is a combined pump and turbine with single shaft*
- *Compact size*
  (Simple auxiliary machinery, no external shaft seal part etc.)
- *No vacuum pump and No condensate pump*
  (Less battery load required)
- *Mechanical flow control system*
  (No battery required for flow control)
- *Self water lubricated (oil-less)*
- *Functional up to ~250°F*
  (Design temperature is 171°F)

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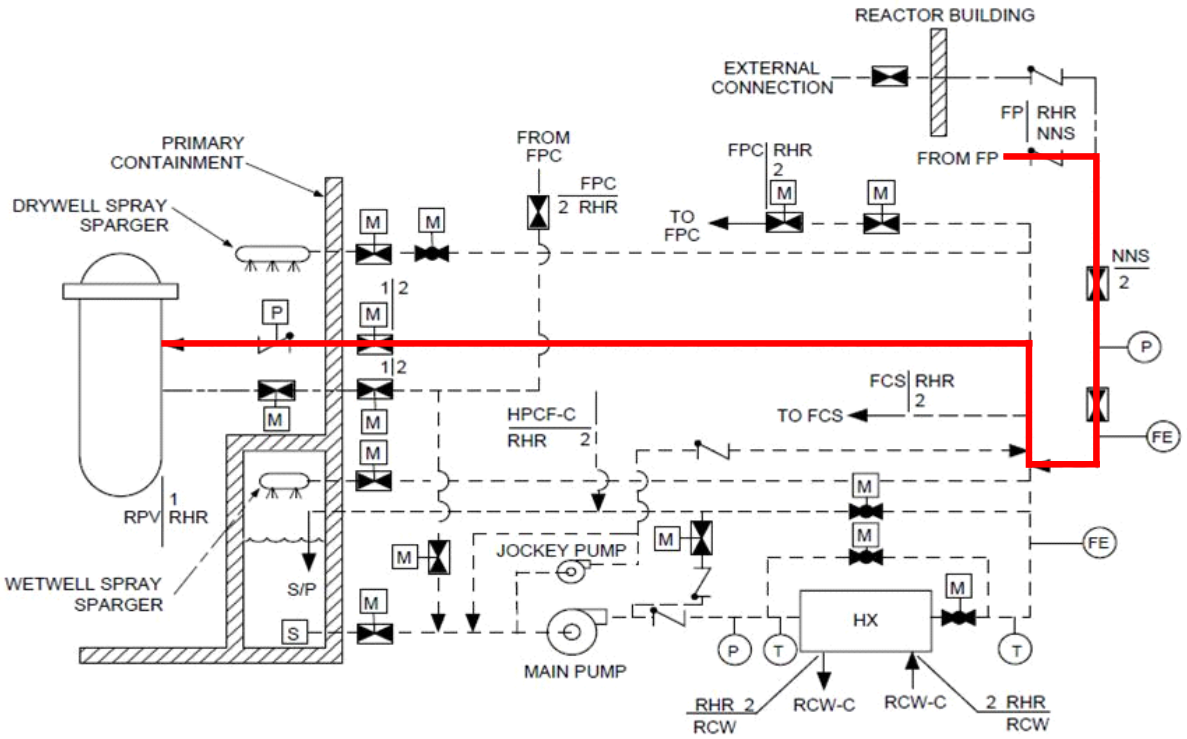
US-ABWR Core Cooling with ACIWA

Diverse means of low pressure water injection

- *Installed diesel driven fire pump*
- *All necessary valves are accessible and can be operated manually*



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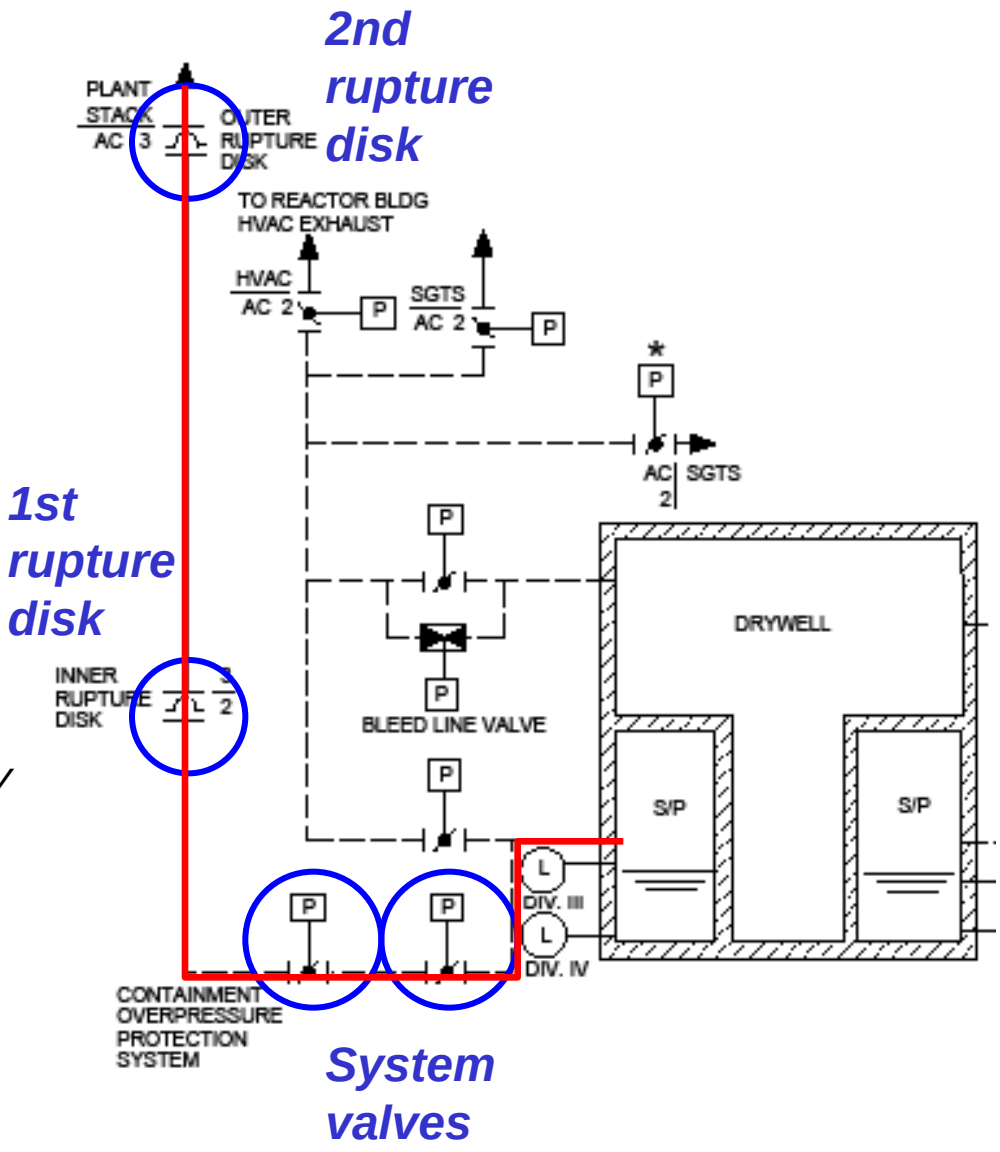
US-ABWR Containment Overpressure Protection

Containment Overpressure Protection System

-Venting provided from suppression pool
-Passive System does not require operator action
-System valves are normally open and fail open
-System can be isolated post disk rupture if desired

Rupture disks

-1st rupture disk:
part of the primary containment boundary
setpoint pressure = 2 Pd
-2nd rupture disk:
installed to maintain inerted condition in COPS pipe



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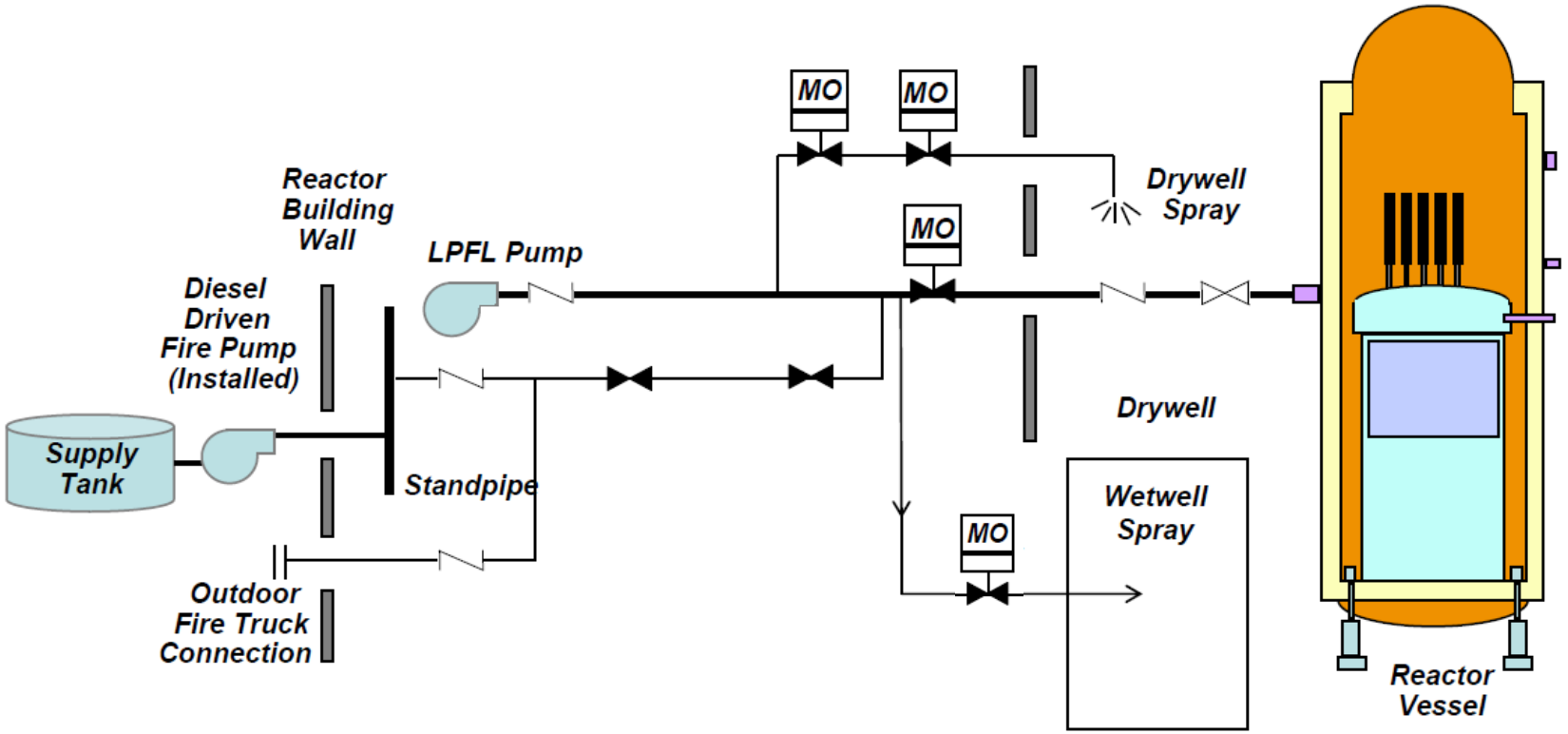
US-ABWR Containment Pressure Reduction with ACIWA

- ***ACIWA can be aligned to Drywell or Wetwell Spray headers;***
  Capable of connecting a fire truck to the system through an existing connection at grade level



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US-ABWR Spent Fuel Pool Cooling During SBO

- ***Fuel Pool Cooling and Cleanup (FPC) system is available if connected to CTG***
- ***With no FPC, under the maximum abnormal heat load with the pool gates closed, pool will boil in approximately 16 hours***
  - *Provides sufficient time for operator to connect fire hoses for pool make-up*
  - *Without make-up water the fuel will remain covered for approximately 77 hours*
- ***Permanent redundant plant pipe installed at opposite ends of the RB with external temporary connections to allow hook up for make-up water to spent fuel pool***
- ***Diesel-driven Fire Protection System (FPS) pump capable of supplying water to pool via RHR and FPC piping***

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US-ABWR SBO Response Capability Without CTG

- **US-ABWR design can mitigate 72 hour SBO without CTG**

	First 8-Hours	After 8-Hours
Core Cooling	RCIC (powered by DC batteries)	ADS RHR/ACIWA (FPS or portable diesel driven pump)
Containment Integrity	No action required (Press. / Temp. < Design value)	COPS (Passive PCV venting system rupture disk press. = 2Pd)
SFP Cooling	No action required (Temp. < Boiling temp.)	RHR/ACIWA (FPS or portable diesel driven pump)

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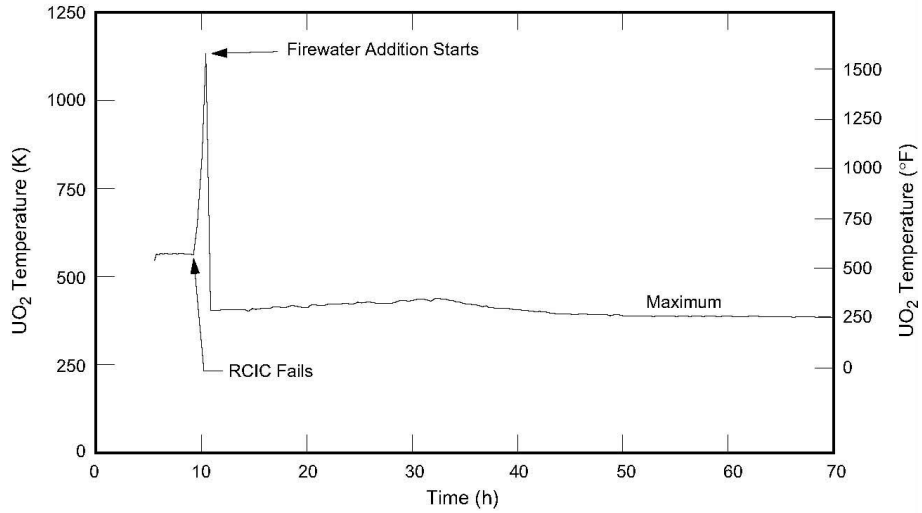
US-ABWR SBO Response Capability Without CTG

Sequence of Events

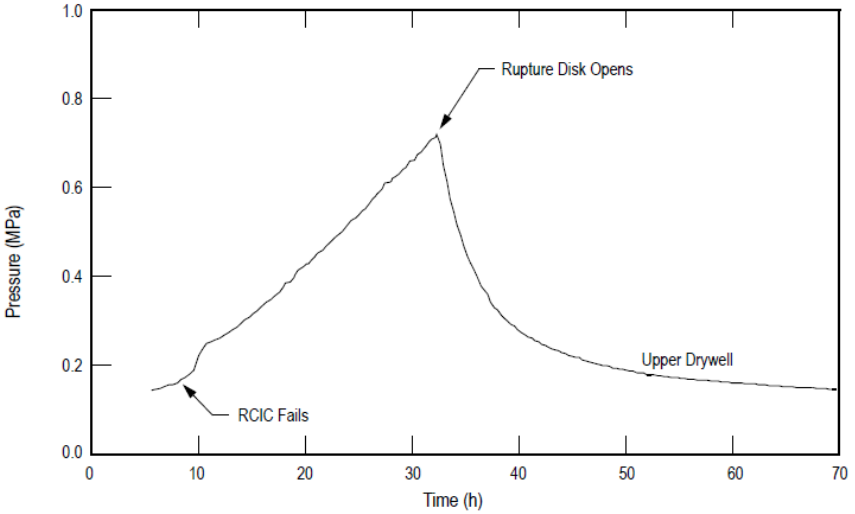
Time	Event
0.0	MSIV Closure
4.2 s	Reactor Scrammed
52.0 s	RCIC Injection, Suction from CST
1.3 h	RCIC Suction Switched to Suppression Pool
4.4 h	RCIC Suction Switched to CST
8.0 h	RCIC Failure
9.0 h	Suppression Pool began to overflow to Lower Drywell
9.8 h	Manual ADS
9.9 h	Collapsed Water Level Falls below Top of Active Fuel Firewater Addition System Injection Begins
32.3 h	Rupture Disk Opened

- *Core temperature peaks before fuel damage occurs due to ACIWA water injection*
- *Containment pressure is maintained below allowable limit by COPS*

- ***No Core Damage***
- ***No Loss of Containment Integrity***



UO2 Temperature



Drywell Pressure

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US-ABWR SFP Instrumentation

Temperature and Level Monitors

- *Provide indication via plant computer and annunciate in the main control room*
- *Powered by non-Class 1E vital 120 AC, from separate Plant Investment Protection (PIP) buses, backed by the CTG*

Local Area Radiation Monitors

- *Annunciate locally and in the main control room*
- *Powered by non-Class 1E vital 120 AC, from separate PIP buses, backed by the CTG*

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SECY-12-0025 Issues: Tier 1 Activities

2.1 – Seismic and flooding reevaluations

2.3 – Seismic and flooding walkdowns

4.1 – Station Blackout (SBO) regulatory actions

4.2 – Mitigating strategies for beyond design basis events

5.1 – Reliable hardened vents for Mark I and II containments

7.1 – Spent fuel pool instrumentation

8 – Strengthen & Integrate EOPs, SAMGs, & EDMGs

9.3 – Enhanced EP staffing and communications

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SECY-12-0025 Issues: Tier 2 Activities

2.1 – Other Natural External Hazards

7.2 – Provide safety-related AC power to the SFP makeup system

7.3 – Revise Tech Specs to address enhanced instrumentation and new AC power requirements

7.4 – Seismically qualified spray to SFP

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4.1 SBO Rulemaking

- ***New Regulation will be issued in 2014***

- ***US-ABWR can cope with Prolonged SBO***
  - *Alternate Power Source: CTG*
  - *Core Cooling w/o CTG: RCIC, ACIWA with FPS Pump*
  - *SFP Cooling w/o CTG : ACIWA with FPS Pump*
  - *Containment Integrity: COPS*

- ***Toshiba will incorporate requirements of the new SBO Regulation***

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4.2 Mitigation Strategy for Beyond-DBE

Order

- *Three phase approach required for mitigating beyond-DBE*
- *The initial phase: use of installed equipment and resources*
- *The transition phase: portable, onsite equipment and consumables*
- *The final phase: offsite resources to sustain those functions indefinitely*

US-ABWR Design

Even w/o CTG, three safety functions are sustained for more than 72 hr

- *Core Cooling for the initial 8 Hours: RCIC with DC batteries*
- *Core Cooling after RCIC termination: ACIWA/RHR with FPS pump*
- *SFP cooling: ACIWA/RHR with FPS pump*

  External hookup of portable pump
- *Containment: passive containment hardened vent*

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5. Reliable Hardened Vent (RHV)

Order: 5.1 RHV for Mark I/II Containments

- *Remove decay heat and maintain control of containment pressure within acceptable limits following beyond design basis events*
- *Accessible and operable under a range of conditions, including a prolonged SBO and plant conditions resulting from inadequate containment cooling*

Tier 3: 5.2 RHV for Other Containments

US-ABWR Design

- Containment Design: Reinforced Concrete Containment Vessel (RCCV)

- Containment Vent Design:

Hardened Vent

Passive Design (Rupture Disks with Normally Open Valves)

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7.1 Reliable SFP Instrumentation

Order

- *Instruments: a permanent, fixed primary instrument channel and a backup channel with independent power source*
- *Measurement range: from normal water level to top of fuel rack*
- *Arrangement: reasonable missile protection for level instrumentation*
- *Mounting: seismically qualified to retain its design configuration*
- *Qualification: reliability at boiling condition and SFP radiation level*
- *Power Supply: separate power supply for permanent instruments*
- *Display: Control Room, Alternate Shutdown Panel or other appropriate accessible location*

US-ABWR Design

- *Temperature/ Level/ Area Radiation monitors provided and displayed in Control Room*
- *Powered by non-Class 1E vital 120AC from PIP buses, backed-up by CTG*

NRC ISG issued by August 31, 2012

- *New Instrumentation will be added consistent with NRC Order*

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7.2 SFP Makeup Capability (Tier 2)

Recommendation

- *Safety-related AC power for SFP makeup system*

US-ABWR Design

- *Residual Heat Removal (RHR) system can be used for the SFP makeup, which is powered by safety-related AC power (EDG)*

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Other Tier 2 Activities

- ***7.3 – Revise Technical Specifications to address enhanced instrumentation and new AC power requirements***
  - *Monitor NRC and BWROG efforts in this area for application to US-ABWR*

- ***7.4 – Seismically qualified spray to SFP***
  - *Design spray to meet seismic requirements*

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US-ABWR: DC Renewal Application

- ***Appendix 1E will be added to address Fukushima-related Tier 1 and Tier 2 matters similar to existing Appendix 1A, "Response to TMI Related Matters"***

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Conclusion

- ***The US-ABWR design is robust for Fukushima-like Beyond Design Basis Events***
- ***Safety of US-ABWR will be further enhanced by addressing the NRC recommendations and new NRC regulations***
- ***Toshiba appreciates the opportunity to meet with the NRC and discuss the robust safety design of the US-ABWR and our plans to further enhance this safety***

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