US-APWR

9th Pre-Application Review Meeting

Safety Features

August 23, 2007

Mitsubishi Heavy Industries, Ltd.

Meeting Attendees

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Objectives of Meeting

- **Provide an overview of the following safety features of the US-APWR**
  - ✓ **Safe Shutdown**
  - ✓ **Station Blackout (SBO)**
  - ✓ **Layout Design**
- **Obtain feedback from the NRC and improve the quality of the Design Control Document of the US-APWR**

Contents

Presentation Items

- We will explain Safe Shutdown and Station Blackout as Following Reasons:

Design Base Event	
1.RCPB, CPB	Explained #2 PAR
2.Safe Shutdown	Explain during this PAR
3.Engineered Safety Features	Explained #3,#6 PAR
Beyond Design Base Event	
1.Severe Accident	Explained #7,#8 PAR
2.CCF of Digital I&C	Explained #3 PAR
3.Station Blackout	Explain during this PAR

- **RCPB : Reactor Coolant Pressure Boundary**
- **CPB : Containment Pressure Boundary**
- **CCF : Common Cause Failure**

- We will explain Layout Features to Maintain Safe Shutdown Function against Hazards

1. Safe Shutdown

Contents

1.1 Safe Shutdown Design Description

- **Codes, Standards and Regulatory Guides**
  - ✓10 CFR 50.55a
  - ✓10 CFR 50.34
  - ✓10 CFR 52.47
  - ✓10 CFR 52.79
  - ✓GDC 1, 2, 4, 13, 19, 24, 34, 35, 38
  - ✓SRP 7.4
  - ✓SRP 5.4.7, BTP 5-4

1.1 Safe Shutdown Design Description (Cont'd)

- **Design Bases**
  - ✓ Safe Shutdown means bringing and maintaining the plant to the conditions specified in plant technical specifications as Hot Standby or Cold Shutdown
  - ✓ Safety-related Systems are used to complete and maintain the safe shutdown condition
  - ✓ Safe Shutdown Systems are specific to safe shutdown, and not directly relate to mitigation of accident consequences
  - ✓ Safe Shutdown can be accomplished in the Main Control Room and at Remote Shutdown Panel

1.1 Safe Shutdown Design Description (Cont'd)

➢ Required Functions

✓ Functions required for safe shutdown:

- Reactivity control
- Reactor coolant makeup (RCS makeup)
- Reactor pressure control (RCS pressure control)
- Decay heat removal (Including RCS cooling)

✓ Support systems:

- Electrical power systems
- Instrumentation & Control Systems (I&C)
- Cooling systems (CCWS, ESWS)
- Heating Ventilation & Air Conditioning (HVAC)

RCS : Reactor Coolant System
CCWS : Component Cooling Water System
ESWS : Essential Service Water System

1.1 Safe Shutdown Design Description (Cont'd)

➢ Design Requirements

Systems required for safe shutdown shall:

- Perform the required functions assuming single failure during on line maintenance
- Provide the required capacity and reliability to perform intended safety functions on demand
- Provide the required capacity to function during and after Design Basis Events, such as an earthquake, and anticipated operational occurrences
- Provide the capability to operate with on-site electrical power (assuming off-site power is not available), or with off-site electrical power available (assuming on-site power is not available)

1.2 Safe Shutdown Front Line Systems

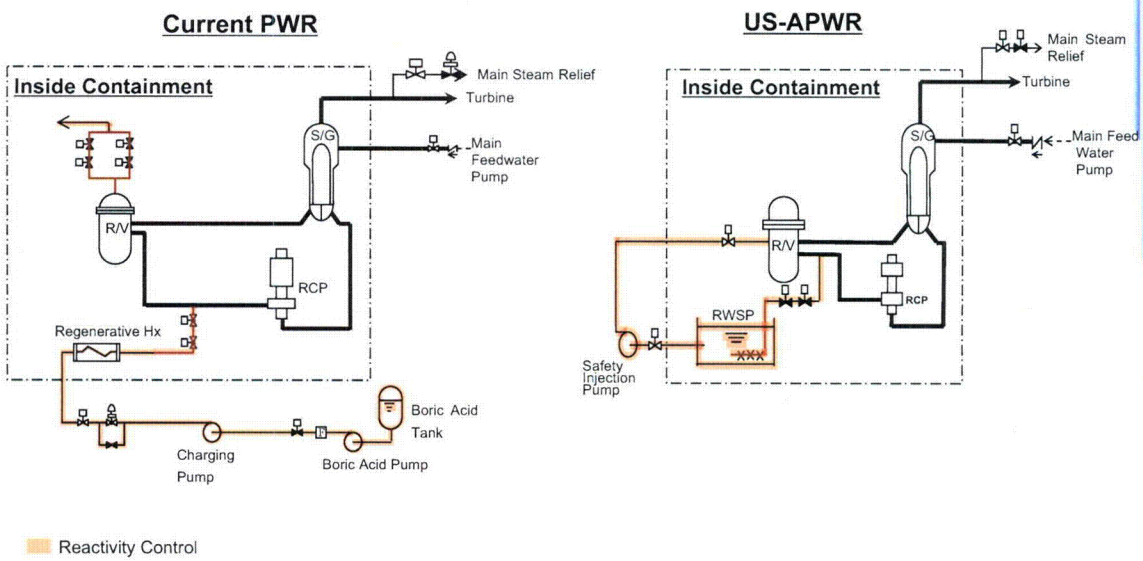
✓Reactivity control

Current PWR	US-APWR	**Reasons for Selecting System**	Compliance to NRC Req.
•Using CVCS •Boron injection from BAT using BA Pump, Charging Pump and Charging line •Letdown using Reactor Vessel Head letdown	•Feed & Bleed using SI Pumps and emergency letdown lines •Borated water source is RWSP •Need to be depressurized below SI pump injection pressure	•Safe Shutdown function does not rely on CVCS which satisfies US utility requirements	•Meets SRP 7.4 •Same design as SP-90

- CVCS : Chemical Volume Control System
- RWSP : Refueling Water Storage Pit
- SI Pump : Safety Injection Pump
- BAT : Boric Acid Tank, BA Pump : Boric Acid Pump

1.2 Safe Shutdown Front Line Systems (Cont'd)

✓Reactivity control (Cont'd)



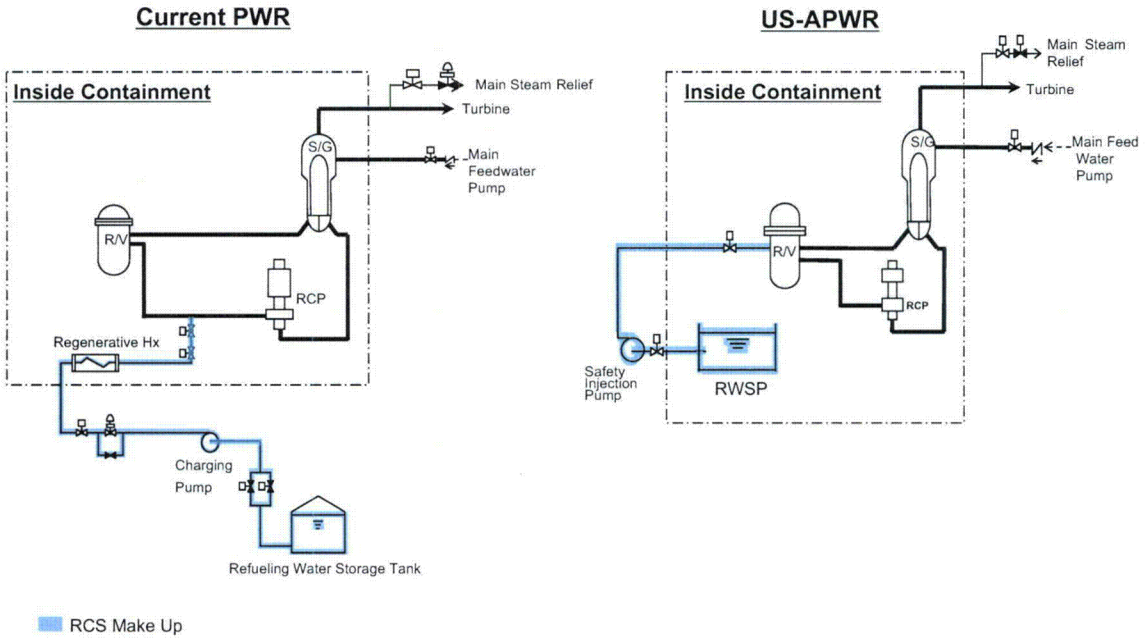
1.2 Safe Shutdown Front Line Systems (Cont'd)

✓RCS makeup

Current PWR	US-APWR	**Reasons for Selecting System**	Compliance to NRC Req.
•Make up using Charging Pump •Borated water source is RWST	•Make up using SI Pump •Borated water source is RWSP •Need to be depressurized below SI pump injection pressure	•Safe Shutdown function does not rely on CVCS which satisfies US utility requirements	•Meets SRP 7.4 •Same design as SP-90

1.2 Safe Shutdown Front Line Systems (Cont'd)

✓RCS makeup (Cont'd)



1.2 Safe Shutdown Front Line Systems (Cont'd)

✓RCS pressure control

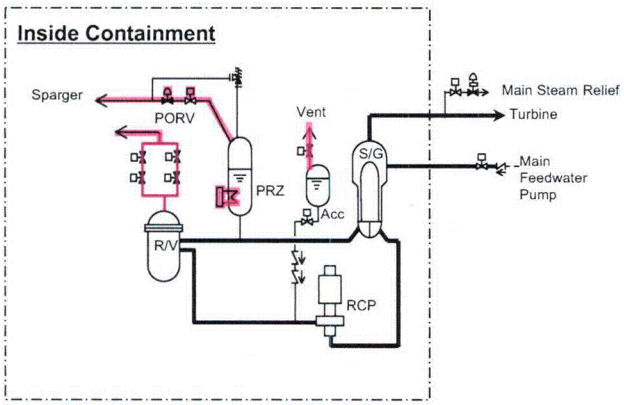
Current PWR	US-APWR	**Reasons for Selecting System**	Compliance to NRC Req.
•Pressurized by Pressurizer backup heater •Depressurized by PORV •RV vented by using RV Head Vent Line •Accumulator N_2 vented by using Vent Line	•Pressurized by Pressurizer backup heater •Depressurized by SDV •RV vented by using RV Head Vent Line •Accumulator N_2 vented by using Vent Line	•US-APWR adopts SDV since IAS is non safety and eliminates automatic actuation which satisfies US utility requirements	•Meets SRP 7.4

- PORV : Pressurizer Power Operated Relief Valve (Air Operated Valve)
- SDV : Safety Depressurization Valve (Motor Operated Valve)
- IAS : Instrument Air System

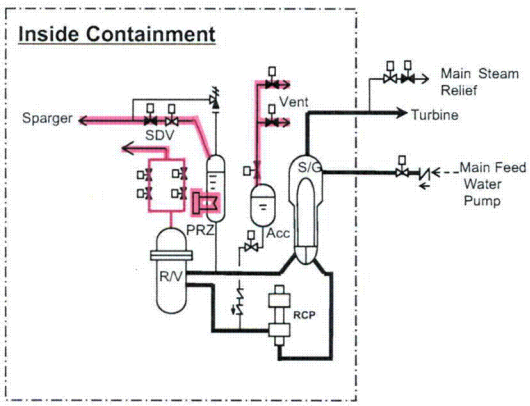
1.2 Safe Shutdown Front Line Systems (Cont'd)

✓RCS pressure control (Cont'd)

Current PWR



US-APWR



RCS Pressure Control

1.2 Safe Shutdown Front Line Systems (Cont'd)

✓Decay heat removal and RCS Cooling

Current PWR	US-APWR	**Reasons for Selecting System**	Compliance to NRC Req.
Decay Heat Removal and Cooling by SG • 3 AFW Pumps (2 M/D, 1 T/D) •AFW supplied by AFW Pumps •AFW source is AFW Tank •Steam relieved by MSRV	Decay Heat Removal and Cooling by SG • 4 EFW Pumps (2 M/D, 2 T/D) •EFW supplied by EFW Pumps •EFW sources are EFW Pits •Steam relieved by MSRV	•4 Train enables to perform required function assuming single failure during OLM (explained at #6 PAR)	•Meets SRP 7.4 •Basically same as Current PWR

- AFW : Auxiliary Feed Water
- EFW : Emergency Feed Water
- M/D : Motor Driven, T/D : Turbine Driven
- MSRV : Main Steam Relief Valve
- OLM : On Line Maintenance

1.2 Safe Shutdown Front Line Systems (Cont'd)

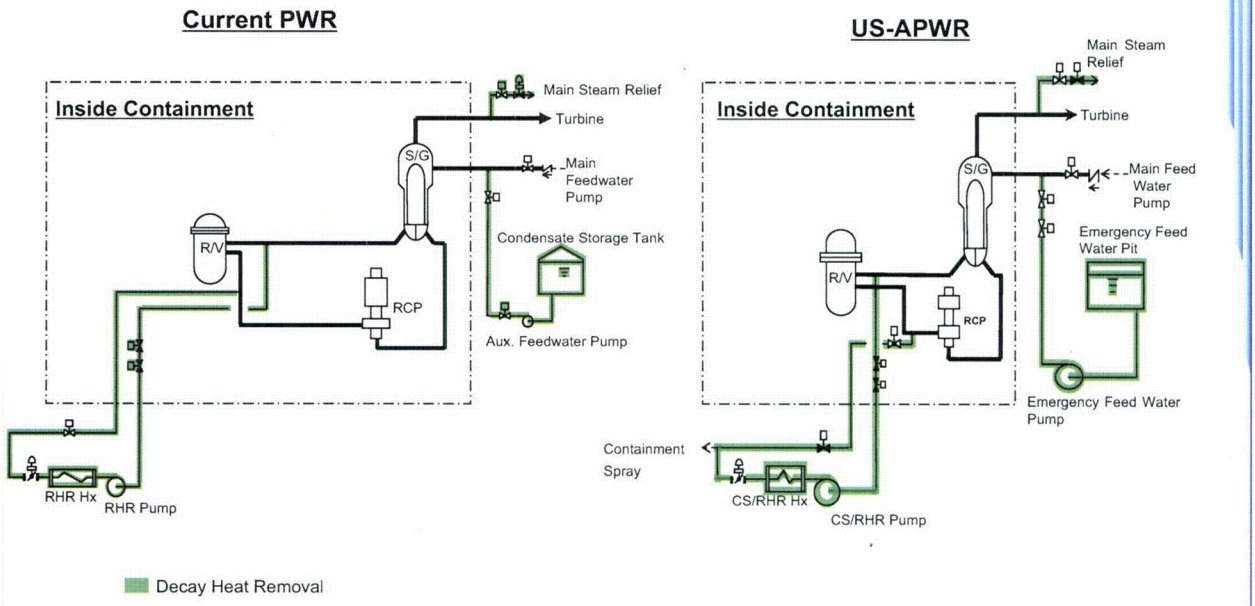
✓Decay heat removal and RCS Cooling (Cont'd)

Current PWR	US-APWR	**Reasons for Selecting System**	Compliance to NRC Req.
Cooling by RHRS •2 Trains •RCS cooled using RHR Pump and RHR Hx	Cooling by RHRS •4 Trains •RCS cooled using CS/RHR Pump and CS/RHR Hx	•4 Train enables to perform required function assuming single failure during OLM (explained at #6 PAR)	•Meets SRP 5.4.7, BTP 5-4, SRP 7.4 •Basically same as Current PWR

- RHRS : Residual Heat Removal System
- CS/RHR : Containment Spray and Residual Heat Removal
- Hx : Heat Exchanger

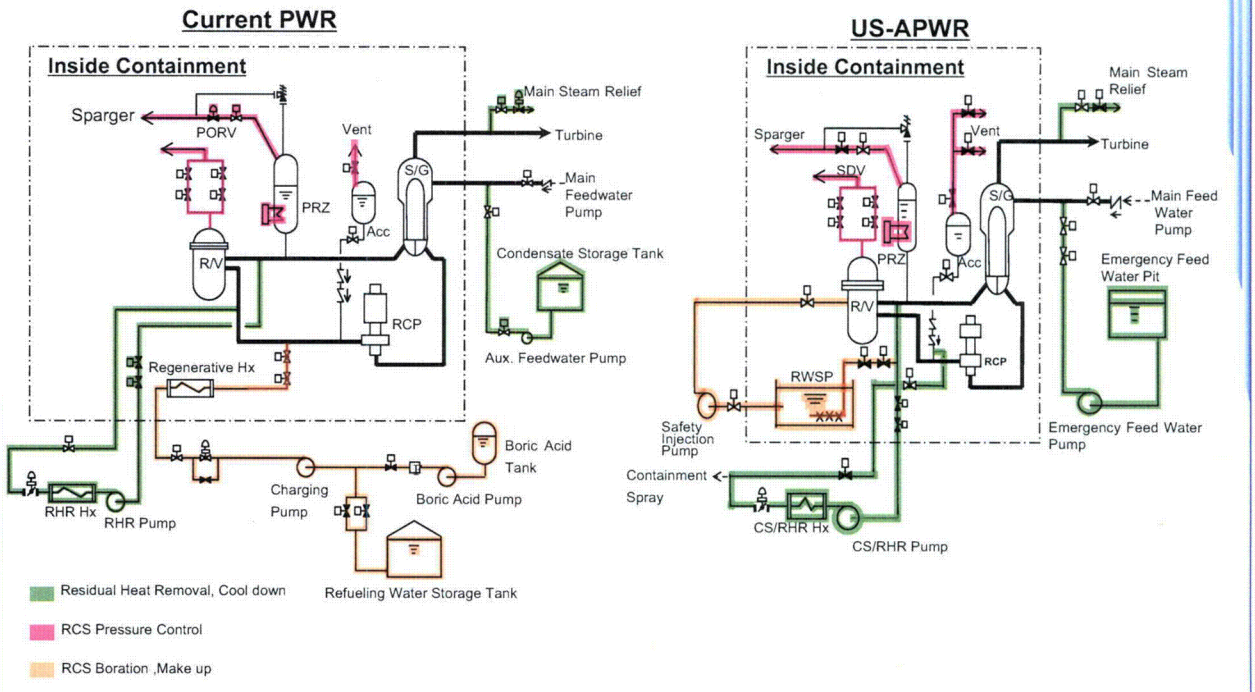
1.2 Safe Shutdown Front Line Systems (Cont'd)

✓Decay heat removal and RCS Cooling (Cont'd)



1.2 Safe Shutdown Front Line Systems (Cont'd)

✓Overall Safe Shutdown Systems Outline Schematics



1.3 Safe Shutdown Support Systems

✓Support Function and Components

Support System		Remarks
Cooling Systems (CCWS, ESWS)	•ESW Pump •CCW Pump, CCW Hx	Including Ultimate Heat Sink
HVAC Systems	•Main Control Room HVAC System •Class 1E Electrical Room HVAC System •Emergency Feed Water Pump Area HVAC System •Safeguard Component Area HVAC System	Including Essential Chilled Water System
Electrical Power Systems	Safety Power Systems	

1.3 Safe Shutdown Support Systems (Cont'd)

✓Support Function and Components (Cont'd)

Support System	Key Parameters	Remarks
I&C	・Pressurizer water level ・Pressurizer pressure ・RCS pressure ・RCS temperature ・Reactor Vessel water level ・RHR flow ・Accumulator tank pressure ・SG water level, Main Steam pressure ・Safety Injection flow rate ・RWSP water level ・EFWP water level, EFW flow rate	Including Control System

1.3 Safe Shutdown Support Systems (Cont'd)

- Safe Shutdown Support Systems
  - Cooling Systems (CCWS, ESWS)
  - HVAC Systems
  - Main Control Room HVAC System*
  - I&C**
  - Electrical Power Systems***

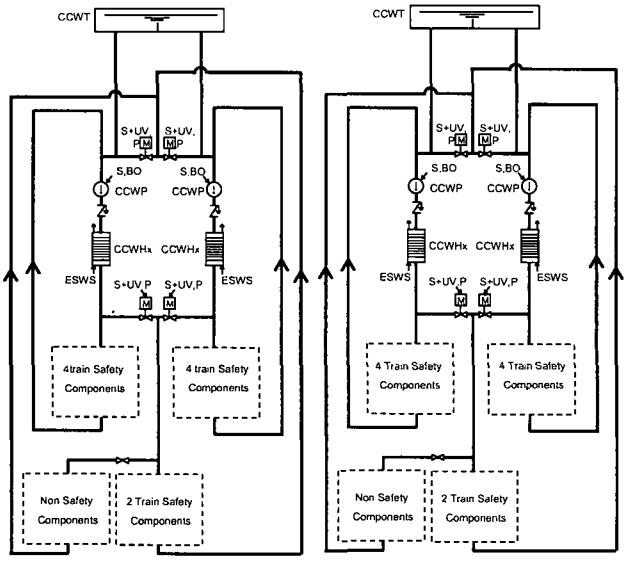
* Explained at #6 PAR
** Explained at #3 PAR
*** Explained at #7 PAR

(1) Cooling Water System (CCWS,ESWS)

- Codes, Standards and Regulatory Guides
  - ✓ GDC 2, 4, 5, 44, 45, 46
  - ✓ USNRC Regulatory Guides 1.29, 1.153, 1.206 C.I.9.2
- Design Bases
  - ✓ Provide sufficient cooling capacity for normal operations and for accident conditions and abnormal operational transients
  - ✓ Maintain the safety functions during and after a safe shutdown earthquake
  - ✓ Sufficient redundancy to accomplish the safety functions assuming a single failure and on line maintenance

(1) Cooling Water System (CCWS,ESWS) (Cont'd)

- CCWS System Design
  - ✓ 4 safety train configuration (Each train consists of 1 CCWP and 1 CCW Hx)
  - ✓ Separated into 2 independent sections even in normal operation (Each section has 1 CCWT with separator plate)
  - ✓ Non safety components and 2 train safety components (e.g. SFPHx) are connected to the line which branch off the header line
  - ✓ The header lines will be isolated automatically by isolation signals (e.g. S+UV, or P signal)
  - ✓ CCW can be supplied to safety grade components by reopening the isolation valves when it's necessary

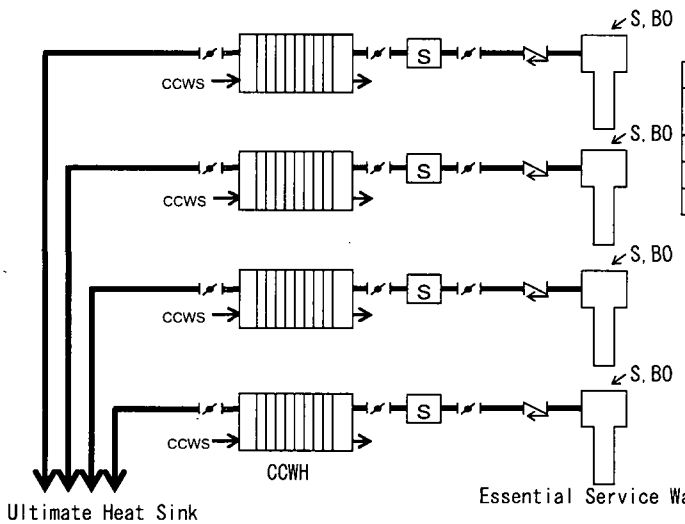


Legend

CCWT	Component Cooling Water Surge Tank
CCWP	Component Cooling Water Pump
CCWHx	Component Cooling Water Heat Exchanger
ESWS	Essential Service Water System
SFPHx	Spent Fuel Pit Heat Exchanger
P	Containment Spray Signal
S	Safety Injection Signal
BO	Blackout Signal
UV	Under Voltage Signal

(1) Cooling Water System (CCWS,ESWS) (Cont'd)

- ESWS System Design
  - ✓ Completely separated into 4 train configuration (Each train consists of 1 ESWP)
  - ✓ Cooling only for the CCW Hx



Legend

CCWS	Component Cooling Water System
CCWHx	Component Cooling Water Heat Exchanger
S	Strainer
S	Safety Injection Signal
BO	Blackout Signal

(2) HVAC Systems

➢ HVAC Systems

- ✓ Class 1E Electrical Room HVAC system
- ✓ Emergency Feed Water Pump Area HVAC System
- ✓ Safeguard Component Area HVAC System
- ✓ Essential Chilled Water System

➢ Codes, Standards and Regulatory Guides

- ✓ GDC 2, 4, 5 and 17

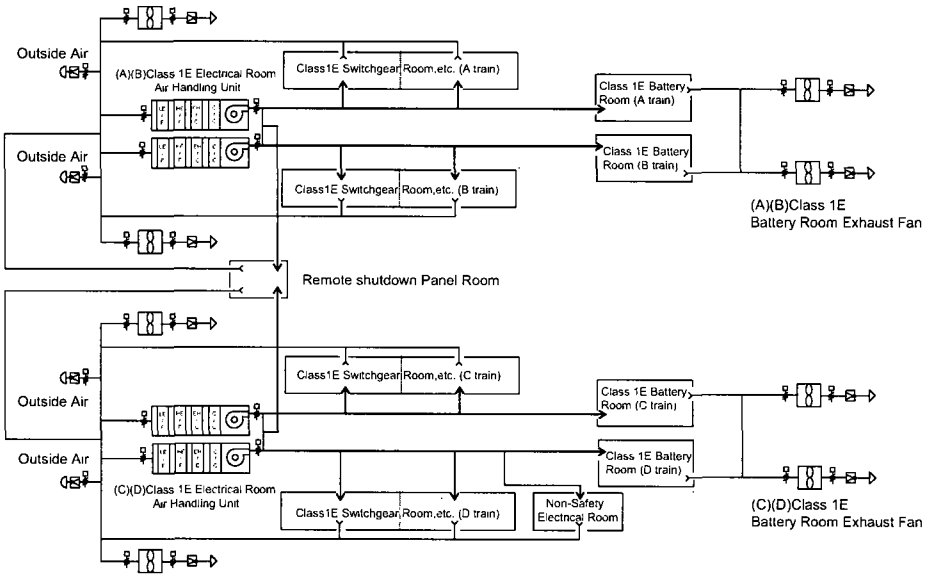
➢ Design Bases

- ✓ Provide suitable environmental conditions for safety related components and equipment.
- ✓ Retain HVAC safety function during and after a design basis accident to provide suitable environmental conditions for safety related components and equipment.

(2) HVAC Systems (cont'd)

➢ Class 1E Electrical Room HVAC System

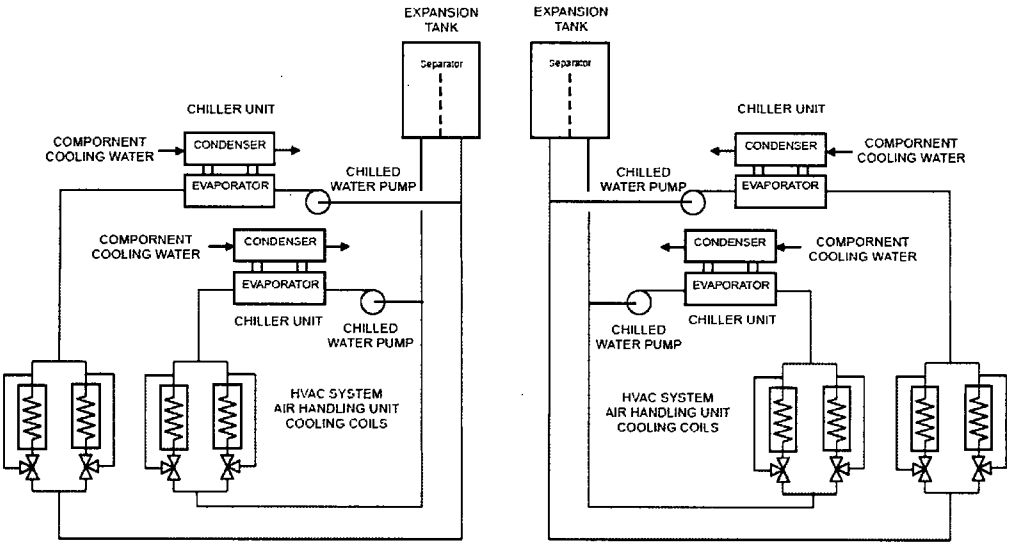
- ✓ 4 safety train configurations.
- ✓ Separated into two independent sections.
  (Each Air Handling Unit has 100% capacity for each section)
- ✓ 4 train separation is possible during an emergency event. (e.g. Fire)



(2) HVAC Systems (cont'd)

➢ Essential Chilled Water System

- ✓ 4 safety train configurations
  (each train consist of one Chiller Unit and one Chilled Water Pump)
- ✓ One expansion tank with separator plate is shared with two trains.



1.4 Conclusions

- ➢ The US-APWR has Safe Shutdown capability using safety-related components.
- ➢ Four train design concept provides Safe Shutdown capability assuming single failure during on line maintenance of one train.
- ➢ Comments and suggestions received from the NRC will be considered to improve the quality of the Design Control Document (DCD)

2. Station Blackout

Contents

2.1 Codes, Standards and Regulatory Guides

➢ Codes, Standards and Regulatory Guides

- ✓ 10 CFR 50.2
- ✓ 10 CFR 50.63
- ✓ USNRC Regulatory Guide 1.155

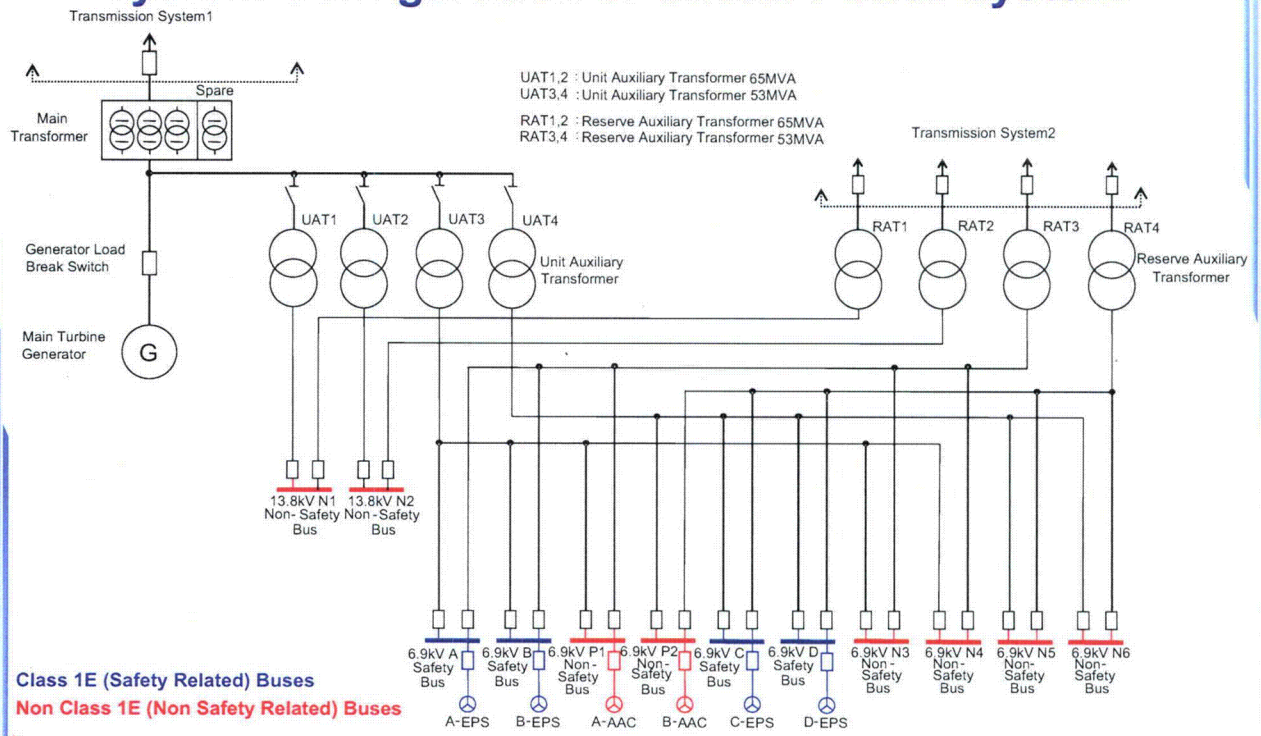
2.2 Definition

➢ Definition of Station Blackout (SBO)

- ✓SBO refers to the complete loss of alternate current electric power to the essential and nonessential switchgear buses.
- ✓SBO therefore involves the loss of offsite power concurrent with turbine trip and failure of onsite emergency ac power system (4 trains, 4 Class 1E emergency generators), but not the loss of available AC power to buses fed by station batteries through inverters or the loss of power from “Alternate AC (AAC) sources”.

2.3 Onsite Power System

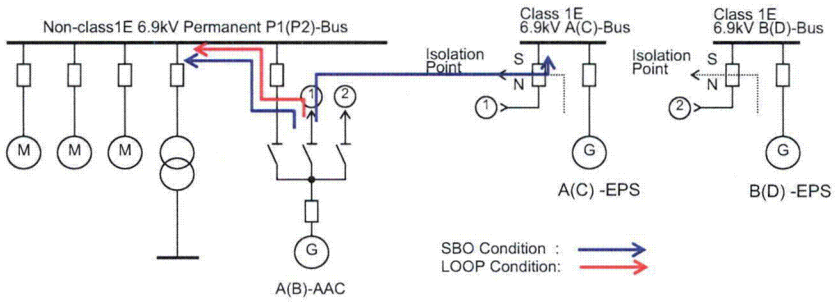
➢ System Configuration of Onsite Power System



2.3 Onsite Power System (Cont'd)

➢ Design Features of Onsite Power System

- ✓ Class 1E AC electrical power system consists of four (4) separate trains. Each train includes one Class 1E Emergency Power Source (EPS). Class 1E DC power system consists of four (4) separate trains. Each battery can supply the loads for two (2) hours, without any AC power input
- ✓ AACs of a different type (Starting System, Capacity etc.) and are provided to minimize the potential for common mode failure with either the offsite power or the EPS system. The AAC is a non-class 1E gas turbine-generator package connected to a 6.9kV AC "Permanent" bus



When a LOOP occurs, the AAC supplies power to "permanent" bus automatically. Interlocks will prevent the AAC and EPS from being operated in parallel on same bus.

2.3 Onsite Power System (Cont'd)

➢ Operation of AAC under the SBO Condition

When a SBO occurs, the AAC power source feeds the selected safety related (Class 1E) division in accordance with the following procedure:

1) Switching will be done manually to prevent starting loads on any other division.
2) Loads that need to be stopped on the "permanent" bus will be tripped manually.
3) The required breaker to the back-up division will be closed manually.
4) Back-up bus will be energized and loaded as necessary for coping with SBO. The loads will be started manually.

This procedure will be accomplished within one hour.

2.4 Countermeasures for SBO

➢ Basic Concept for coping with SBO

SBO occurs

All offsite power and four EPSs will be lost. Two alternate AC power sources (AACs) and batteries will be still available.

Switching of buses and starting loads [No AC Power]

Tie-line between permanent MV* bus and safety MV bus will be connected.
Needed loads (safety loads and non-safety loads) are re-stored.
All operations can be achieved within one hour.

Plant Target and Safety [AAC Power is available]

Plant can maintain integrity of components and safe condition
(e.g. Maintain integrity of RCP seal and maintain decay heat removal) until completion of switching buses and re-starting loads. Plant can keep the Hot-Standby condition for more than 8 hours (R.G.1.155) without AAC fuel supply from offsite.**

*** MV : Medium Voltage**
****Standard AAC fuel tanks have 7 days (IEEE std 308) capacity same as Emergency Power System**

2.4 Countermeasures for SBO (Cont'd)

➢ Operation of Plant under the SBO Condition

Function	No AC Power (Less than one hour)	AC Power supplied by AAC (Beyond 8 hours)
Reactivity Control	Not required	Supply BAT water using Charging pump
RCS make up	Not required	Supply RWSAT water using Charging pump
RCS pressure control	Not required	Pressurized by PZR Backup Heater Depressurized by SDV
Decay heat removal	EFW Pit, T/D EFW Pump Steam relieved by MSRV	Supply EFW Pit* water using T/D EFW Pump Steam relieved by MSRV
Cooling of RCP seal	MHI RCP seal can keep integrity without cooling	RCP seal injection using Charging Pump, Water source is RWSAT
Supporting System	I&C	I&C, Cooling System, HVAC

- BAT : Boric Acid Tank
- RWSAT : Refueling Water Storage Auxiliary Tank
- PZR : Pressurizer
- SDV : Safety Depressurized Valve
- EFW Pit : Emergency Feed Water Pit
- T/D EFW Pump : Turbine Driven Emergency Feed Water Pump
- MSRV : Main Steam Relief Valve

* : Use Secondary Demineralized Water Tank after EFW Pit water is empty.

2.4 Countermeasures for SBO (Cont'd)

➢ Evaluation

- ✓ AAC will start automatically within 100 seconds after SBO occurs. Reenergizing of bus by AAC and restarting of loads will be completed within one hour after SBO occurs.
- ✓ Plant can maintain safe condition until completion of reenergizing by AAC and restarting required loads. RCP seal can maintain integrity without cooling until required loads are restored.
- ✓ Plant can maintain Hot Standby condition with only one AAC, one permanent division (and loads) and one Class 1E division (and loads) for more than 8 hours.

2.5 Conclusions

- ➢ US-APWR can keep the Hot-Standby condition for more than 8 hours in case of SBO event
- ➢ Comments and suggestions received from the NRC will be considered to improve the quality of the Design Control Document (DCD)

3. Layout Design

Contents

3.1 Overview of US-APWR Plant Layout

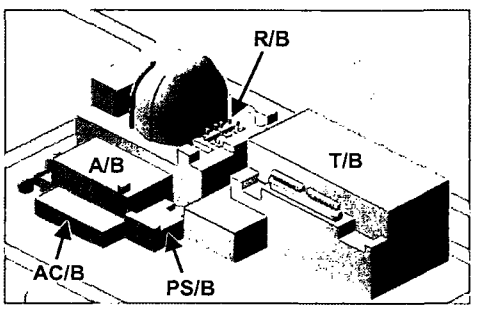
Features of US-APWR Plant Layout

- Economical Benefit by Standardized Single Unit
- Shielding to Minimize Radiation Exposure, and Complete Separation of Radioactive Control Area
- Quakeproof Square Footprint & Isolated Base Mat of Seismic Category-I Buildings
- Turbine axis is oriented perpendicular to Safety Buildings
- Protect Safety Systems against Hazards

(e.g. Flooding, Missiles, Tornado, Fire)

Major Buildings

R/B : Reactor Building
PS/B : Power Source Buildings
T/B : Turbine Building
A/B : Auxiliary Building
AC/B : Access Building



3.1 Overview of US-APWR Plant Layout

Enhanced Criteria for New Reactor

- Compliance with Fire Protection Criteria
Regulatory Guide 1.189
"Safe shutdown can be achieved assuming that all equipment in any one fire area (excluding the control room and reactor containment) will be rendered inoperable"

US-APWR is designed to provide "Physical Separation" for Safe Shutdown Systems

3.2 Regulatory Requirements

10 CFR 50 Appendix-A, General Design Criteria

Structures, Systems, and Components (SSC's) Important to safety shall be designed to meet following criteria:

- **Criterion 2 : Design Basis for Protection Against Natural Phenomena**
- **Criterion 3 : Fire Protection**
- **Criterion 4 : Environmental and Missile Design Basis**

3.2 Regulatory Requirements

Regulatory Guidance for Implementing Requirements

- R.G. 1.59 Design Basis Floods for Nuclear Power Plants (NPPs)
- R.G. 1.76 Design Basis Tornado and Tornado Missiles for NPPs
- R.G. 1.102 Flood Protection for NPPs
- R.G. 1.115 Protection against Low-Trajectory Turbine Missiles
- R.G. 1.117 Tornado Design Classification
- R.G. 1.189 Fire Protection for NPPs

3.3 Protective Design Features against Hazards

Protection against Floods

Mitigation of Internal Flood Source

- Provide watertight compartment for non-safety tank room

Layout Safety Components above internal Flood Level

- Provide concrete foundation of safety components with proper height

Robust Structure to Withstand External Flood Loads

- Safety components are located in safety buildings

Prevent Water Immersion against External Flood

- Exterior openings/penetrations are appropriately sealed

Protection against Tornado & Missiles

Robust Structure to Withstand Wind Loads

- Safety components are located in seismic category-I buildings

Protection of Safety Components by Barriers

- Pipe whipping restraints/barriers are provided (if required)

Robust Exterior Protects against Tornado Missiles

- Provide sufficient wall/roof thickness of protective buildings

Provide Required Thickness of Wall / Ceiling

- Provide required thickness to satisfy that the total damage probability of turbine missile to be less than 10^{-7}/year

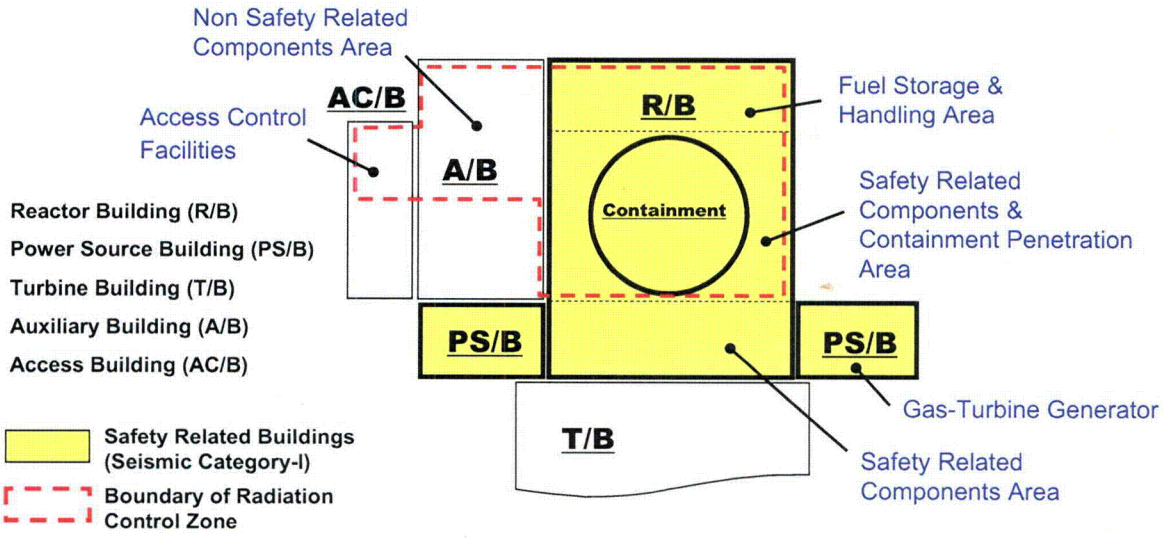
Fire Protection

Physical Separation for Safe Shutdown Systems

- Assumes safety components in a fire area are inoperable
- 4 train systems are installed in independent compartments (Control Room and Containment are excluded from this approach)
- Provide local concrete shaft / tunnel for cable routing

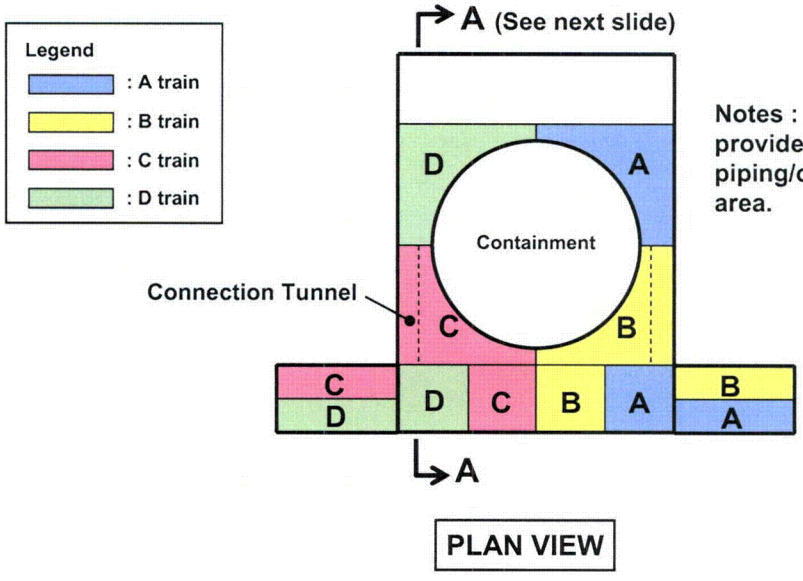
Buildings to be protected from hazards

- Building exterior is designed to protect against external hazards influence
- Interior structure walls are designed to protect against internal hazards Influence



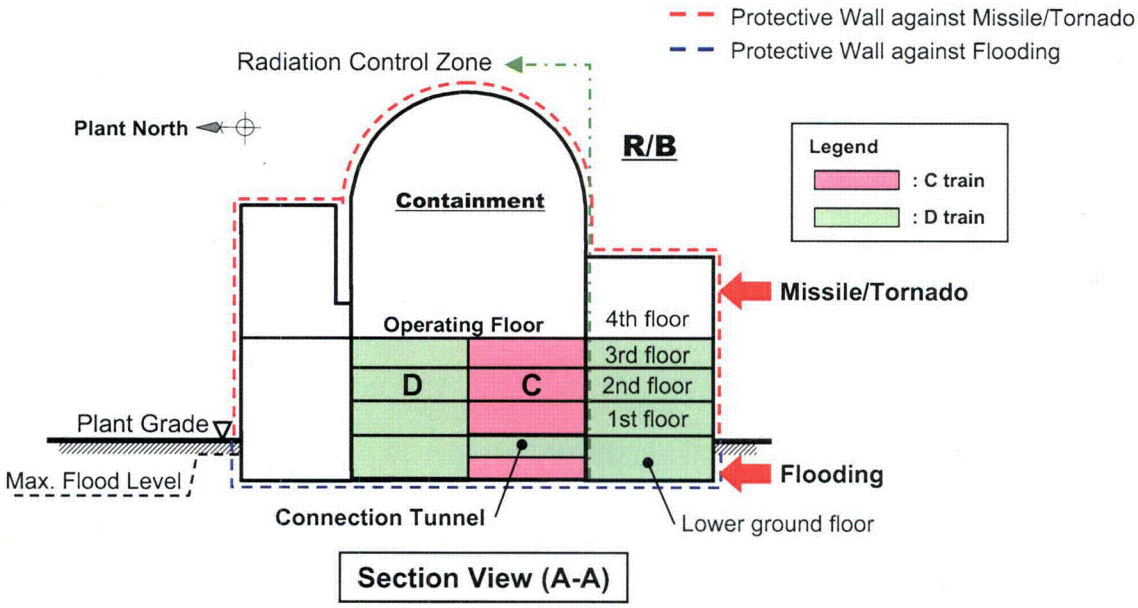
Concept of Physical Separation

Four train systems are installed in independent compartments



Notes : Connection tunnels are provided to route the train related piping/cable between separated train area.

Concept of Physical Separation (Cont'd)



- Countermeasures of protective design consistent with current plants
- Safety related components are installed into seismically qualified buildings
- Safety buildings are designed to provide physically separated compartments for safe shutdown systems to meet enhanced fire protection criteria for new reactors

3.5 Conclusions

- US-APWR layout and specific design features complies with 10CFR 50 Appendix-A GDC
- Comments and suggestions received from the NRC will be considered to improve the quality of the Design Control Document (DCD)