US-APWR

6th Pre-Application Review Meeting

Engineered Safety Features

March 22, 2007

Mitsubishi Heavy Industries, Ltd.

Meeting Attendees

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Acting Manager
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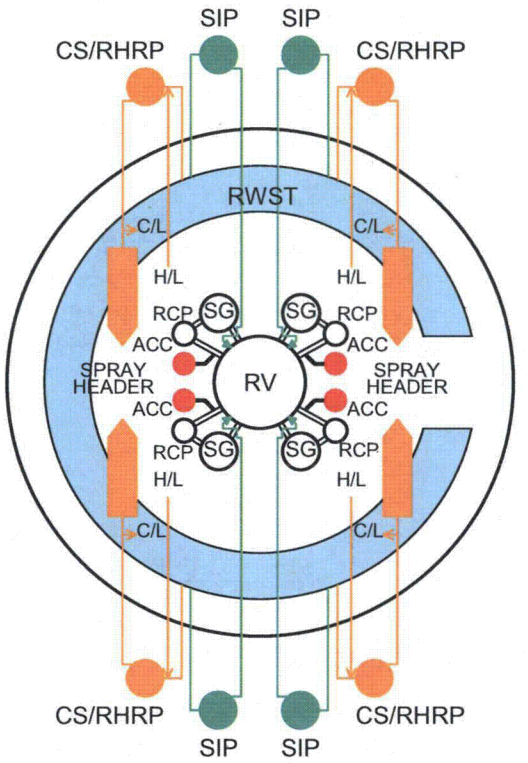
Objectives of Meeting

- Provide an overview of the Engineered Safety Features (ESF) of the US-APWR
- Obtain feedback from the NRC and improve the quality of Design Control Document of US-APWR

Presentation Summary

- ESF design is similar to current PWR plants already licensed by the NRC
- The main features:
  - 4 train safety systems
  - In-containment RWSP
  - Advanced Accumulators
- US-APWR ESF design meets US Regulations
- For each ESF system, this presentation discusses:
  - Codes, Standards and Regulations
  - Design Bases
  - System Design



Contents

1. Containment System

Contents

1.1 Containment Functional Design

- **Codes, Standards and Regulatory Guides**
  - ✓10 CFR 50.46
  - ✓10 CFR 50 Appendix J
  - ✓GDC 4, 16, 38, 39, 40, 41, 50, 52, 53, 54, 55, 56, and 57
  - ✓USNRC Regulatory Guides 1.7, 1.11, 1.26, 1.29

1.1 Containment Functional Design (Cont'd)

➢ Design Bases

- ✓The containment vessel is designed to minimize leakage and meets NRC requirements for radioactive releases
- ✓The design pressure and temperature of the containment vessel are defined by the following postulated accidents;
  - Loss-of-coolant accident (LOCA)
  - Main steam line break (MSLB)

1.1 Containment Functional Design (Cont'd)

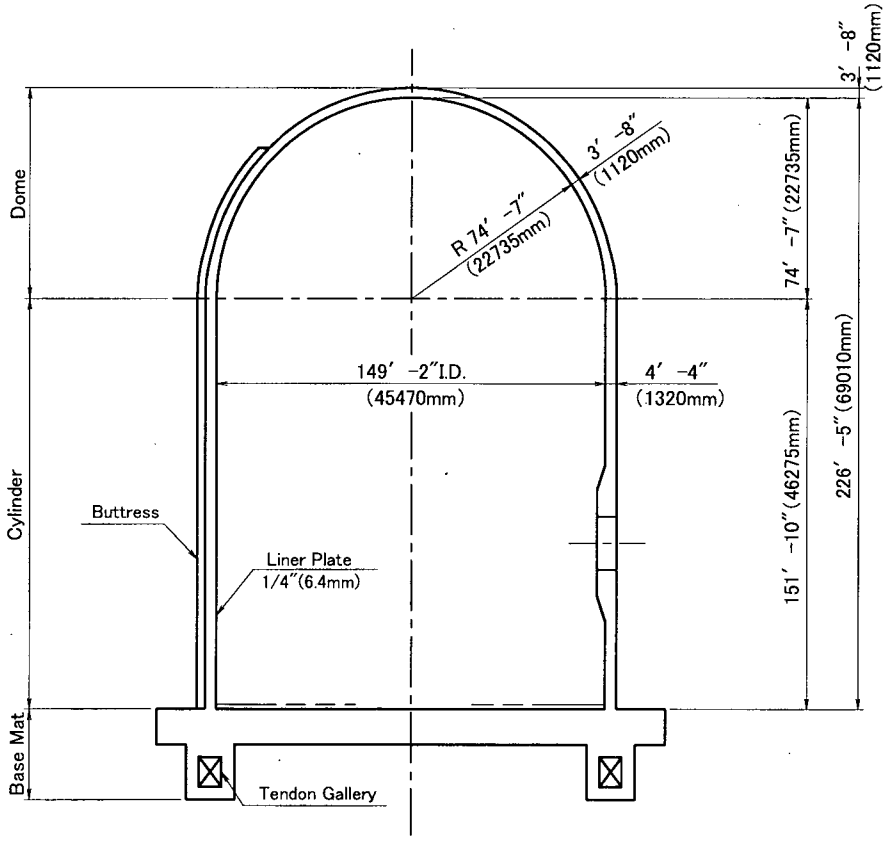
➢ Design Features

- ✓The containment vessel consists of a pre-stressed, post-tensioned concrete structure and a reinforced concrete foundation slab (Robust and Reliable)
- ✓The inside surface of the structure is lined with carbon steel
- ✓This type of containment vessel is adopted in many U.S. plants

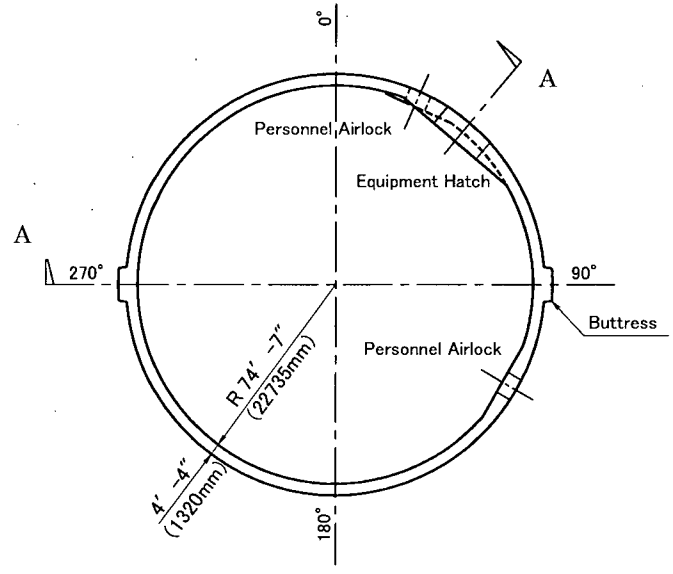
1.1 Containment Functional Design (Cont'd)

➢Configuration of Containment Vessel

Type	Pre-stressed Concrete Containment Vessel with Carbon Steel Liner
Design Pressure	83psia (68psig)
Number of buttresses	2



A – A Vertical Section



1.2 Containment Heat Removal System

➢Codes, Standards and Regulatory Guides

- ✓10 CFR 50.46
- ✓GDC 38, 39, 40, 41
- ✓USNRC Regulatory Guides 1.82 Rev.3

➢Design Bases

- ✓Containment Spray System (CSS) performs Containment cooling following LOCA
  - to reduce pressure and temperature below acceptable levels and to provide long term containment cooling
  - to reduce release of radioactive products to the environment by reducing the pressure difference between containment and environment
- ✓CSS is designed with sufficient redundancy to accomplish the specified safety functions assuming a single failure following an accident with one train out of service for maintenance

1.2 Containment Heat Removal System (Cont'd)

➢System Design

- ✓ 4 Independent trains
- ✓ 4 Containment Spray/Residual Heat Removal Pumps (CS/RHRP)

  4 Containment Spray/Residual Heat Exchangers (CS/RHRHx)

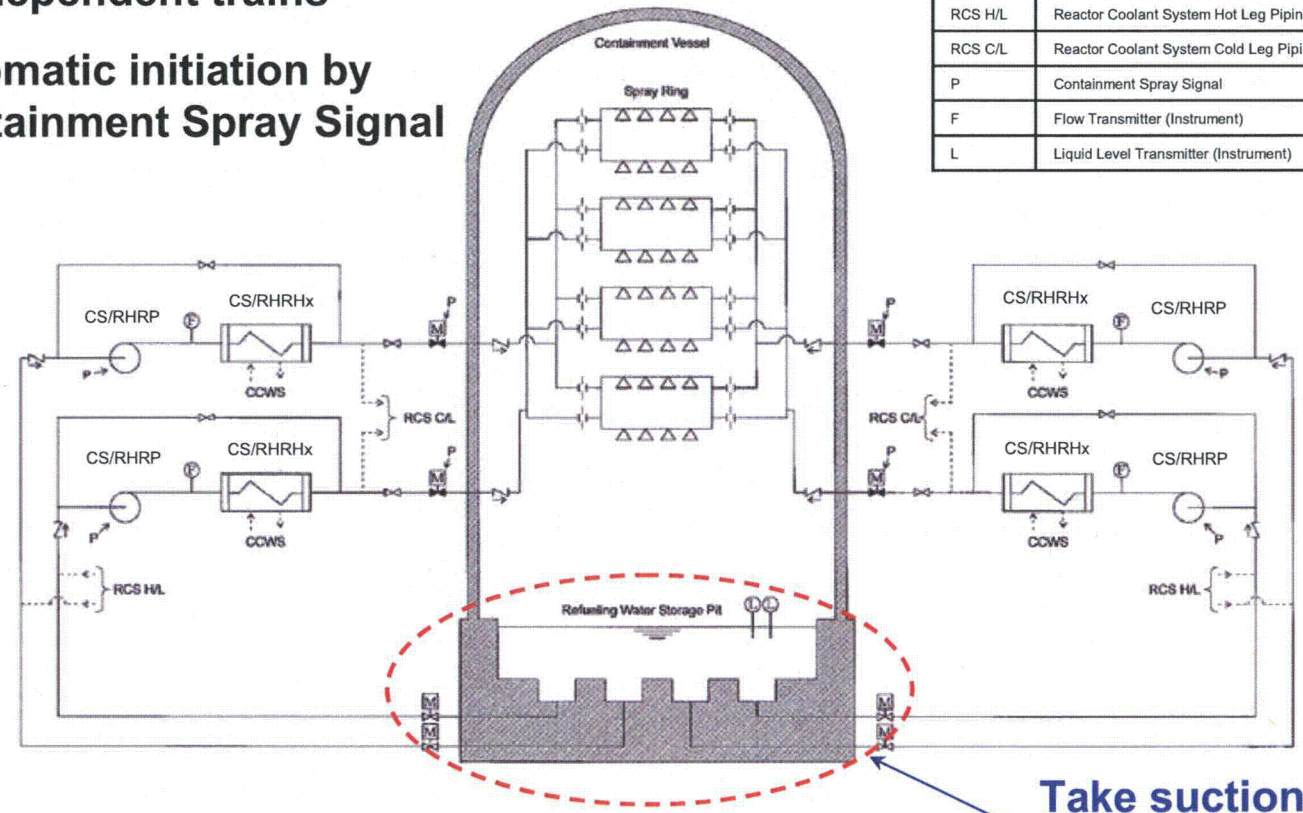
  (Each pump and heat exchanger has 50% capacity)
- ✓ Automatically initiates by a Containment Spray Signal (e.g. Containment Pressure High)
- ✓ Water Source : Refueling Water Storage Pit (Recirculation switchover is eliminated)
- ✓ All pumps, motor operated valves, and instruments have emergency backup power

1.2 Containment Heat Removal System (Cont'd)

➢Outline of CSS

- ✓ 4 Independent trains
- ✓ Automatic initiation by Containment Spray Signal

CCWS	Component Cooling Water System
RCS H/L	Reactor Coolant System Hot Leg Piping
RCS C/L	Reactor Coolant System Cold Leg Piping
P	Containment Spray Signal
F	Flow Transmitter (Instrument)
L	Liquid Level Transmitter (Instrument)



1.2 Containment Heat Removal System (Cont'd)

➢ Containment Spray Features

- ✓CS pumps/Heat Exchangers used for RHR functions during shutdown
- ✓Spray Ring Header

1.2 Containment Heat Removal System (Cont'd)

➢CS pumps/Heat Exchangers used for RHR functions during shutdown

- ✓In current PWR plants, RHRS functions as the low head safety injection system (Common use of RHR and LHSI)
- ✓In US-APWR, the function of the low head safety injection (LHSI) is integrated into the Advanced Accumulator and safety injection pumps (SIP)

Comparison of Systems

System	US-APWR	Current PWR
Containment Spray System	CS/RHRS	CSS
Residual Heat Removal System	CS/RHRS	RHRS/LHSI
Low Head Safety Injection System	Advanced Accumulator and SIP	RHRS/LHSI
Accumulator Injection System	Advanced Accumulator	Accumulator
High Head Safety Injection System	SIP	SIP

1.2 Containment Heat Removal System (Cont'd)

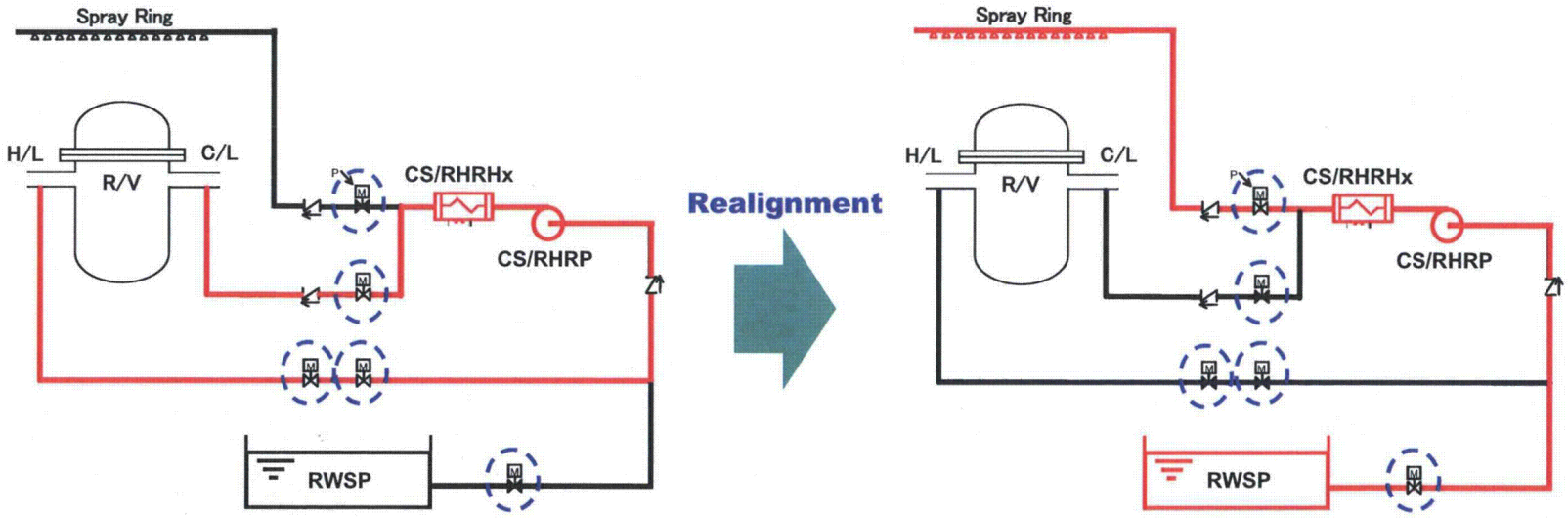
- **CS pumps / Heat Exchangers used for RHR functions during shutdown (Cont'd)**
  - ✓**During Power Operation**
    - •Available for CSS
  - ✓**During Shutdown Operation**
    - •Operating as RHRS
    - •Available for CSS (Manual)
  - ✓**During Accident Conditions**
    - •Operating as CSS
    - •Available for Long Term RWSP cooling

1.2 Containment Heat Removal System (Cont'd)

➢CS pumps / Heat Exchangers used for RHR functions during shutdown (Cont'd)

✓During Shutdown Operation

- Operating as RHRS
- Operators can realign from RHR mode to Containment Spray mode by changing motor operated valve positions when containment spray is required to initiate



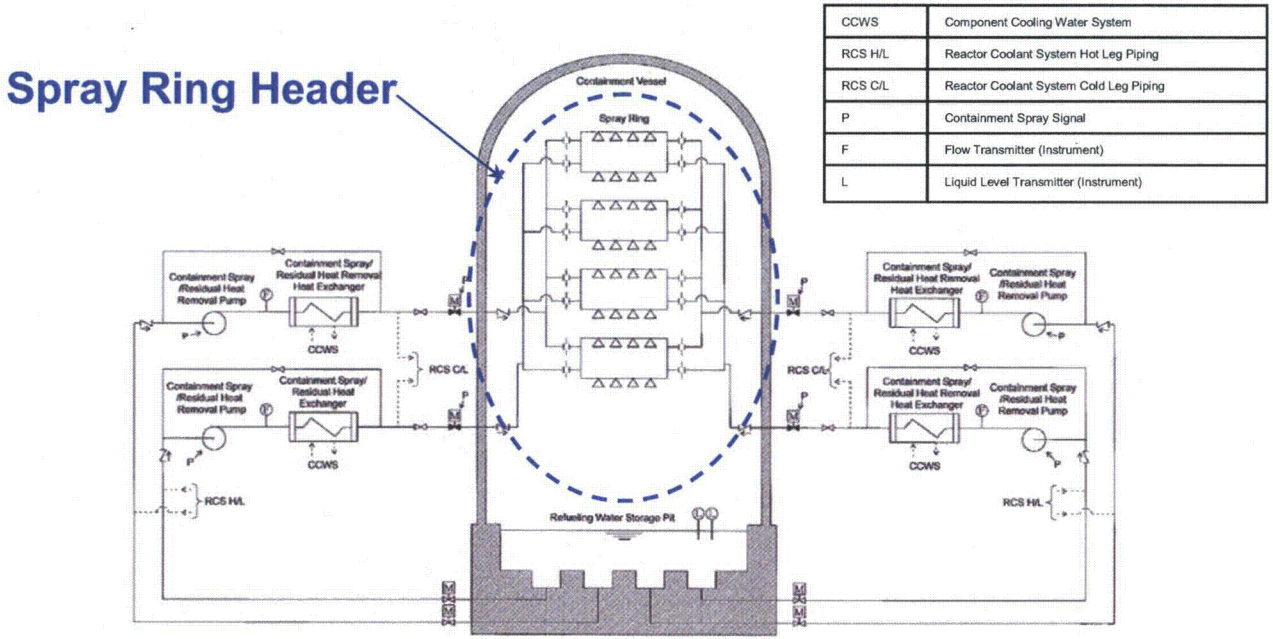
RHR Mode

CS Mode

1.2 Containment Heat Removal System (Cont'd)

➢Spray Ring Header

✓Spray Ring of US-APWR is composed of 4 concentric interconnected rings.



CCWS	Component Cooling Water System
RCS H/L	Reactor Coolant System Hot Leg Piping
RCS C/L	Reactor Coolant System Cold Leg Piping
P	Containment Spray Signal
F	Flow Transmitter (Instrument)
L	Liquid Level Transmitter (Instrument)

1.2 Containment Heat Removal System (Cont'd)

➢Spray Ring Header (Cont'd)

- ✓Spray Ring Header has the following features;
  - •Passive component with simple structure
  - •Fatigue is not expected since constant temperature and atmospheric condition during normal operation and any stresses due to temperature change does not occur
  - •Not affected by local pressure in the specific area or temperature increasing since the Spray Ring Header is installed in the vicinity of top of the containment
  - •Stress level of this piping during LOCA is low
- ✓Therefore the redundancy requirements of GDC 38 are met

1.2 Containment Heat Removal System (Cont'd)

➢Spray Ring Header (Cont'd)

U.S. Plants with Common Spray Ring Header

Plants	*Start of Commercial Operation*
South Texas Project No.1	*1988*
South Texas Project No.2	*1989*

1.3 Containment Isolation System

➢ Codes, Standards and Regulatory Guides

- ✓ 10 CFR 50.34(f)(2)
- ✓ GDC 54, 55, 56, 57
- ✓ US Regulatory Guide 1.11, 1.26, 1.29

➢ Design Bases

- ✓ The containment isolation system provides appropriate isolation of lines penetrating the containment to prevent the release of radioactive product to the environment following LOCA

➢ System Design

- ✓ The containment isolation system provides automatic isolation of lines penetrating the containment by containment isolation signal (e.g. Reactor Pressure low)

1.3 Containment Isolation System (Cont'd)

➢Containment Sump Isolation Valve Guard Pipe

- There is no guard pipe for the containment sump isolation valve and containment sump discharge line
- This design is based on SRP 6.2.4 as shown below:

> "If, in lieu of a housing, conservative design of the piping and valve is assumed to preclude a breach of piping integrity, the design should conform to the requirements of SRP Section 3.6.2."

- SRP 3.6.2 stated below:

> "Leakage cracks need not be postulated in those portions of piping from containment wall to and including the inboard or outboard isolation valves provided they meet the requirements of the ASME Code, Section III, NE-1120, and the stresses calculated by the sum of Eqs. (9) and (10) in ASME Code, Section III, NC-3653 do not exceed 0.4 times the sum of the stress limits given in NC-3653."

- Since the design of this line can meet this requirement, no guard pipe design is adopted

1.3 Containment Isolation System (Cont'd)

➢Containment Sump Isolation Valve Guard Pipe

U.S. Plants with No Guard Pipe

Plants	*Start of Commercial Operation*
McGuire No.1	*1981*
McGuire No.2	*1984*
Catawba No.1	*1985*
Catawba No.2	*1986*
South Texas Project No.1	*1988*
South Texas Project No.2	*1989*

1.4 Combustible Gas Control in Containment

- **Code, Regulations and Guides**
  - ✓10 CFR 50.34(f)
  - ✓10 CFR 50.44
  - ✓GDC 41, 42, and 43
  - ✓USNRC Regulatory Guide 1.7

1.4 Combustible Gas Control in Containment (Cont'd)

➢ Design Bases

- ✓ Mixed atmosphere during design-basis and significant beyond design-basis accidents
- ✓ Hydrogen monitors

➢ System Design

- ✓ Containment hydrogen concentration is not too high because of adopting large and dry type containment
- ✓ Mixed atmosphere by natural circulation
- ✓ Hydrogen monitor system
- ✓ Hydrogen igniters are installed for severe accident

2. Emergency Core Cooling System

➢ Codes, Standards and Regulatory Guides

- ✓ 10 CFR 50.46
- ✓ 10 CFR 50.34(f)
- ✓ GDC2, 4, 5, 17, 27, 35, 36, 37
- ✓ Unresolved Safety Issues (USI)
- ✓ Generic Safety Issues (GSI)
- ✓ IEEE Standard 279-1971, 603-1998
- ✓ USNRC Regulatory Guide 1.82 Rev.3

2. Emergency Core Cooling System (Cont'd)

➢ Design Bases

- ✓ Emergency Core Cooling System (ECCS) performs core cooling during LOCA
- ✓ ECCS performs emergency boration to mitigate accidents such as main steam line break, main feed water line break, and so on
- ✓ ECCS performs emergency boration/letdown and emergency makeup to assure Safe Shutdown
- ✓ ECCS is designed with sufficient redundancy to accomplish the specified safety functions assuming a single failure following an accident with one train out of service for maintenance

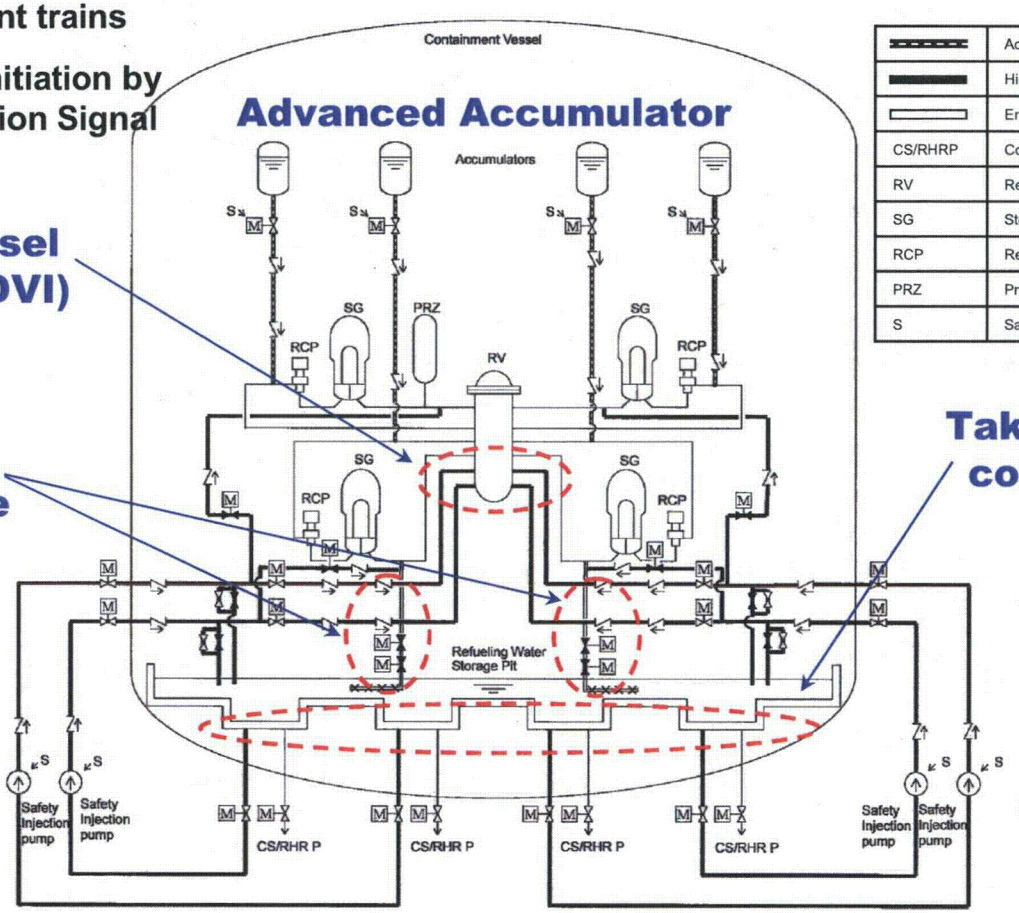
2. Emergency Core Cooling System (Cont'd)

➢System Design

- ✓ 4 Independent trains and 4 Advanced Accumulators
- ✓ Injection Point
  SIP : Direct Vessel Injection (DVI) and Hot Leg
  ACC : Cold Leg (C/L)
- ✓ Water Source: Refueling Water Storage Pit (RWSP)
- ✓ Capacity
  SIP : 50%/pump for Large LOCA
  ACC : 33%/tank for Large LOCA
- ✓ Automatically initiated by a Safety Injection Signal (e.g. Reactor Pressure Low)
- ✓ All pumps, motor operated valves, and instruments have emergency backup power
- ✓ Emergency boration/letdown and emergency makeup during Safe Shutdown is accomplished by SIP and Emergency Letdown Line

2. Emergency Core Cooling System (Cont'd)

- ✓ 4 Independent trains
- ✓ Automatic initiation by Safety Injection Signal



	Accumulator System
	High Head Injection System
	Emergency Letdown System
CS/RHRP	Containment Spray/ Residual Heat Removal Pump
RV	Reactor Vessel
SG	Steam Generator
RCP	Reactor Coolant Pump
PRZ	Pressurizer
S	Safety Injection Signal

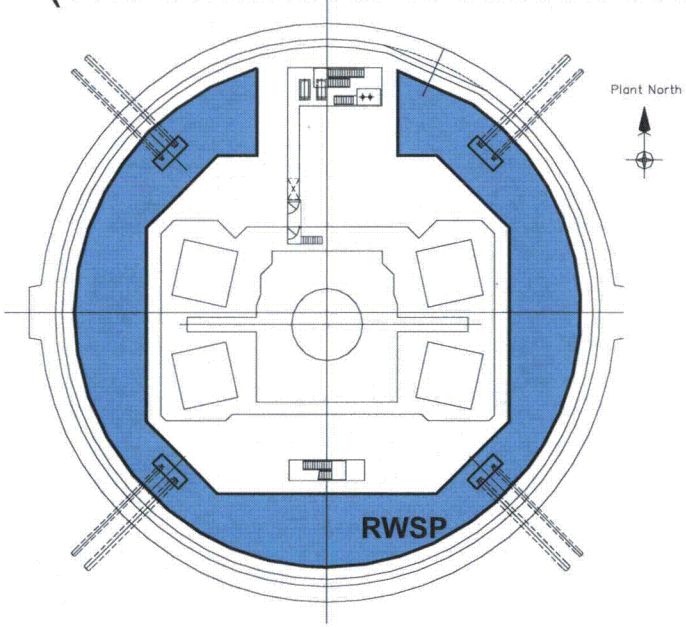
Outline of Emergency Core Cooling System

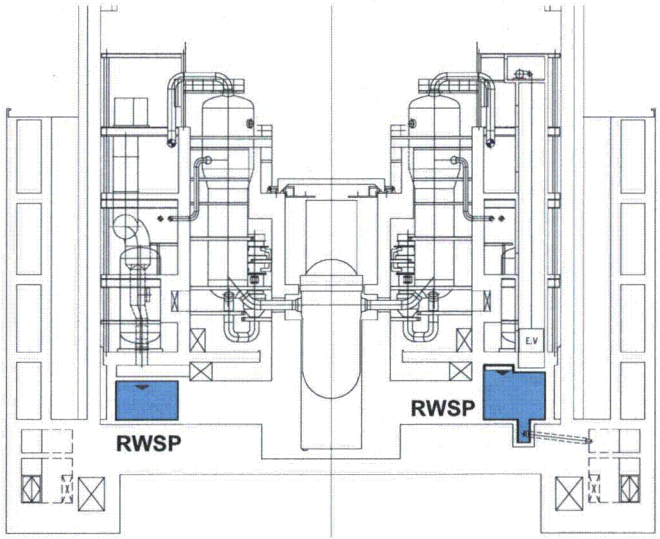
2. Emergency Core Cooling System (Cont'd)

➢System Design (Cont'd)

✓In-containment Refueling Water Storage Pit

- RWSP is located at the lowest part of containment
- RWSP provides a continuous suction source for both the Safety Injection and the CS/RHR pumps
  (The switchover of suction source is eliminated)



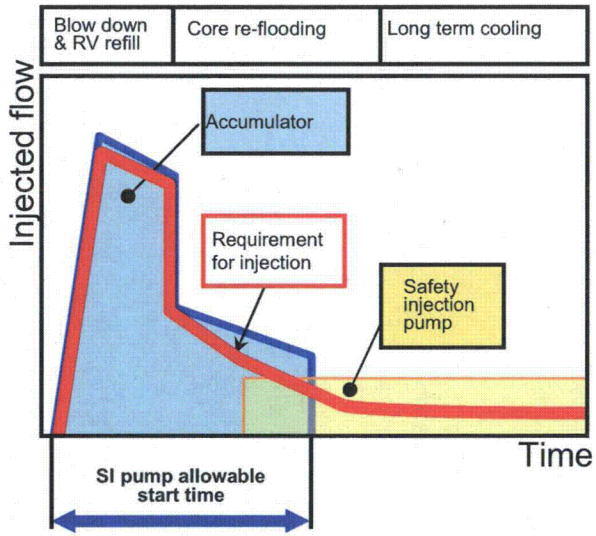


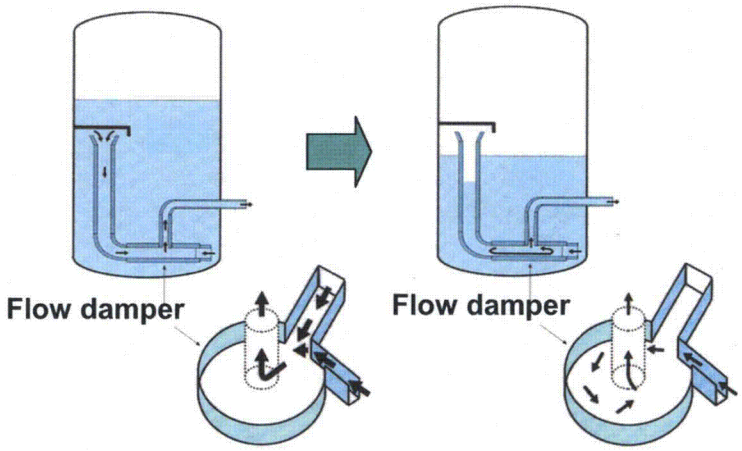
2. Emergency Core Cooling System (Cont'd)

➢System Design (Cont'd)

✓Advanced Accumulator

- Automatic switching of injection flow rate by flow damper
- Integrates function of low head injection system
- Long accumulator injection time allows longer time for safety injection pump to start





Topical Report of Advanced Accumulator was submitted to the NRC

2. Emergency Core Cooling System (Cont'd)

➢System Design (Cont'd)

✓Conservative Countermeasures provided for GSI-191

- Sufficient water head for Net Positive Suction Head (NPSH)
- Sufficient surface area for strainer
- Appropriate selection of insulation material
- Appropriate selection of pH control buffer

3. Habitability System

➢ Codes, Standards and Regulatory Guides

- ✓ 10 CFR 50.34 (f) (2) (xxviii)
- ✓ GDC 4, 5 and 19
- ✓ USNRC Regulatory Guides 1.52,1.78 and 1.196

➢ Design Bases

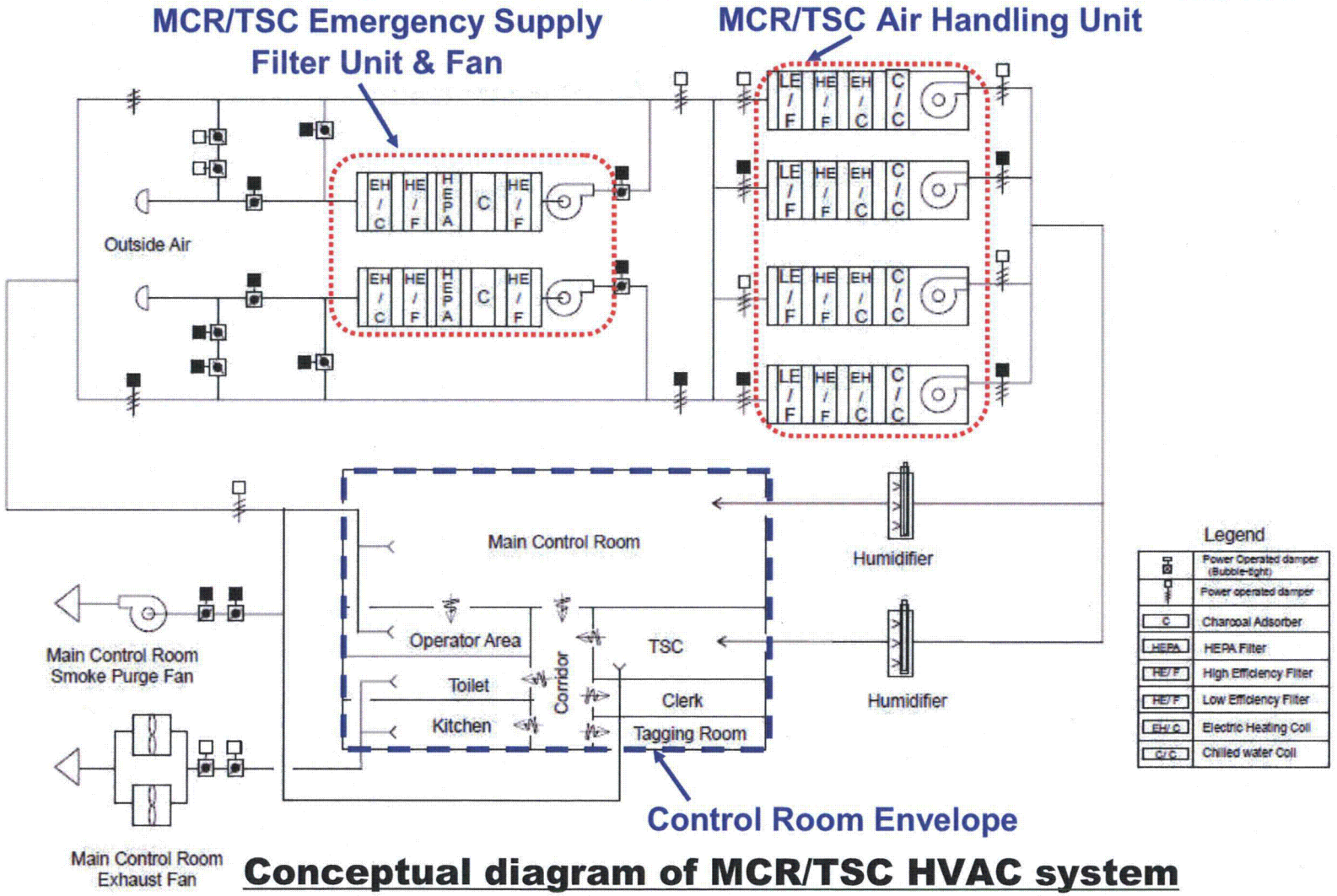
- ✓ Control room envelope includes areas requiring access during an accident
- ✓ Maintain suitable conditions in the main control room for operators
- ✓ Protect operators from airborne radioactivity, smoke and toxic gas

3. Habitability System (cont'd)

➢System Design

- ✓Control Room Envelope
  - Main Control Room, Technical Support Center, kitchen, toilet etc.
- ✓MCR/TSC HVAC System
  - 4 x 50% MCR/TSC Air Handling Units (AHU)
  - 2 x 100% MCR/TSC Emergency Supply Filter Units & Fans
  - Airtight Isolation Dampers
- ✓Maintain positive pressure with MCR/TSC HVAC during an accident
- ✓Automatic transfer to emergency mode by safety injection signal or high radiation signal
- ✓Manual transfer to recirculation mode when smoke is detected in air intake line
- ✓Operator dose is within the acceptance limit
  - Dose evaluation will be confirmed in the DCD

3. Habitability System (cont'd)



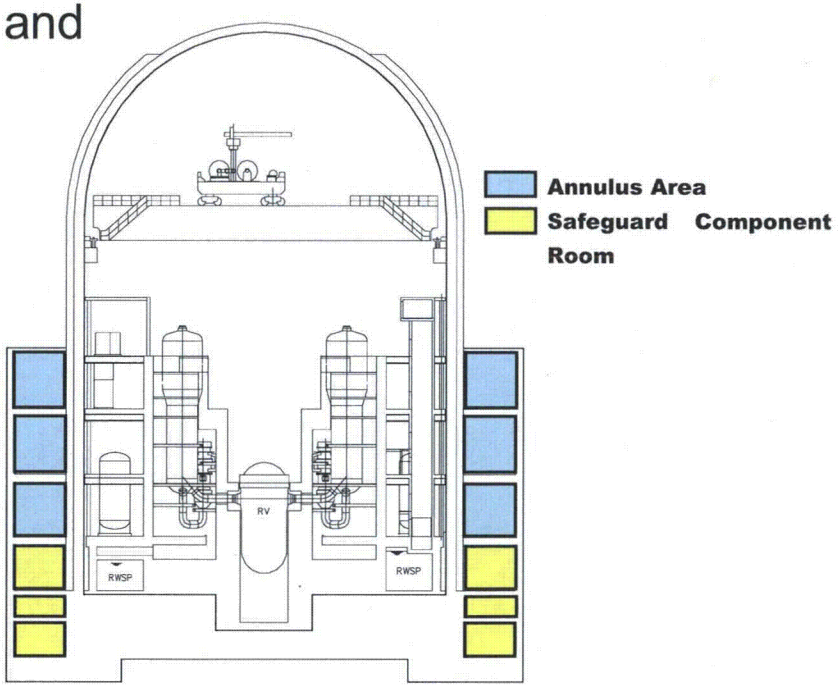
Conceptual diagram of MCR/TSC HVAC system

Contents

4.1 pH Control

4.2 Annulus* Air Cleanup System

*Annulus is defined as Annulus Area and Safeguard Component Room



4.1 pH Control

- Sump water pH adjustment following LOCA is provided by adding appropriate buffer agent

- pH control buffer will be selected to reduce / minimize sump debris in accordance with conservative countermeasures developed for GSI-191

4.2 Annulus Air Cleanup System

- **Codes, Standards and Regulatory Guides**
  - ✓10 CFR 100
  - ✓GDC 41, 42, 43 and 64
  - ✓USNRC Regulatory Guide 1.52, 1.140
- **Design Bases**

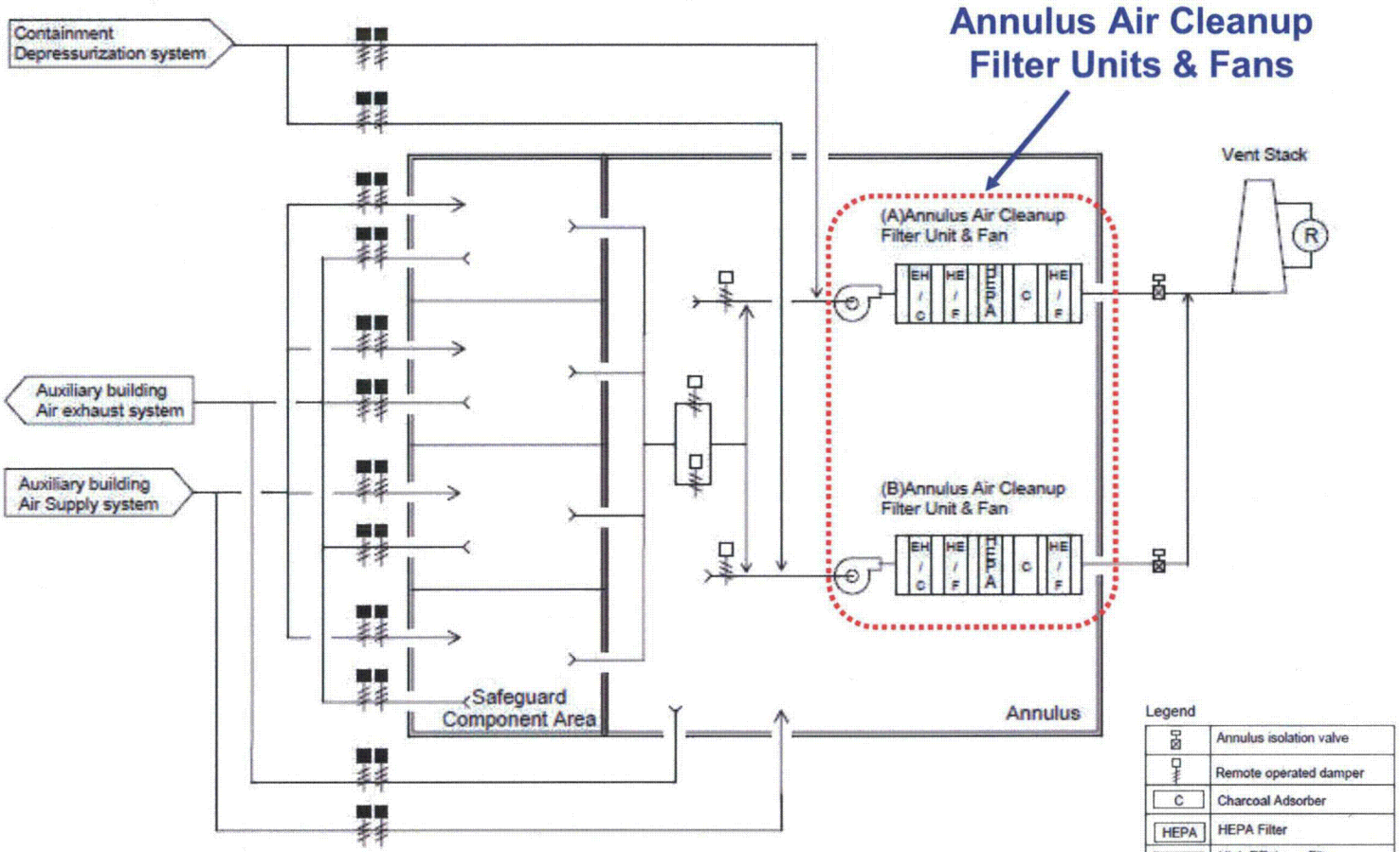
  Annulus Air Cleanup System performs;
  - ✓Prevent uncontrolled radioactive release from containment penetration and safeguard components to environment

4.2 Annulus Air Cleanup System (Cont'd)

➢ System Design

- ✓ 2 x 100% Annulus Air Cleanup Filter Units & Fans
- ✓ Annulus Area and Safeguard Component Area are maintained at a negative pressure with respect to adjacent area during accident conditions
- ✓ Automatically initiate by Safety Injection Signal
- ✓ A radioiodine decontamination factor of charcoal adsorbers is not credited for the calculated dose of accident conditions
  - Dose evaluation will be confirmed in the DCD
- ✓ Used for containment depressurization during normal operation (charcoal adsorbers are needed for normal operation)

4.2 Annulus Air Cleanup System (Cont'd)



Conceptual diagram of Annulus Cleanup System

5. Emergency Feedwater System

➢ Codes, Standards and Regulatory Guides

- ✓ 10 CFR 50.34(f)
- ✓ 10 CFR 50.62(c)
- ✓ 10 CFR 50.63
- ✓ Branch Technical position 7-4
- ✓ Branch Technical position RSB 5-1
- ✓ Branch Technical position ASB 10-1
- ✓ SRP 10.4.9
- ✓ GDC2, 4, 5, 19, 34, 44, 45, 46
- ✓ NUREG-0611

5. Emergency Feedwater System (Cont'd)

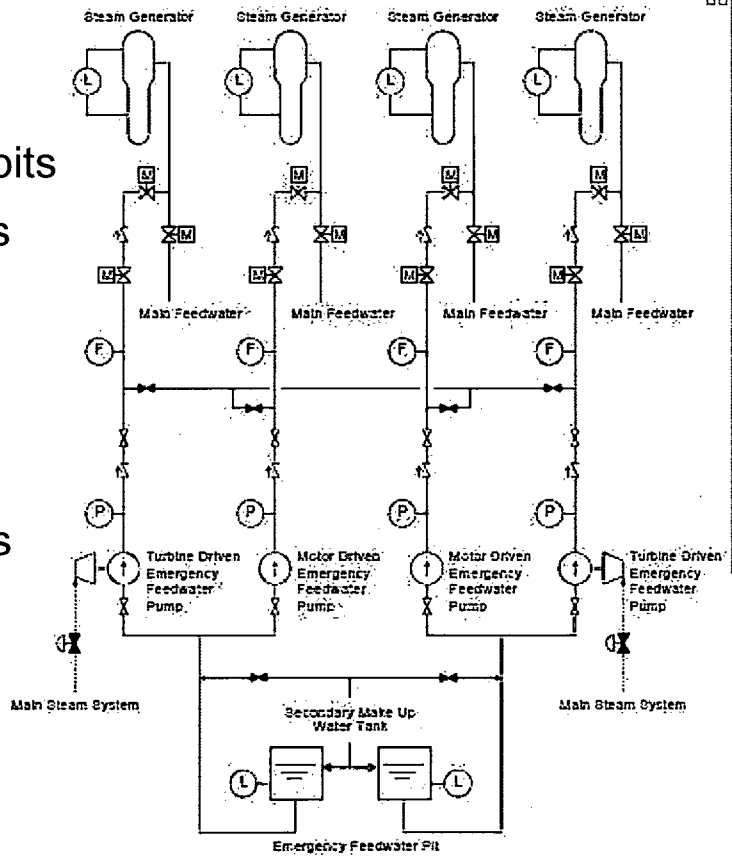
➢ Design Bases

- ✓ Emergency Feedwater System (EFWS) maintains the capability of the steam generators to remove reactor heat and other RCS residual heat by converting the feedwater to steam, which is then discharged to the condenser or to the atmosphere
- ✓ EFWS satisfies the requirement that the pumps be powered by diverse power sources
- ✓ EFWS is automatically initiated in appropriate transients and accidents
- ✓ EFWS is designed with sufficient redundancy to accomplish the specified safety functions assuming a single failure following an accident with one train out of service for maintenance

5. Emergency Feedwater System (Cont'd)

➢ System Design

- ✓ 4 Independent trains
- ✓ 2 safety grade independent water sources
  - Two 50% capacity emergency feedwater pits
  - Cross connection inlet of the pumps backs up each feedwater source
- ✓ Diverse power sources for the pumps
  - 2 motor-driven pumps (50 % / pump)
  - 2 turbine-driven pumps (50 % / pump)
- ✓ Cross connection inlet and outlet of the pumps (normally isolated)
- ✓ When a MSLB, FLB or SGTR event occurs EFW is automatically isolated from the failed steam generator (SG).
- ✓ Requirement : 2 SGs - 2 pumps for accidents
- ✓ Success Criterion : 2 SGs - 1 pump for PRA, SBO



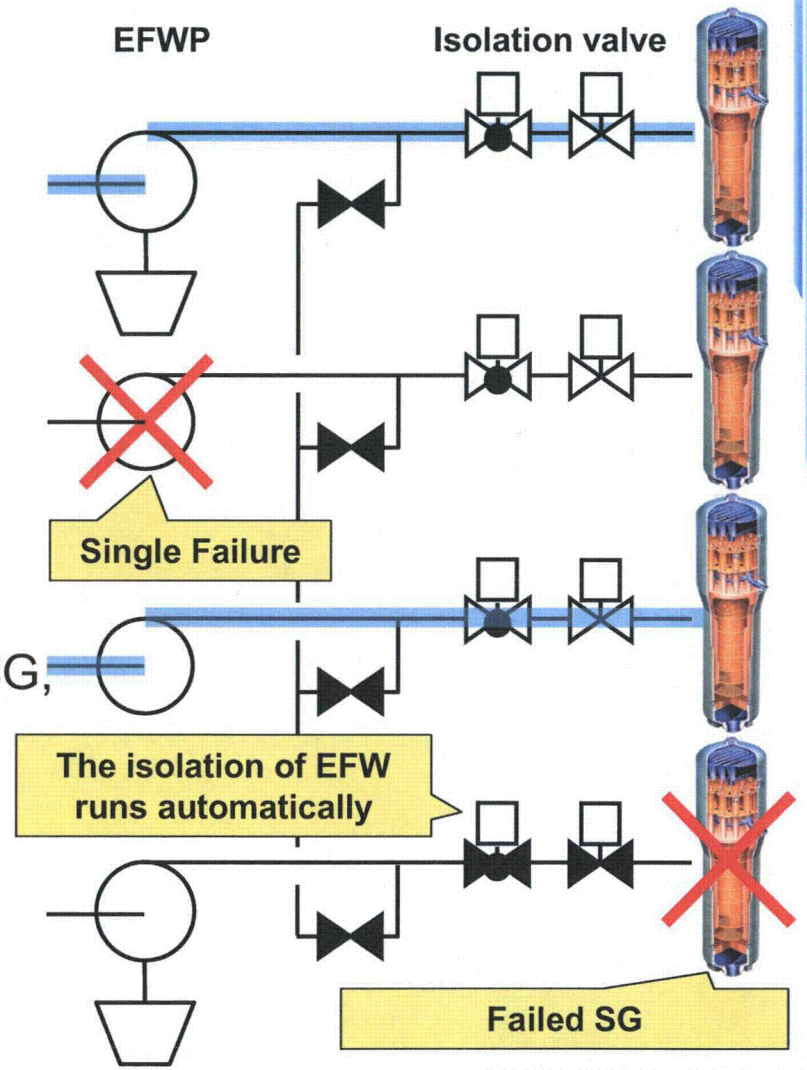
5. Emergency Feedwater System (Cont'd)

➢ EFWS performance Without On-Line Maintenance

Cross connection outlet of the pumps are CLOSED

- Assuming;
  - Any Single Active Component Failure
  - One Failed SG

2 EFWPs can feed to each intact SG, so that sufficient feedwater flow is accomplished



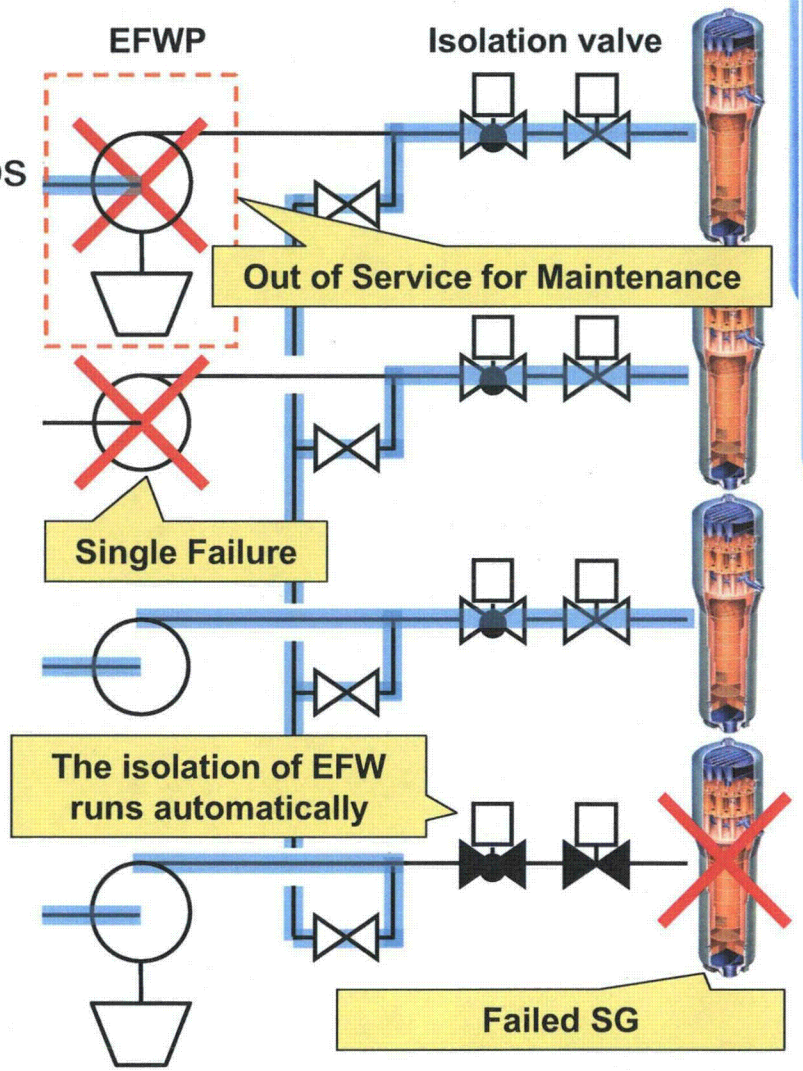
5. Emergency Feedwater System (Cont'd)

➢EFWS performance With On-Line Maintenance

Cross connection outlet of the pumps are OPEN

•Assuming;
- Any Single Active Component Failure
- Maintenance Outage of one EFWP
- One Failed SG

2 EFWPs can feed to 3 intact SGs, so that sufficient feedwater flow is accomplished



5. Emergency Feedwater System (Cont'd)

➢EFWS performance during transients and accidents

✓ Automatic isolation of EFW for reducing operator loads

- After detecting a failed SG (MSLB, FLB), the SG will be isolated automatically by EFW isolation signals from the broken SG (e.g. Isolated with low steam pressure signal)

- After detecting a failed SG (SGTR), the SG will be isolated automatically by EFW isolation signals from the broken SG (e.g. Isolated with high SG water level signal) in order to prevent SG over filling

6. Conclusions

- Overview of Engineered Safety Features planned for the US-APWR has been provided to the NRC
- Comments and suggestions received from NRC will be considered to improve the quality of DCD
- Details of Engineered Safety Features will be provided in DCD
  - ✓ Topical Report is not planned except for the Advanced Accumulator