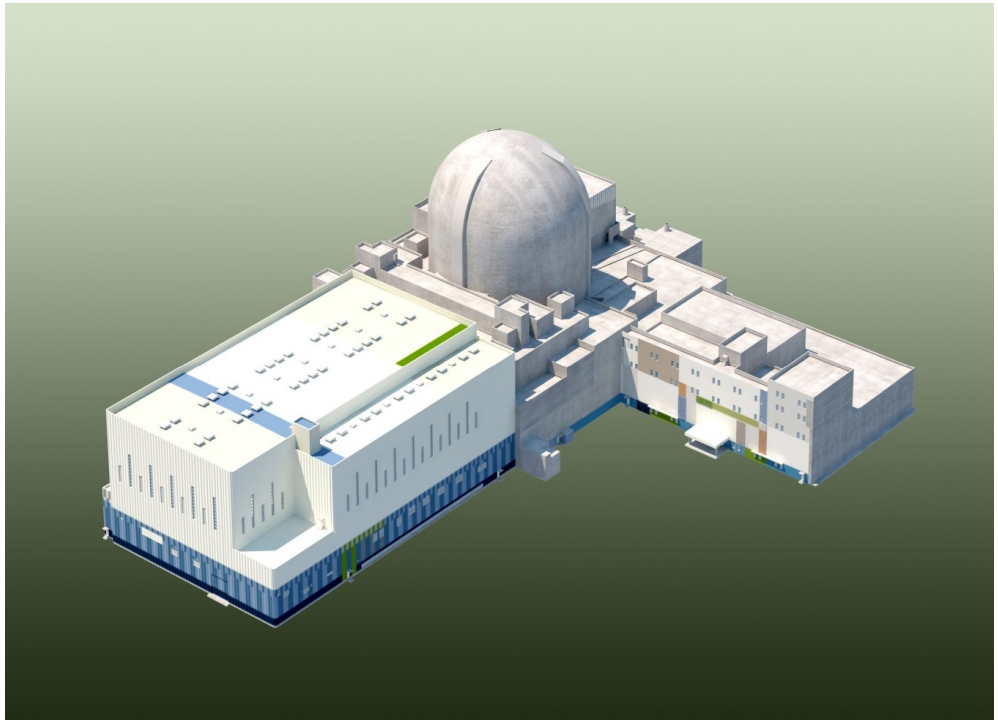
APR1400 System Design (Containment System)



KEPCO/KHNP

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1. Introduction

This presentation is to present an overview of the design features for the APR1400 standard design regarding the containment systems.

1. Introduction

❑ Regulatory Bases

- ➢ Containment P/T Analyses
  - 10CFR50 Appendix A, GDC 16, 38, 50
  - NUREG-0800 (SRP 6.2.1) Containment Function Design
  - ANSI/ANS 56.4 Recommendations for P/T Analysis Methodology
- ➢ Containment Spray System
  - 10CFR50 Appendix A, GDC 2, 4, 5, 17, 38, 39, 40
- ➢ Containment Isolation System
  - 10CFR50 Appendix A, GDC 52, 54, 55, 56, 57
  - RG 1.11(Rev.1), RG 1.141(Rev.1), RG 1.155
- ➢ Containment Hydrogen Control System
  - 10CFR50 Appendix A, GDC 41, 42, 43, 10CFR50.34(f)(2)(ix), 10CFR50.44
  - RG 1.7 (Rev.3)
- ➢ Design Features to Address GSI-191
  - RG 1.82 (Rev.4), GL 2004-02, NEI 04-07, Safety Evaluation for NEI 04-07

2. APR1400 Design Features

2.1 Containment P/T Analyses

2.2 Containment Spray System

2.3 Containment Isolation System

2.4 Containment Hydrogen Control System

2.5 Design Features to Address GSI-191

2.1 Containment P/T Analyses

❑ Analysis Model

- GOTHIC Containment/RCS Model
- Conservative Break flow model & Wall Heat transfer model
- Case Analyses
  - LOCA : 5 cases (Hot leg / cold leg break, Slot break)
  - Secondary system pipe breaks : 10 cases (CSS or MSIV single failure)

❑ Analysis Results

- The containment is designed to have a minimum 10% of pressure margin.
  - Calculated peak pressure of 51.1 psig, and the containment design pressure of 60 psig
- Containment pressure is well reduced and maintained at less than 50% of the peak pressure within 24 hours after the postulated accident.
  - Containment pressure at 24 hours : 42.4% of the peak pressure
  - Containment spray system has sufficient heat removal capability to reduce the containment pressure during the accident.

2.2 Containment Spray System

❑ Function

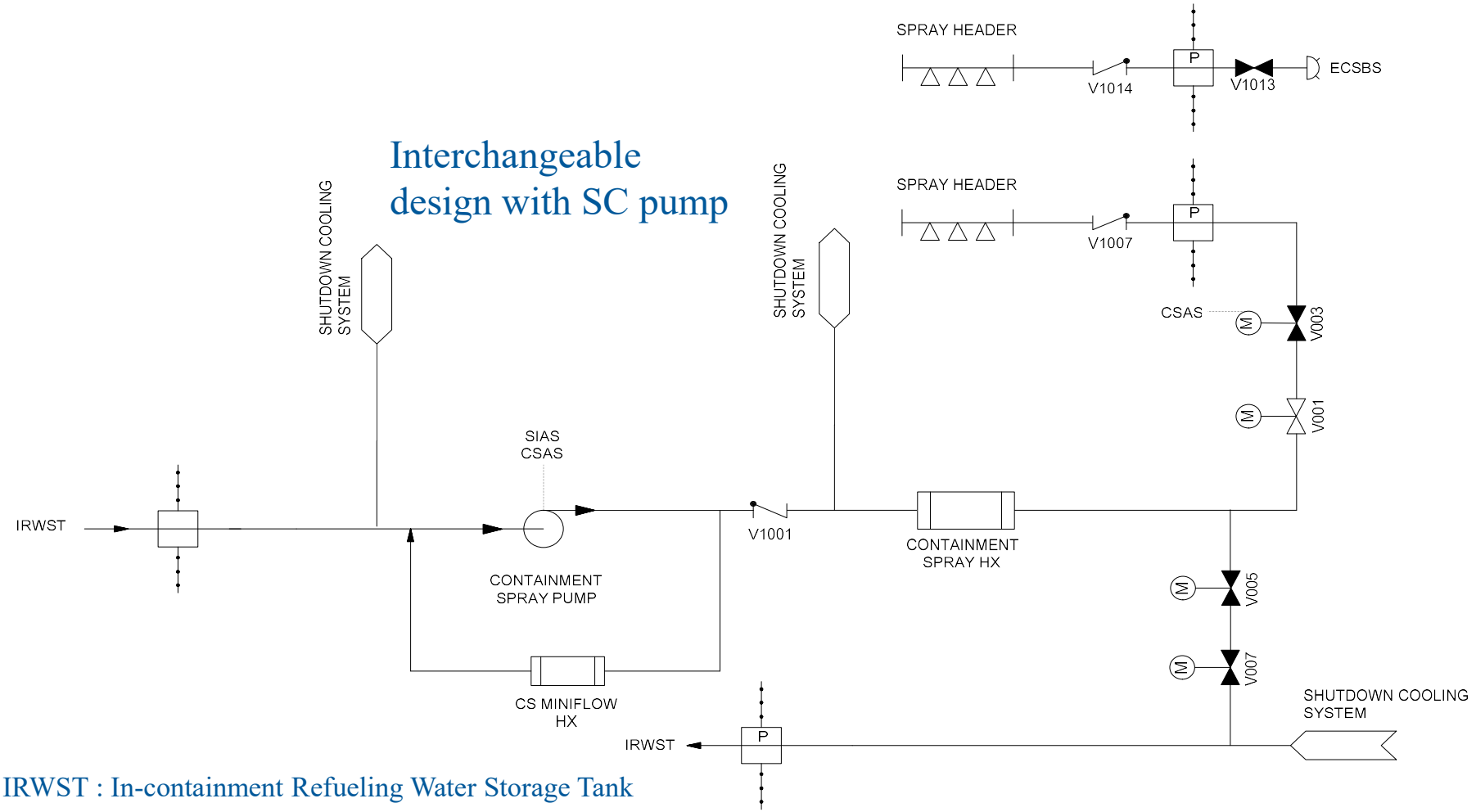
- ➢ Containment pressure and temperature reduction following MSLB or LOCA
- ➢ Fission products removal from containment atmosphere following LOCA

❑ Configuration

- ➢ Two 100 % capacity divisions
- ➢ In each division, a containment spray(CS) pump, a CS heat exchanger, a CS pump mini-flow heat exchanger, CS header, CS nozzles, valves and associated I&C
- ➢ An emergency containment spray backup system (ECSBS) for severe accident management

2.2 Containment Spray System

❑ Schematic Diagram for CS System (Division I)



IRWST : In-containment Refueling Water Storage Tank

Note : Division I is shown for the representative configuration.

2.3 Containment Isolation System

❑ Function

- Means of isolating fluid systems that pass through containment penetrations to confine release of any radioactivity from containment following postulated DBA

❑ Configuration

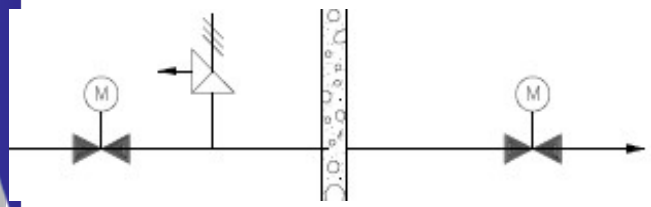
- Isolation design is achieved by applying acceptable common criteria (GDC 55, 56, 57) to penetrations in many different fluid systems and by using containment pressure to provide a CIAS.
- APR1400 DCD Tier 2 Figure 6.2.4-1

2.3 Containment Isolation System

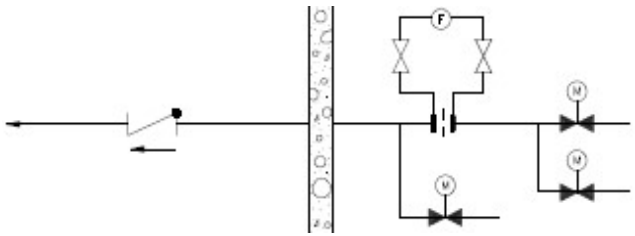
❑ Configuration examples according to GDC requirements

GDC 55

Inside CTMT Outside CTMT



SCS

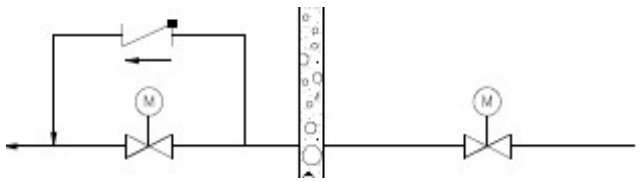


SIS

GDC 56

Inside CTMT Outside CTMT

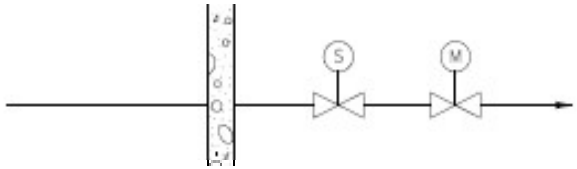
CSS



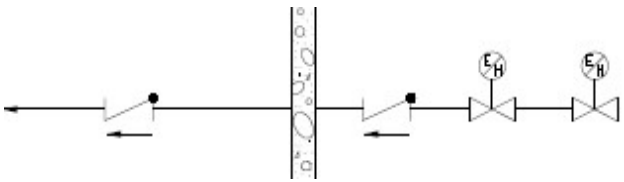
CCWS
(Letdown Hx)

GDC 57

Inside CTMT Outside CTMT



SGBDS



FWS

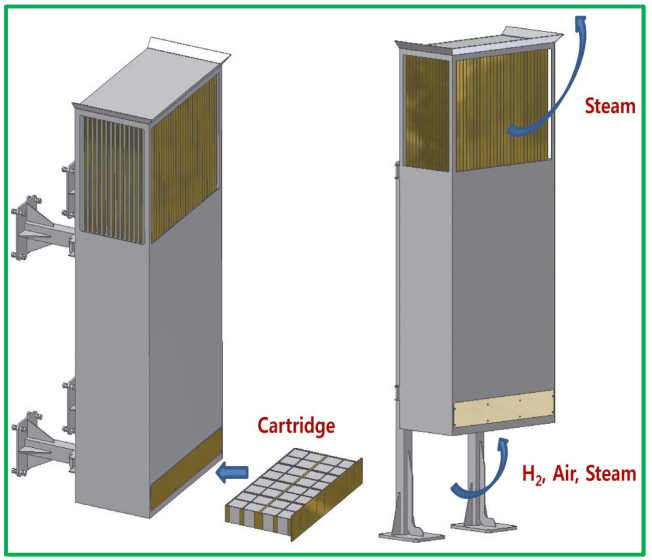
2.4 Containment Hydrogen Control System

❑ Function

- Control hydrogen concentration in containment and IRWST below 10% by volume during severe accident

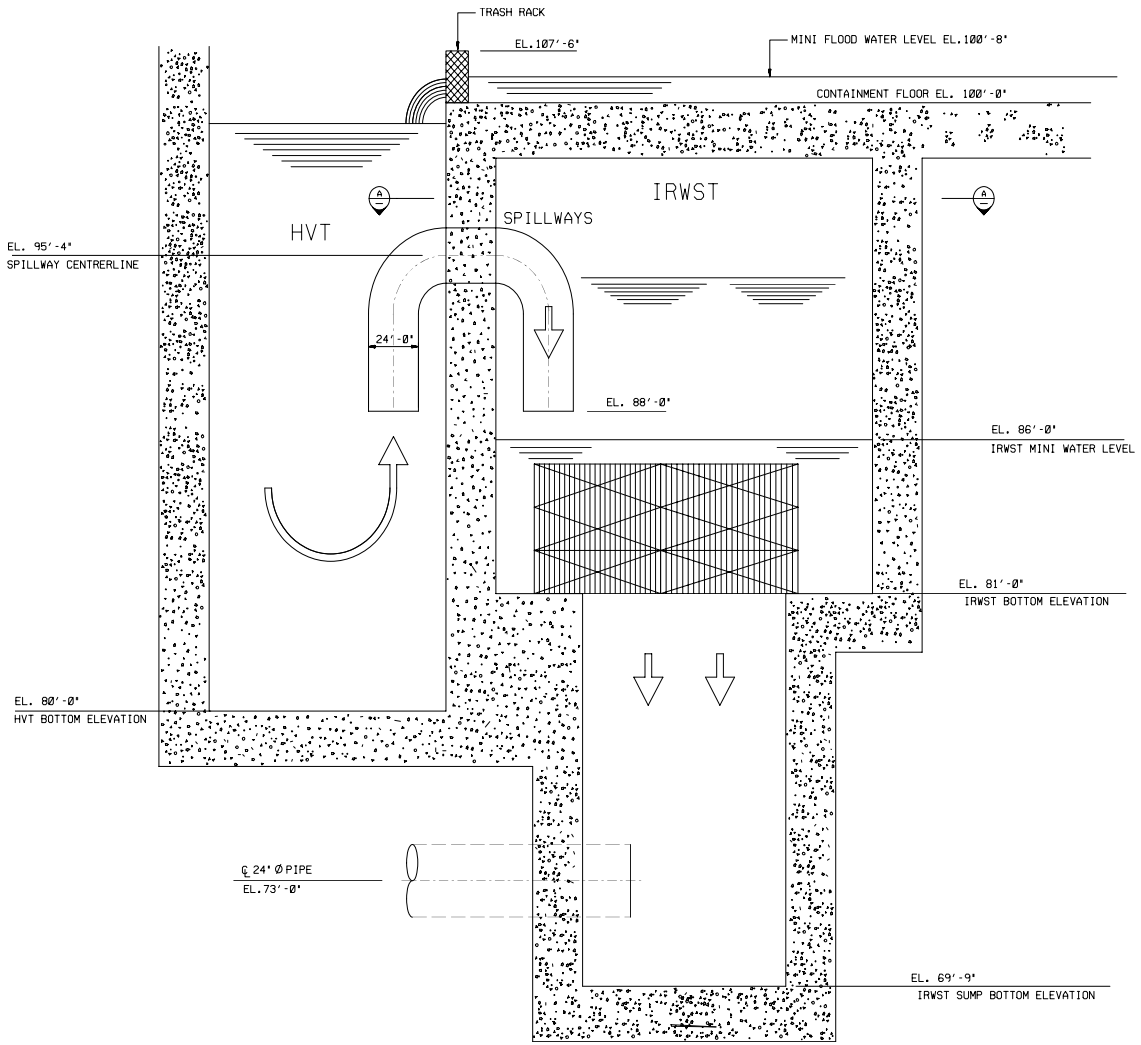
❑ Configuration

- 30 Passive Autocatalytic Recombiners (PARs) in containment and inside the IRWST vent stack
  - Self-actuated, No power supply and operator action is needed.
- 8 Hydrogen Igniters (HIs)
  - ac-powered glow plug
  - Manual actuation in the MCR/RSR
  - Non-class 1E, but supplied from Class 1E bus with electrical isolation device to enhance the reliability of HIs
  - SBO : AAC generator supplies power.
  - Non-class 1E dedicated DC battery for complete loss of ac power



2.5 Design Features to Address GSI-191

❑ Flow Path to IRWST Sump Strainer during LOCA for APR1400



2.5 Design Features to Address GSI-191

❑ GSI-191 Evaluation

- ➢ Debris Generation
- ➢ Chemical Effect
- ➢ Debris Head Loss
- ➢ ECCS Pump NPSHa
- ➢ Ex-vessel Downstream Effect
- ➢ In-vessel Downstream Effect

❑ Evaluation Report

- ➢ APR1400-E-N-NR-14001-P/NP, “Design Features to Address GSI-191”

2.5 Design Features to Address GSI-191

❑ GSI-191 Evaluation : Debris Generation

- ➢ According to the guidance of NEI 04-07, RCS hot-leg line (diameter of 42 in) break is selected, and this break location bounds variations in debris generation by size, quantity, and type of debris from other break locations.
  - Generated debris : RMI, coatings (epoxy, IOZ), latent debris (fiber, particle), concrete, aluminum
- ➢ For conservatism, APR1400 is assuming that all generated coatings and all latent debris are transported to the sump in the IRWST.

❑ GSI-191 Evaluation : Chemical Effect

- ➢ WCAP-16530-NP-A , Rev.0 methodology referenced in RG 1.82
- ➢ APR1400 is considering plant specific LOCA conditions, and determines conservative quantities of chemical precipitates during 30 days mission time with the WCAP-16530-NP-A , Rev.0 methodology.
  - AlOOH (398.2 lbm), $NaAlSi_3O_8$ (9.5 lbm), $Ca_3(PO_4)_2$ (1.5 lbm)

2.5 Design Features to Address GSI-191

- **GSI-191 Evaluation : <u>Debris Head Loss</u>**
  - APR1400 design conservatively assumes that all of break-generated coatings, latent debris, and chemical precipitates are transported directly to a single sump. (Flow conditions : 1 SIP + 1 CSP)
  - Allowable head loss : 2 ft-water (for NPSH evaluation)
  - Debris head loss test was performed with assumptions (i.e. effective strainer area, test fluid temperature), and the test result (0.81 ft-water) shows that the allowable head loss (2 ft-water) which is used for NPSH evaluation has sufficient margin.

2.5 Design Features to Address GSI-191

❑ GSI-191 Evaluation : ECCS Pump NPSHa

- NPSHa = $h_{atm} + h_{static} - h_{loss} - h_{vapor}$
- Containment Accident Pressure (CAP) in APR1400 standard design
  - $T_{IRWST} > 212^{o}F$, $h_{atm} = h_{vapor}$
  - $T_{IRWST} < 212^{o}F$, h_{atm} = initial containment pressure before LOCA
  - In the evaluation of the NPSHa for ECCS pumps, APR1400 standard design credits the CAP for the IRWST temperature greater than $212^{o}F$ with the assumption of that the CAP is equal to the IRWST liquid vapor pressure.

2.5 Design Features to Address GSI-191

❑ GSI-191 Evaluation : ECCS Pump NPSHa

- $NPSH_{reff} = (1+ \text{uncertainty}) NPSH_{r3\%}$
  - Uncertainty factors are considered based on guidance in SECY-11-0014.
  - 21% margin is applied for effects of uncertainty factors.
  - $NPSH_{reff}$ for CSP and SIP will be verified through ASME QME-1.
  - $NPSH_{reff}$ calculation results

Pump	Flowrate (gpm)	$NPSH_{r3\%}$ (ft-water)	$NPSH_{reff}$ (ft-water)
SI Pump	1,235	18.23	22
CS Pump	5,425	14.4	17.5

- NPSH evaluation results (Minimum margin at high temperature)

Pump	$NPSH_a$ (ft-water)	$NPSH_{reff}$ (ft-water)	Margin (ft-water)
SI Pump	23.73	22.0	1.73
CS Pump	20.50	17.5	3.00

2.5 Design Features to Address GSI-191

❑ GSI-191 Evaluation : ECCS Pump NPSHa

- Containment Accident Pressure (RAI 25-7844 Q06.02.02-6)
  - ACRS recommends that best estimate analyses with explicit consideration of uncertainties should be performed to evaluate the available NPSH margins for the limiting LOCA event and a range of ECCS operating configurations. (Correspondences btw ACRS and NRC)
  - SECY-11-0014 (Jan. 31, 2011), "Use of containment accident pressure in analyzing emergency core cooling system and containment heat removal system pump performance in postulated accidents"
  - APR1400 is working on the conservative estimation of the NPSH margin uncertainty, and the risk calculation for assessing the plant risk associated with crediting containment accident pressure in the NPSH assessment.

2.5 Design Features to Address GSI-191

❑ GSI-191 Evaluation : Ex-vessel Downstream Effect

- ➢ Strainer Bypass Testing (Scale-down test)
  - Filter bag is used to collect bypassed fiber.
  - Bypassed fiber debris mass : 1.67 kg (through 4 sump strainers)
- ➢ Ex-vessel downstream effects assessment (WCAP-16406-P-A, Rev.1)
  - SI pump and CS pump evaluation will be qualified according to ASME QME-1-2007 endorsed by RG 1.100, Rev.3.
  - CS heat exchanger and CS mini-flow heat exchanger Evaluation

    - No plugging due to lager tube ID and enough tube velocity

    - Performance and Wear : Vendor will confirm.
  - Evaluation on valves, orifice, spray nozzles, pipes, instrument tubing, and chemical effects

    - No blockage, no debris settling, and negligible wear are expected in APR1400 standard design.

2.5 Design Features to Address GSI-191

❑ GSI-191 Evaluation : In-vessel Downstream Effect

- WCAP-16793-NP, Rev.2
- In-vessel downstream test
  - Hot-leg break, Cold-leg break, Cold-leg break after hot-leg switchover
  - Mock-up Fuel Assembly (FA) of PLUS7 : ½ full length
  - The amount of bypass fiber per FA : 6.93 g/FA < 15 g/FA limit
  - The test results show that the maximum pressure drop through the FA is within the allowable pressure drop with sufficient margin.
- LOCADM analyses
  - The analyses results for deposit thickness, and peak cladding temperature satisfy the acceptance criteria (50 mils, 800°F)
- A sufficient driving force is available to maintain an adequate flow rate, and the long-term core cooling capability is adequately maintained in the APR1400.

3. Conclusion

- The APR1400 containment system complies with US regulatory requirements.
- The design features regarding GSI-191 have been evaluated in accordance with the NRC RG 1.82, Rev.4.
- The containment integrity and the plant safety are maintained with sufficient design margins during any postulated accident conditions.