APR1400
Advanced Power Reactor 1400
Contents

- Introduction
- What is APR1400?
- Conclusions
Korean Nuclear Infrastructure

- Operation & Maintenance
- PM of Construction and R&D
- Oversea Business

KINS
- Nuclear Regulatory Body

KAERI
- National Research Institute

KHNP

KOPEC
- System Design
- Architect Engineering

KNF
- Fuel Design & Manufacturing
- Core Design

KPS
- Maintenance Service

Doosan
- Component Design & Manufacturing

Hyundai etc.
- Construction

Many Vendors
- BOP Components Supply

Component Design & Manufacturing
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<th>Nuclear Power Plants in Korea</th>
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### Units (MWe)

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<tr>
<th>Location</th>
<th>Units</th>
<th>Details</th>
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<tr>
<td>Kori</td>
<td>8</td>
<td>7,937</td>
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<td>Shin Ulchin #1,2</td>
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<td>Wolsong</td>
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<td>Shin Wolsong #1,2</td>
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## Nuclear Power Plants in Korea

### In Operation
- **Units**
- **Units (MWe)**
- **20**
- **17,716**

### Under Construction
- **8**
- **9,600**

### Total
- **28**
- **27,316**

### Capacity Factor:
- **Korea**
- **World Average**
- **90.3**
- **93.2**
- **91.4**
- **92.3**
- **90.3**

(As of Dec., 2007)
Why KHNP?

- Abundant Operation and Construction Experiences
- World-Best Operational Records
- Continuous Construction Since 1970s
- Cost Effective and Reliable Supply Chain
- Successful Developments of Reactor Technology
- Well-Qualified Human Resources

APR1400 Under Construction

- SKN 3&4 Ground Breaking on Nov., 2007
- SUN 1&2 Detailed Construction Plan set on Dec., 2005
What is APR1400?
General Description - Technical Basis

Safety

- Core damage frequency < 1.0E-5/RY
- Containment failure frequency < 1.0E-6/RY
- Occupational radiation exposure < 1 man·Sv/RY

1,400 MWe
- Under Construction : SKN # 3,4 / SUN # 1,2

1,000 MWe
- In Operation : YGN #5,6 / UCN #5,6
- Under Construction : SKN #1,2 / SWN #1,2

1,000 MWe
- In Operation : YGN #3,4 / UCN #3,4
General Arrangement - Building Design

- **Reactor Containment Building (RCB)**
  - Pre-stressed cylindrical wall and hemispherical dome concrete structure
  - Wrapped around by auxiliary building

- **Compound Building (CB)**
  - Accessible from both units
  - Housing common facilities of Access control, Radwaste treatment, Hot machine shop, etc

- **Auxiliary Building (AB)**
  - Quadrant arrangement to enhance safety
  - Accommodating MCR, Emergency D/G, Fuel handling facilities

- **Turbine Building (TB)**
  - Steel structure with reinforced concrete turbine pedestal
  - Common tunnel for all underground facilities
General Arrangement - Principles of Layout

1. Safety Systems: Physically separated layout
2. Protection against internal & external hazards
3. Flood protection: ANSI/ANS-2.8
4. Fire protection: SECY-93-087 & NFPA804
5. Radiation protection: ALARA principle
General Arrangement

- Quadrant Arrangement of Safety Systems

SIP (Safety Injection Pump)  SCP (Shutdown Cooling Pump)  CSP (Containment Spray Pump)  CCWP (Component Cooling Water Pump)
General Arrangement

• Fire & Flood Protection Design

- Flood Barrier
- Fire Barrier (3Hr)
- Fire (3Hr) & Flood Barrier
General Arrangement

• Radiation Protection Design

- Hot Area
- Clean Area
System & Components

- Reactor Coolant System
  - 2 Hot legs and 4 Cold legs
  - 4 Reactor Coolant Pumps
  - 2 Steam Generators

- Plant Safety
  - Safety Injection System
  - Safety Depressurization & Venting System
  - Aux. Feedwater System
  - SAs Mitigation System

- MMIS & TG
  - I&C System
  - Main Control Room
  - Turbine & Generator
System & Components - Reactor Coolant System

Measures to reduce radiation exposure
- Reduced Cobalt contents in base material

Measures to enhance RV Integrity
- No weld seam in fuel region shell
- Using low Copper contents material

Integrated Inner Barrel Assembly
- Welded IBA to UGS upper flange
  - Eliminating tie rods, round nuts, snubber flange & Block

Integrated Lower Internal Assembly
- Integrated core support barrel, core shroud, and lower support structure in one assembly
System & Components - Reactor Coolant System

Enhanced Thermal Margin
High Burn up of 55,000 MWD/MTU
Improved Neutron Economy
Improved Seismic Resistance
Reduced Grid-to-Rod Fretting Wear Susceptibility
Increased Debris Filtering Efficiency
Improved Fuel Productivity
**Design Parameters**
- Total free volume: 2,400 ft³
- Coolant volume at full power: 1,100 ft³
- Heater capacity: 2,400 kW

**Increased Volume**
- Enhancing coping capability against plant transients

**Pilot Operated Safety Relief Valve**
- Performing over-pressure protection and safety depressurization
- Reliable valve operation without chattering and leakage
- Low susceptibility for valve stuck-open
**Type**
- Vertical bottom suction & horizontal discharge
- Single stage impeller
- Motor-driven centrifugal pump

**Shaft Seal Assembly**
- First and Second face-type mechanical seals
  - Reducing RCS pressure to volume control tank pressure
- Third face-type low-pressure vapor seal
  - Withstanding RCS pressure when RCP is not in operation
System & Components - Reactor Coolant System

Steam Generator

**Design Parameters**
- Number of tubes: 13,102 / SG
- Plugging margin: 10%
- Tube material: Inconel 690

**Improved Upper Tube Support Bars & Plate**
- Increased anti-vibration bars
  - Reducing flow-induced tube vibration

**Modified SG Inlet Nozzle Angle**
- Increasing space to install SG nozzle dam
  - Improving stability in mid-loop operation
**Integrated Head Assembly**

**Integrated Components**
- Cooling shroud assembly
- CEDM cooling facilities
- Missile shielding material

**Benefits of IHA**
- Shortening refueling time
- Reducing occupational radiation exposure
- Decreasing components storage area
System & Components - Plant Safety

Safety Injection System

Mechanically Independent 4 Trains
- 1 SIP/train
- 1 SIT/train

Direct Vessel Injection
- No safety injection water spillage in cold-leg break LOCA

Fluidic Device in Safety Injection Tank
- Extending safety injection duration of SIT
- Playing a role of low pressure SIP
System & Components - Plant Safety

Safety Depressurization & Venting System

Functions
- Controlling RCS pressure in normal operation and Design Base Accidents
- Allowing feed & bleed operation in total loss of feed water accident

Design Characteristics
- 4 POSRVs on the top of pressurizer
- Discharging pressurizer fluid to IRWST to prevent contamination of containment
In-Containment Refueling Water Storage Tank

**Functions**
- Heat sink in rapid RCS depressurization and feed & bleed operation
- Water source to Safety Injection System and Containment Spray System in DBA
- Water source to Cavity Flooding System and IVR-ERVC system in Severe Accidents

**Design characteristics**
- Collecting discharged fluid from POSRV
- Performing containment sump function
- Removing Safety Injection Pump suction switchover for long-term cooling in LOCA
System & Components - Plant Safety

Containment Spray System
- Functions
  - Removing airborne iodine and particulates
  - Reducing containment pressure in DBAs
- Design characteristics
  - 2 pumps (Backed up by 2 SCPs)
  - Water source: IRWST

Containment Hydrogen Control System
- Functions
  - Maintaining hydrogen concentration below design criterion
- Design characteristics
  - 30 Passive Autocatalytic Recombiners (PAR)
  - 10 Glow plug type igniters
**Auxiliary Feedwater System**

**Functions**
- Removing core residual heat in LOMF, SGTR, and small LOCA

**Design characteristics**
- Redundantly actuated by Engineering Safety Features Actuation System and Diverse Protection System
- System configuration
  - $2 \times 100\%$ motor driven pumps
  - $2 \times 100\%$ turbine driven pumps
  - $2 \times 100\%$ dedicated tanks housed in auxiliary building
**System & Components - Plant Safety**

**Cavity Flooding System**
- Flooding reactor cavity to cool molten core
- Water Source: IRWST
- Water driving force: Gravity
- Designed in accordance with SECY-93-087
  - Cavity floor area > 0.02 m²/MW_t

**In-Vessel Retention-ERVCS**
- Submerging reactor vessel lower head to cool and to retain molten core in reactor vessel
- Water Source: IRWST
- Water driving force: SCP, BAMP
Advanced I&C Design

- Adopted different type and manufacturer’s product for defense against common mode failure
- Applied open architecture concept for easy system modification and upgrade
- Used commercial off-the-shelf hardware, software, and network platforms having more than 3,000 years operating experience
- Applied fault tolerant design by adopting fail-safe concept
- Used multi-loop controller for non-safety system to be simplified and economical
Advanced MCR Design

- Optimized design through Human Factors Engineering evaluations
- Major components
  - Redundant compact workstation
  - Large display panel
  - Safety console
  - Backup against total DCS failure
  - Computerized procedure system
**Turbine & Generator**

**Turbine**
- Number: 1 double flow HP TBN, 3 double flow LP TBN
- Type: Tandem-compound
- Turbine speed: 1,800 rpm
- Output: 1,455 MWe
- Last stage blade: 52 inch

**Generator**
- Cooling
  - Stator winding: Water
  - Stator core, Rotor: Hydrogen
- Voltage: 24 kV, 3 Phase
- Frequency: 60 Hz
Design Verification

Direct Vessel Injection

DIVA (Downcomer Injection Visualization and Analysis)
- Investigating multi-D phenomena in downcomer during reflood of cold-leg LBLOCA
- Working fluid: Air-Water, Test scale: 1/10, 1/7, 1/5 of APR1400 & 1/7, 1/4 of UPTF
MIDAS (Multi-dimensional Investigation in Downcomer Annulus Simulation)

- Measuring ECC bypass in the reflood phase of cold-leg large break LOCA
- Working fluid: Steam-Water, Test scale: 1/5 of APR1400 & 1/4 of UPTF
Design Verification

Fluidic Device in SIT

- Evaluating safety injection flow performance of Safety Injection Tank with fluidic device
- Test facility: Same size and pressure condition as APR1400

VAPER (Valve Performance Evaluation Rig)
Design Verification

Fluidic Device in SIT

- Extending safety injection duration of SIT to effectively use SIT coolant
- Playing a role of low pressure safety injection pump
Design Verification

- Measuring air, steam, and water blowdown load on SDVS & IRWST structures
- Investigating thermal mixing between discharged fluid and water in IRWST

IRWST & Sparger

B&C (Blowdown & Condensation) Loop
ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation)

- State-of-the-art integral loop test facility commissioned in 2006
- 1/2-height & 1/144-area, Full pressure & temperature simulation of APR1400
Design Verification

Main Control Room

Full scope & APR1400 specific dynamic mockup tests

- Verifying & validating human factors engineering for normal and emergency operation
- Performed by licensed operators and human factors specialists
Design Verification

- HERMES: Measuring natural circulation flow through region between reactor vessel and insulator
- CHF Test: Investigating critical heat flux and thermal margin
Construction - Measures to Reduce Construction time

**Civil Works**
- Pre-fabrication and structure module
- Steel linear plate module
- Deck plates method

**Mechanical & Electrical works**
- Modularization of reactor internals
- Automatic welding of RCS pipe
- Over the top method for NSSS major components installation

Advanced Technologies
Construction - Design Verification by 3D CAD System

Automatic Modeling

- Automatic generation of virtual plant through connecting with Engineering Data Base System

- Design Review

- Producing various deliverables
APR1400
Advanced Power Reactor 1400

Enhanced Safety

- Increased thermal margin
- Physically separated quadrant arrangement of safety systems
- Adoption of new design features confirmed through design verification program
- Reinforced seismic design basis
Improved Cost Effectiveness

- Increased capacity factor and reduced unplanned trips
- Reduced construction time by advanced technologies
- Reduced construction bulk materials
Convenient Operation & Maintenance

- Full digitalized I&C system and operator-friendly man-machine interface
- Facilities for maintenance & inspection
- Increased operator action time
- Reduced occupational radiation exposure
APR 1400
Advanced Power Reactor 1400

The best choice for customers who seek advanced and economical nuclear power plant
Energy that brightens the world, Nuclear Energy