The Westinghouse Advanced Passive Pressurized Water Reactor, **AP1000™**

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Director, Engineering Services
Background

- Late ’80: USA Utilities under direction of EPRI and endorsed by NRC: *Advanced Light Water Reactor Utility Requirements Document (URD)* with policy and design requirements for next generation
- In Europe similar document *European Utility Requirements (EUR)*
- **Passive** is also *simpler, smaller and much improved*
- **Passive** has much higher expectations (ex. maintain safe shutdown for 72 hrs. after design base event w/o operator action vs. 30’ for evolutionary)
Simplification and Standardization are Key to Future Nuclear Plant Construction

- Simplicity and standardization in **Design** through reduced number of components and bulk commodities
- Simplicity in **Safety** through use of passive safety systems
- Simplicity in **Construction** through modularization
- Simplicity in **Procurement** through standardization of components and plant design
- Simplicity in **Operation and Maintenance** through use of proven systems and components, and man-machine interface advancements

**Improved Safety, Competitive Economics and Good Performance**
AP1000 Investment in Technology

- Extensive Testing of Passive Safety Systems
- Simplified Passive Safety Systems
- US NRC Certified
- PRA and Severe Accident Mitigation Features
- Reduced Components and Commodities
- Proven Advanced Design Features
- Modular Construction
- Short Construction Schedule
AP1000 Design Certification Received From NRC 12/30/05
THE PLANT

Our Design Certification includes:

- Containment
- Auxiliary Building
- Annex Building
- Turbine Building
- Radwaste Building
- Diesel Generator Building
- Everything in Buildings

It is based upon:

- Passive Core Cooling
- Passive Control Room Habitability
- Passive Containment Cooling
- Passive Fire Protection
- Passive Security Features
AP1000 Addresses Security Needs

- Passive plants are less vulnerable to aircraft impact –
  - Smaller footprint
  - Fewer safety-related components
  - Fewer safety systems outside containment
- NEI/EPRI study shows containment integrity maintained after aircraft impact
- Westinghouse interacting closely with US NRC regarding security
- Westinghouse working with EPP utility group on hardening building for airplane crash resistance capability
AP1000 Reactor Coolant System*

- Pressurizer
- Steam Generator
- Hot Leg Pipe
- Cold Leg Pipe
- Reactor Vessel
- High Inertia Canned Motor Pumps
Familiar but Improved Reactor Coolant System

- Fuel, Internals, Reactor Vessel
  - Top-mounted fixed in-core instrumentation
  - Ring-forged reactor vessel (no longitudinal welds)
  - Improved materials - 60 yr life
  - All-welded core shroud (not bolted)
- Steam Generators
  - Similar to large Westinghouse SGs in operation
**Reactor Coolant System Loop – Building Interface and Primary Shield**

- Hot Leg ID (31 in), Cold Leg ID (22 in), and Surge Line ID (18 in)
Proven AP1000 Major Components

- Canned motor Reactor Coolant Pumps mounted in steam generator lower head
  - No shaft seals
- Simplified Main Loop
  - Reduces welds 50%, supports 80%
- Pressurizer
  - 50% larger than operating plants
  - Eliminate PORV
Proven AP1000 Components

Reactor Vessel Internals
Doel 4, Tihange 3

Control Rod Drive Mechanisms
Westinghouse plants worldwide

Fuel
South Texas 1&2, Doel 4, Tihange 3

Large Model F steam generators
ANO-2, San Onofre, Waterford, Palo Verde

Pressurizer
70 Westinghouse plants worldwide

Canned motor reactor coolant pumps
Fossil boilers and other industrial applications (inverted canned motor pumps)
## Comparison of Selected Parameters

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Doel 4 / Tihange 3</th>
<th>AP1000</th>
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</thead>
<tbody>
<tr>
<td>Net Electric Output, MWe</td>
<td>985</td>
<td>1117</td>
</tr>
<tr>
<td>Reactor Power, MWt</td>
<td>2988</td>
<td>3400</td>
</tr>
<tr>
<td>Hot Leg Temperature, °F</td>
<td>626</td>
<td>610</td>
</tr>
<tr>
<td>Number of Fuel Assemblies</td>
<td>157</td>
<td>157</td>
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<tr>
<td>Type of Fuel Assembly</td>
<td>17x17</td>
<td>17x17</td>
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<tr>
<td>Active Fuel Length, ft</td>
<td>14</td>
<td>14</td>
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<tr>
<td>Linear Heat Rating, kW/ft</td>
<td>5.02</td>
<td>5.71</td>
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<tr>
<td>R/V I.D., inches</td>
<td>157</td>
<td>157</td>
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<tr>
<td>Vessel Thermal Design Flow, gpm</td>
<td>295,500</td>
<td>299,880</td>
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<tr>
<td>Steam Generator Surface Area, ft²</td>
<td>68,000</td>
<td>125,000</td>
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<tr>
<td>Reactor Coolant Pump Flow, gpm</td>
<td>103,400</td>
<td>78,750</td>
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<tr>
<td>Pressurizer Volume, ft³</td>
<td>1400</td>
<td>2100</td>
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</table>
Advanced Control Room
AP1000 Main Control Area Layout

Security – Related Information – Withhold under 10CFR2.390
Major Safety Advancements of AP1000

- No Reliance on AC Power
- No Operator Action Required to Assure Safety
- Long Term Plant Safety Assured without Active Components (Natural Forces Only)
- Containment is Not Breached for Postulated Design Basis Events
- In Severe Accidents, Reactor Vessel Cooling Keeps Core in Vessel
- Large Margin to Safety Limits
- Defense in Depth - Active Systems Provide ADDITIONAL first line of defense
Passive Safety – What’s it all about?

- Passive Safety Systems utilizes naturally occurring physical phenomena such as natural circulation of air, water and steam.
- Gravity and gas pressure drive the flow of cooling water.
- Natural heat transfer occurs through conduction, convection and evaporation.
- There are no safety related pumps and motor-operated valves.
- A few battery powered valves align the passive safety systems upon actuation signals.
- Reactor safety functions are achieved without using any safety related AC power.
Approach to Safety

- Passive safety-related systems
  - Use “passive” process only, no active pumps, diesels, …
    - One time alignment of valves
    - No support systems required after actuation
      - No ac power, cooling water, HVAC, I&C
    - Greatly reduced dependency on operator actions
  - Mitigate design basis accidents without non-safety systems
  - Meet NRC PRA safety goals without use of non-safety systems

- Active non-safety-related systems
  - Reliably support normal operation
    - Redundant equipment powered by on-site diesels
  - Minimize challenges to passive safety systems
  - Not required to mitigate design basis accidents
AP1000 Passive Safety Injection
Simplification of Safety Systems Dramatically Reduces Building Volumes

Standard PWR

AP1000

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Simplicity in Design and Safety

- Proven 2-loop reactor coolant system with canned motor pumps
- Use of passive safety systems
- No reliance on safety grade AC power
- In-vessel retention for severe accidents
- No operator action for 72 hours
Passive Core Cooling System at Work
Passive Containment Cooling System

AP1000
Ultimate Heat Sink is the Atmosphere
Severe Accident Mitigation
In-Vessel Retention

• Core melt scenario
AP1000 designed to retain core debris within the reactor vessel
  • Cooling water flow path in vessel/insulation annulus
  • Cooling flow driven by natural circulation
  • Water source: In containment refueling water storage tank
  • Automatic depressurization
• Large release frequency: 5.9 x 10^-8 per reactor year;
  URD requires < 10^-6
AP1000 Most Tested Reactor
Passive Containment Cooling Test Facility Demonstrated the Effectiveness of Passive Containment Cooling
AP1000 Passive Safety System Design Improves Economics and Construction Schedule

- 50% Fewer Safety-grade Valves
- 35% Fewer Pumps
- 80% Less Safety-grade Pipe
- 45% Less Seismic Building Volume
- 70% Less Cable
AP1000 Provides Safety and Investment Protection

Core Damage Frequency per Year (All Events)

<table>
<thead>
<tr>
<th>U.S. NRC Requirements</th>
<th>Current Plants</th>
<th>Utility Requirements</th>
<th>AP1000 Results</th>
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<tbody>
<tr>
<td>$1 \times 10^{-4}$</td>
<td>$5 \times 10^{-5}$</td>
<td>$&lt;1 \times 10^{-5}$</td>
<td>$5.1 \times 10^{-7}$</td>
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</tbody>
</table>
Comparison of Seismic Category I Buildings

WESTINGHOUSE GENERATION II PWR

1. Shield / Containment
2. Auxiliary Building
3. Fuel Area
4. Diesel Generators

1. Shield / Containment
2. Auxiliary Building
3. Fuel Area
4. Diesel Generators

AP1000

5. Essential Service Water Pumphouse
6. Emergency Fuel Oil Storage
7. Refueling Water Storage Tank
AP1000 Construction Simplification

Think: 1) more power/m³ of concrete, 2) less to decommission

<table>
<thead>
<tr>
<th></th>
<th>Concrete, m³</th>
<th>Rebar, metric tons</th>
<th>Power, MWe</th>
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</thead>
<tbody>
<tr>
<td>Sizewell B:</td>
<td>520,000</td>
<td>65,000</td>
<td>1188</td>
</tr>
<tr>
<td>AP1000:</td>
<td>&lt;100,000</td>
<td>&lt;12,000</td>
<td>1117</td>
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Modules Designed into AP1000 from the Beginning

<table>
<thead>
<tr>
<th>Module Type</th>
<th>Number</th>
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<tbody>
<tr>
<td>Structural</td>
<td>122</td>
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<tr>
<td>Piping</td>
<td>154</td>
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<tr>
<td>Mechanical Equipment</td>
<td>55</td>
</tr>
<tr>
<td>Electrical Equipment</td>
<td>11</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>342</strong></td>
</tr>
</tbody>
</table>

Pump/Valve Module

Raceway Module

Structural Module

Depressurization Module
Module Program

- Structural steel and plate modules designed to be fabricated, outfitted, installed and then filled with concrete after installation.
- The process effectively removes the reinforcing steel installation (typically a largely manual operation) from the work face to the fabrication facility and implements it in parallel with other installation activities.
- The scope and content of these modules includes multi floors, rooms/areas and all disciplines.
Modular Construction Allows More To Be Done in Parallel
Result: Shorter Construction Schedule
Module Program

CA 20 Overview

- Overall Dimensions:
  - Width: 46.5 ft.
  - Length: 67.3 ft.
  - Height: 68.8 ft.

- Estimated Weight:
  - Walls and Floors: 770 tons
  - Outfitting (components, piping, rebar): 89 tons
  - Total Outfitted: 859 tons
Module Program

CA 20 view with walls removed to show outfitted equipment prior to installation
Module Program

Composite Structural Module CA 01
Steel Plate Structural Wall Module*
Module Program

● CA 01
Construction Program

Westinghouse Advanced Plant Virtual Construction

AP1000
The Westinghouse AP1000™

A compact station

- 3415 MWe. Primary system
- 1117 MWe
- 2-loops, 2 steam generators
Meets European Utility Requirements

- EUR (European Utility Requirements) effort launched in December 1991 by five European Utilities, later joined by six others
- AP1000 compliance assessment is detailed and thorough: over 5000 requirements have been assessed
- EUR Certified
Proposed AP1000 Sites in U.S.

- Bellefonte, TVA: 2 AP1000s
- Lee Nuclear, Duke: 2 AP1000s
- Harris, Progress Energy: 2 AP1000s
- Vogtle, Southern Co.: 2 AP1000s
- Levy County, Progress Energy: 2 AP1000s
- VC Summer, SCE&G/Santee Cooper: 2 AP1000s
AP1000 Units in China

Two units at Haiyang
Two units at Sanmen

Preliminary design, engineering and long-lead procurement work has already begun.

Power plant construction is expected to begin in 2009, with the first plant becoming operational in late 2013. The remaining plants are expected to come online in 2014 and 2015.
Questions