The AP1000 Reactor
Nuclear Renaissance Option

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What Will Drive A Nuclear Renaissance?

- Continuing excellent performance of existing reactors
- Need for base load electricity capacity
- Nuclear’s contribution to clean air recognized and credited
- Importance of energy security and/or diversity included in capacity planning
- Competitive economics of new nuclear plants compared to alternatives
- Government support and/or incentives for initial projects
- Strong tie between nuclear and hydrogen economy
Critical Issues for New Plants in US

• Capital Cost of the Plant
  – Historical record of meeting project targets sporadic
  – Long time since start of last project
  – Current lack of skilled workforce
  – Complicated design of past plants
  – Vast majority of current plants were custom designed

Reluctance to Accept Current Cost Estimates
Critical Issues for New Plants in US (Cont’d)

- Perceived Risk of a Construction Project
  - Local public or anti-nuclear group opposition
  - Permitting delays
  - Design changes after project start
  - First time implementation of new regulatory processes
  - Regulatory changes after construction start
  - Procurement and/or construction delays
  - Increased concerns over fuel disposal issues
  - Latent technical defects found after start of operations
  - Electric market / price fluctuations

Financial Community Concerns Manifested by Unwillingness to Provide Project Financing
Why Was Advanced Passive AP1000 Design Developed?

- Existing designs with incremental improvements could not meet the deregulated electricity generation cost target
- Westinghouse Passive Plant Technology was mature and licensed in US
- Large investment in Passive Plant Technology development could be leveraged to provide a cost competitive design in a relatively short time
Passive Safety Advantages

- No reliance on AC power
- Automatic response to accident condition assures safety
- Long term plant safety assured without active components (natural forces only)
- Containment reliability greatly increased by passive cooling
- In severe accidents, reactor vessel cooling keeps core debris in vessel
- Large margin to safety limits
- Defense in depth - active non-safety systems provide additional first line of defense
Passive Plant Technology is Mature

• 1300 man-year / ~$500 million design and testing effort
• More than 12,000 design documents completed
• Detailed Bill of Materials developed
• 3D computer model developed
  – Includes structures, equipment, small / large pipe, cable trays, ducts ...
• Very thorough / complete NRC review of AP600
  – 110 man-year effort (NRC) over 6 years
  – Independent, confirmatory plant testing (ROSA, OSU)
  – 380+ meetings with NRC, 43 meetings with ACRS
• NRC design certification of AP600 issued December 1999
• AP1000 currently under design certification review - draft Safety Evaluation Report already issued
AP1000 Design Objectives

• Increase Plant Power Rating to Reduce Cost
  – Obtain capital cost to compete in US deregulated market

• Retain AP600 Design Basis and Detail
  – Increase capability/capacity within “space constraints” of AP600
  – Retain credibility of “proven components”
  – Retain basis and pedigree for cost estimate, schedule, modular scheme

• Retain AP600 Licensing Basis
  – Meet regulatory requirements for Advanced Passive Plants
  – Demonstrate AP600 Test Program and Safety Codes are applicable to AP1000

Build on AP600 Investment
Reactor Coolant System

- Canned motor pumps mounted in steam generator lower vessel head
- Elimination of RCS loop seal
- Large pressurizer
- Top-mounted, fixed in-core detectors
- All-welded core shroud
- Ring-forged reactor vessel
Passive Core Cooling System

- AP1000 has no reliance on AC power
  - Passive Decay Heat Removal
  - Passive Safety Injection
  - Passive Containment Cooling

- Long term safe shutdown state > 72 hours without operator action
Passive Containment Cooling
Passive Plant Test Program

• Separate Effects Component / Sub-System Tests
  – Reactor coolant pump tests
  – Passive residual heat removal heat exchanger test
  – Core makeup tank test
  – Containment water distribution test
  – Containment shell heat and mass transfer tests
  – Containment cooling wind tunnel tests
  – DNB tests
  – Automatic depressurization system test (full scale)

• Integral Systems Tests
  – Long term cooling integral systems test
  – Full height, full pressure integral systems test
  – Large scale integral PCS test

The Most Tested of Next Generation Reactors
Advanced I&C Features

- All Digital, microprocessor-based
- Current design uses Advant (for safety) and Ovation (for non-safety)
- Most I&C is non-safety classification
- Safety systems already licensed by US NRC
- Extensive use of multiplexing and fiber optics
- Smart instruments and electrical equipment (MCCs, switchgear)
- Diverse actuation of key passive safety systems
- Compact Advanced Control Room
Advanced Control Room
AP1000 Approach to Safety

- Passive Safety Systems
  - Use “passive” processes only; no safety-grade active pumps, diesels….
  - Dedicated systems; not used for normal operations
  - Reduced dependency on operator actions
  - Mitigate design basis accidents
  - Meet regulatory safety goals

- Active Non-Safety Systems
  - Reliably support normal operation
  - Minimize challenges to passive safety systems
  - Not required to mitigate design basis accidents or meet safety goals
  - Provide plant investment protection
AP1000 Provides Multiple Levels of System Defense In Depth

- First action is usually by non-safety grade active system
  - High quality industrial grade equipment
- Second action is by safety grade passive system
  - Provides safety case for SAR
  - Highest quality nuclear grade equipment
- Other passive systems provide additional defense-in-depth
  - Example; passive feed/bleed backs up PRHR HX
- Available for all shutdown conditions as well as at power
- More likely events have more levels of defense
# AP1000 Safety Margins

<table>
<thead>
<tr>
<th></th>
<th>Typical Plant</th>
<th>AP1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss Flow Margin to</td>
<td>1 – 5%</td>
<td>19%</td>
</tr>
<tr>
<td>DNBR Limit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedline Break</td>
<td>&gt;0°F</td>
<td>140°F</td>
</tr>
<tr>
<td>Subcooling Margin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG Tube Rupture</td>
<td>Operator actions required in 10 min</td>
<td>Operator actions NOT required</td>
</tr>
<tr>
<td>Small LOCA</td>
<td>3” LOCA core uncovers PCT ~1500 °F</td>
<td>&lt; 8” LOCA NO core uncover</td>
</tr>
</tbody>
</table>
AP1000 Provides Increased Safety and Investment Protection

U. S. NRC Requirements

Current Plants

EPRI Utility Requirements

AP1000 Results

Core Damage Frequency per Year

1 x 10^-4

5 x 10^-5

1 x 10^-5

3 x 10^-7
How We Will Achieve a Competitive Capital Cost

• Basic Design - Simplification
• Power Level - Economics of Scale
• Project Schedule - It Must be Short
• Standardization - A Necessary Commitment
• Modularization - An Integral Part of the Design Process
• Information Technology - Use of Advanced Information Management System
• Project Organization and Structure - Sharing Risk and Rewards
Simplicity of Design Drives Economics

- **Simplicity in Design** through reduced number of components and bulk commodities
- **Simplicity in Safety** through use of passive safety systems
- **Simplicity in Procurement** through standardization of components
- **Simplicity in Operation and Maintenance** through use of proven systems and components, and man-machine interface advancements
Passive Safety Systems Eliminate Components

- 50% Fewer Valves
- 35% Fewer Pumps*
- 80% Less Pipe**
- 80% Fewer Heating, Ventilating & Cooling Units
- 45% Less Seismic Building Volume
- 70% Less Cable

* No safety grade pumps
** Safety Grade
Simplification of Safety Systems Dramatically Reduces Building Volumes

Standard PWR

AP1000

- Natural Convection Air Discharge
- PCCS Gravity Drain Water Tank
- Water Film Evaporation
- Outside Cooling Air Intake
- Steel Containment Vessel
- Internal condensation and natural recirculation
- Air Baffle
Simplifications Reduce O&M

- Reductions in Amount of Safety Equipment
  - Reduces inservice inspections and testing
  - Fewer Technical Specifications
- Use of Non-safety Defense-In-Depth Equipment
  - No ISI / IST or Technical Specifications
  - Most planned maintenance performed at power
- Elimination of Snubbers and Pipe Whip Restraints
- Elimination of Most Charcoal / HEPA Filters
- Advanced Control Room & Remote Shutdown Station
  - Eliminates separate displays, switches, alarms, indicating lights
Modularization Impacts Construction Schedule

- Modules developed as an integral part of the detailed design process
- Allows many repetitive construction activities to be performed in a more controlled environment
- Captures experience and lessons learned more easily
- Provides multi-path parallel construction with large reduction in field labor
- Primary benefit is shorter construction schedule but has potential for cost savings on follow-on units
### Passive Plant Modules

<table>
<thead>
<tr>
<th></th>
<th>STRUCTURAL MODULES</th>
<th>PIPING MODULES</th>
<th>MECHANICAL EQUIPMENT MODULES</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Containment</td>
<td>41</td>
<td>20</td>
<td>12</td>
<td>73</td>
</tr>
<tr>
<td>Auxiliary Building</td>
<td>42</td>
<td>34</td>
<td>29</td>
<td>105</td>
</tr>
<tr>
<td>Turbine Building</td>
<td>29</td>
<td>45</td>
<td>14</td>
<td>88</td>
</tr>
<tr>
<td>Annex Building</td>
<td>10</td>
<td>10</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>122</td>
<td>99</td>
<td>55</td>
<td>276</td>
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Parallel Tasks Using Modularization
Shorten Construction Schedule

- Plant Order
- Site Survey and Preparation
- Factory Production of Modules
- Onsite Module Assembly
- Rail/Truck Shipment of Modules
- Site Construction
- Plant Operation
AP1000 Construction Plan

- Detailed Construction Plan with over 5000 activities has been developed
- Schedule is based on working 5 days/week, 10 hours/day
  - Inspections during second shift
  - Third shift and weekends reserved as contingency
- Construction plan has been linked to 3D computer model, creating a 4D virtual reality construction planning tool
- Schedule verified by construction management companies in US, Japan, and UK
- 60 months total schedule with 36 months from first concrete to fuel load
## AP1000 Passive Plant Economics

<table>
<thead>
<tr>
<th>Aspect</th>
<th>AP1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overnight Capital Cost ($/kWe)</td>
<td>1000 - 1200</td>
</tr>
<tr>
<td>Capital Cost Recovery Charge (¢/kWh)</td>
<td>2.1 – 2.5</td>
</tr>
<tr>
<td>Fuel &amp; O&amp;M Charge (¢/kWh)</td>
<td>1.0</td>
</tr>
<tr>
<td>Decommissioning Charge (¢/kWh)</td>
<td>0.1</td>
</tr>
<tr>
<td>Total Generation Costs (¢/kWh)</td>
<td>3.2 – 3.6</td>
</tr>
</tbody>
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How We Will Reduce the Perceived Risk of a Construction Project

• Improved and Tested Regulatory Processes
  – Standard Plant Licensing Regulation (10CFR52)
  – Implementing Guidance, e.g., Construction Inspection Procedures, ITAAC Procedures
• Government Support for Initial Projects
  – Grants for early activities, e.g., design certification, early site permits, combined construction and operating licenses, and first-of-a-kind engineering
  – Direct loans or loan guarantees (problematic at this time)
  – Accelerating the depreciation schedule
  – Providing investment tax credits
  – Establishing production tax credits
  – Obtaining long-term power purchase agreements
The Path Forward - Standardized ALWRs

- **Maturity of Design**
  - High level of design detail
  - Already licensed
- **Availability of Components**
  - Supply chain exists
  - Competition through worldwide sourcing
- **Understanding by Regulator**
  - Large body of regulatory guidance
  - Implementing procedures
- **Operator Familiarity**
  - Operating philosophy well grounded
  - Easy transition from prior LWR experience

If ALWRs are **not** built soon, the industry will **not** be capable of building other plants later
AP1000 - An Advanced Technology Ready for Deployment

- Passive Safety Systems
- URD Requirements
- Modular Construction
- US Licensing Approval
- Advanced Features Testing
- Reduced Components & Commodity Quantities
- Severe Accidents Mitigation Features
- Short Engineering and Construction Schedule