Decommissioning Considerations in Plant Design

Dr. Jas S. Devgun
Manager
Nuclear Power Technologies
Sargent & Lundy LLC
Chicago, IL U.S.A

Note: The views expressed here are those of the author and do not necessarily reflect the views of his employer or the clients.

March 2, 2011
Phoenix, AZ
Design Features Relevant to Decommissioning

I. Reduction in System Components
II. Reduction in Construction Materials
III. Modular Designs of Systems
IV. Modular Design of Structures
V. Advanced Construction techniques
VI. Better Designs to Avoid Contamination During Operational Phase
VII. Waste Minimization
VIII. Harmonization of International Codes and Standards for Design
## Reduction in Components & Construction Materials

### I & II

### Reduction in Components for New Reactor Designs

<table>
<thead>
<tr>
<th></th>
<th>AP1000</th>
<th>ESBWR</th>
<th>US EPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design life</td>
<td>Design life - 60 years</td>
<td>Design life - 60 years</td>
<td>Design life - 60 years</td>
</tr>
<tr>
<td>Refuel cycle</td>
<td>18 month refuel cycle</td>
<td>24 month refuel cycle</td>
<td>12 to 24 month refuel cycle</td>
</tr>
<tr>
<td>Reduction in components</td>
<td>87% less control cable</td>
<td>11 systems eliminated</td>
<td>44% fewer heat exchangers</td>
</tr>
<tr>
<td></td>
<td>80% less piping</td>
<td>25% of pumps, valves</td>
<td>50% fewer tanks</td>
</tr>
<tr>
<td></td>
<td>50% fewer valves</td>
<td>and motors eliminated</td>
<td>47% fewer valves</td>
</tr>
<tr>
<td></td>
<td>35% fewer pumps</td>
<td></td>
<td>16% fewer pumps</td>
</tr>
</tbody>
</table>
Reduction in Components

AP1000

<table>
<thead>
<tr>
<th>Component</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valves</td>
<td>50% Fewer</td>
</tr>
<tr>
<td>Pumps</td>
<td>35% Fewer</td>
</tr>
<tr>
<td>Pipe</td>
<td>80% Less</td>
</tr>
<tr>
<td>Seismic Building</td>
<td>45% Less</td>
</tr>
<tr>
<td>Cable</td>
<td>85% Less</td>
</tr>
</tbody>
</table>

Compared with a conventional 1000 MW PWR

Source: Westinghouse
## Reduction in Construction Materials

<table>
<thead>
<tr>
<th>Era</th>
<th>Concrete</th>
<th>Rebar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1970s</strong></td>
<td>m³/MWe installed 190+</td>
<td>t (metric)/MWe installed 40+</td>
</tr>
<tr>
<td>Current Designs</td>
<td>90</td>
<td>40</td>
</tr>
<tr>
<td><strong>Comparisons</strong></td>
<td><strong>Total Concrete m³</strong></td>
<td><strong>Total Steel t (metric)</strong></td>
</tr>
<tr>
<td>Sizewell B (UK)</td>
<td>520,000 300,000 351,000</td>
<td>65,000 46,000 &lt;12,000</td>
</tr>
<tr>
<td>US typical ABWR</td>
<td>Approx.10,000</td>
<td></td>
</tr>
<tr>
<td>AP1000</td>
<td>&lt;100,000</td>
<td></td>
</tr>
</tbody>
</table>
Modular Designs – Systems and Structures

AP-1000 Modular Systems – Approx. 200 System modules

Q6-01 Module – RCS Stages 1,2,3 ADS
12’ x 12’ x 15’-9”, 50 t

R161-Aux Bldg Piping Module 41’-3” x 6’ x 10’-11”, 4 ½ t

Q223 Module – Direct Vessel Injection
B Valve Module, 28’ x 37’-3” x 10’-9”, 15 t
ABWR Design Modularization

14 Critical Path area Modules
37 Sub Critical Path area modules
130 Other area modules

Source: JD/Panel
AP-1000 Modular Structures

Approx 150 structural modules

CA20 21 m X 14 m X 21 m, 875 t

CA01 25m X 29m X 26m 750t
Modular Designs – Structures

Super Large Scale Upper Drywell Module
Kashiwazaki-Kariwa

Main Control Room Module - Hitachi

Composite module of piping, valves and structural steel (Toshiba)

JD/Panel
CANDU Design

Modular Construction
Modular Construction
Pros & Cons

Pros
- Reduction in schedule
  - parallel construction
- Reduction in manpower needs
- Reduction of work congestion
- Uniformity in systems and structures
- multiple units at the same site
- Uniformity in design
- Better quality control
- Reduction in facility footprint
- Reduction in system components
- Mass production capability
- Significant cost savings

Challenges
- More detailed engineering at early stages
- Infrastructure
- Larger modules as multiple sub-modules
- Early procurement of materials
- Transportation logistics & cost
- Very Heavy Lift capability
- first-of-a-kind engineering activity
- temporary weather covers
- regulatory codes and standards
- Module connections
Advanced Construction Techniques & Better Designs
V & VI

• Modularization
• Slip Forming
• Open Top Construction
Advanced Construction Techniques

Shimane-3

A Quick Photographic Journey

Lingao-4

VHL in action-Qinshan

JD/Panel 13
Advanced Construction Techniques

Automatic Welding Machine - Shin-Kori

3D CADD - Courtesy Mitsubishi

Slip forming – CANDU 6
## Waste Minimization

### Waste Comparison

<table>
<thead>
<tr>
<th>Waste Volume*</th>
<th>Operational Wastes (Dry and Wet)</th>
<th>Decommissioning Waste (Low Level)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current PWR 1000 MWe</strong></td>
<td>270 m³/y (9540 ft³/y)</td>
<td>18,340 m³ (647,500 ft³)</td>
</tr>
<tr>
<td><strong>AP1000</strong></td>
<td>163 m³/y (5760 ft³/y)</td>
<td>App. 10,000 m³ (353,000 ft³)</td>
</tr>
</tbody>
</table>

**Comparison:** Decommissioning waste (low level) from Main Yankee: 19,800 m³ (700,000 ft³); Double that amount with concrete. 240 Million lbs

Main Yankee: 860MWe PWR; D&D Cost $550 Million
International Codes and Standards for Design

- Greater harmonization of national standards facilitates more uniform regulatory design review and licensing process worldwide.
- Current reactor plant designs are developed by international companies who plan to build these units in many different countries.
  - In many cases a plant built in one country becomes a reference plant for construction of that design in other countries.
- Major components (such as the RPV and the SG) fabrication capability - only a few manufacturers.
- Economies of scale through modular system fabrication modular construction.
- Activities in this regard:
  - ASME – worldwide application
  - IAEA
  - WENRA
Why is this Important

Cost Savings, Better Quality, Better Safety

Capital Cost Estimates

<table>
<thead>
<tr>
<th>Estimate Year</th>
<th>Capital Cost per kWe installed</th>
<th>Reference Plant Cost 1100 MWe</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-2002</td>
<td>$1,200 to $1,500</td>
<td>$2 billion to $4 billion</td>
</tr>
<tr>
<td>2006-2007</td>
<td>$3,600 to $4,000</td>
<td>$4 billion to $4.5 billion</td>
</tr>
<tr>
<td>2008</td>
<td>$5,500 to $8,100</td>
<td>$6 billion to $9 billion</td>
</tr>
</tbody>
</table>
Discussion: Questions to Consider

• Nuclear renaissance – its success (at least in US) may depend on it public acceptance – addressing waste management and decommissioning issues
• D&D 60 plus years away – why should we still consider it
• D&D features part of new designs – how far to optimize
• Would new technologies (in next decades) make our features obsolete or redundant
• Nuclear renaissance – cost economics
  – refurbish or rebuild