ASME South African Workshop AP1000 Overview

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AP1000 Design Overview

- Introduction
- AP1000 Design Overview
- Overview of Reactor Pressure Vessel (RPV) Design Specification

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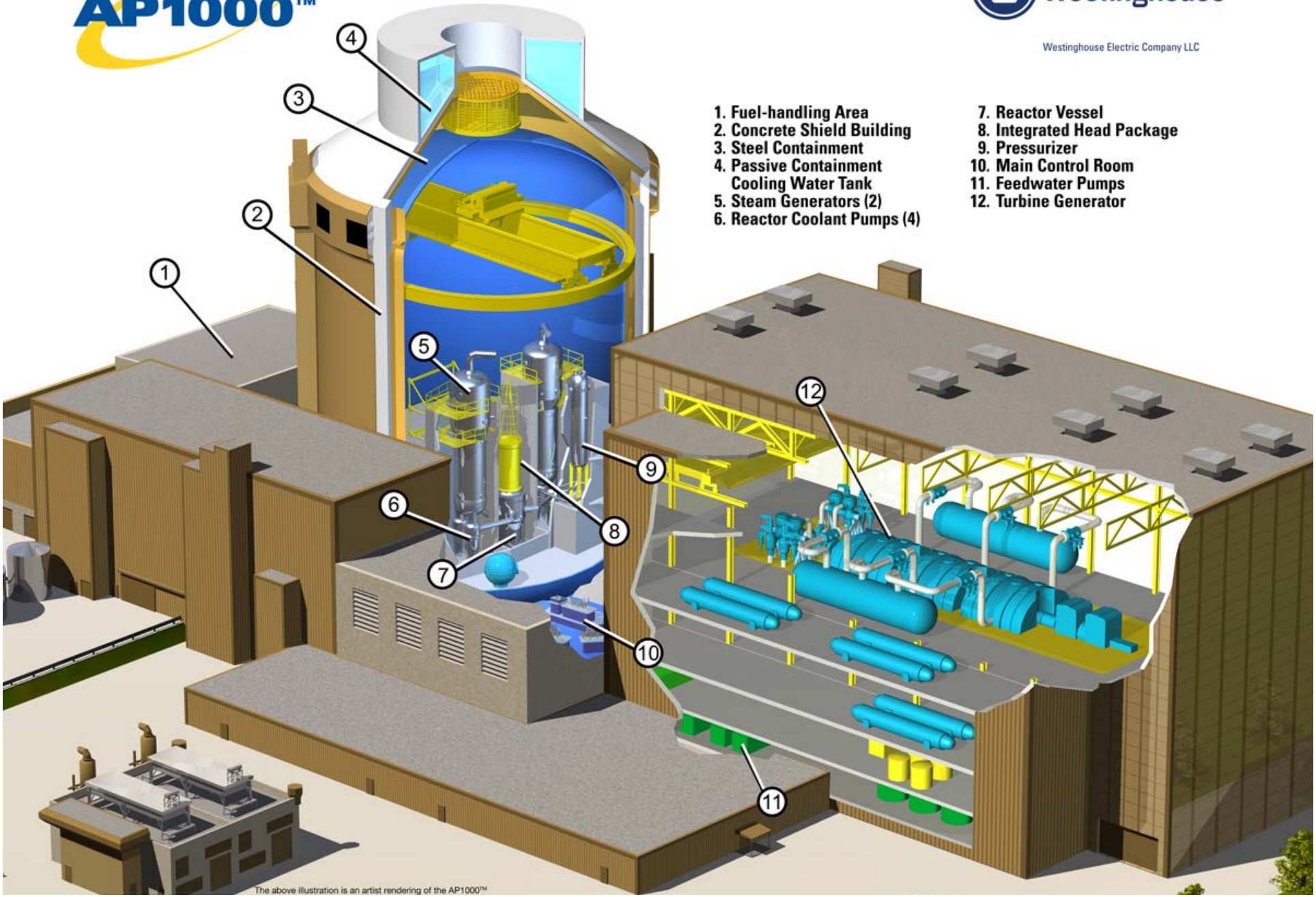


The above illustration is an artist rendering of the AP1000™

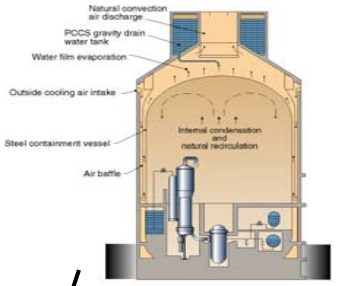
AP1000 Design Overview

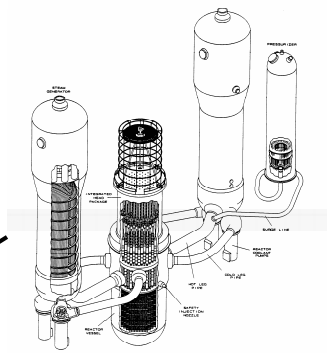
- Background / Design Certification / Licensing / Overall Features
- Reactor Core and Vessel Design (core, control rods)
- **Reactor Coolant System (2 loops, seal-less RCPs)***
- **Passive Safety Systems (one-time valve actuation)***
- Non-Safety Defense-in-Depth Systems (previously safety systems)
- **I&C Systems (2 digital I&C w/data highway, AMSAC replacement)***
- Miscellaneous Plant Information
- AP1000 Classification System Overview

AP1000 Investment in Technology

Extensive Testing of Passive Safety Systems

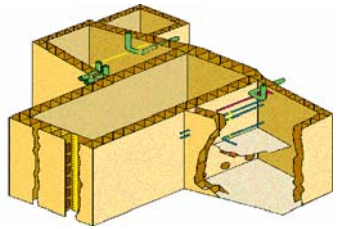
Simplified Passive Safety Systems



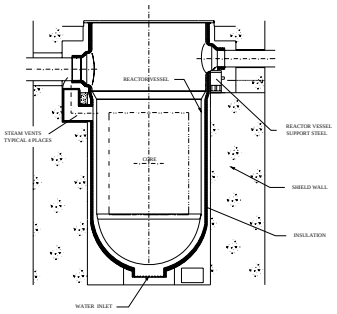


Proven Advanced Design Features

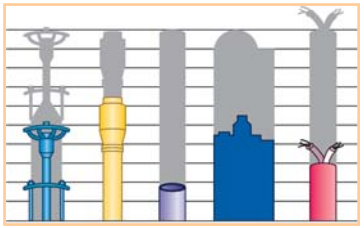
US Licensing Approval



Modular Construction



PRA and Severe Accident Mitigation Features



Reduced Components and Commodities

Short Construction Schedule

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AP1000 - Key Design Features

- Integrated Power Plant Design (NSSS and BOP designs) – 60 yr plant life
- Proven Power-Producing Components (reactor, fuel, etc.)
- Simplified RCS – 2 loops (SGs) with 4 seal-less reactor coolant pumps
- Simplified Passive Safety Systems
- Simplified Non-Safety, Defense-in-Depth (DID) Systems
- Microprocessor, Digital-Technology-Based I&C
- Advanced / Compact Control Room / Electronic Operator Interface
- Optimized Plant Arrangement - Construction, Operation, Maintenance, Safety, Cost
- Extensive Use of Modular Construction – Shorter Construction Schedule

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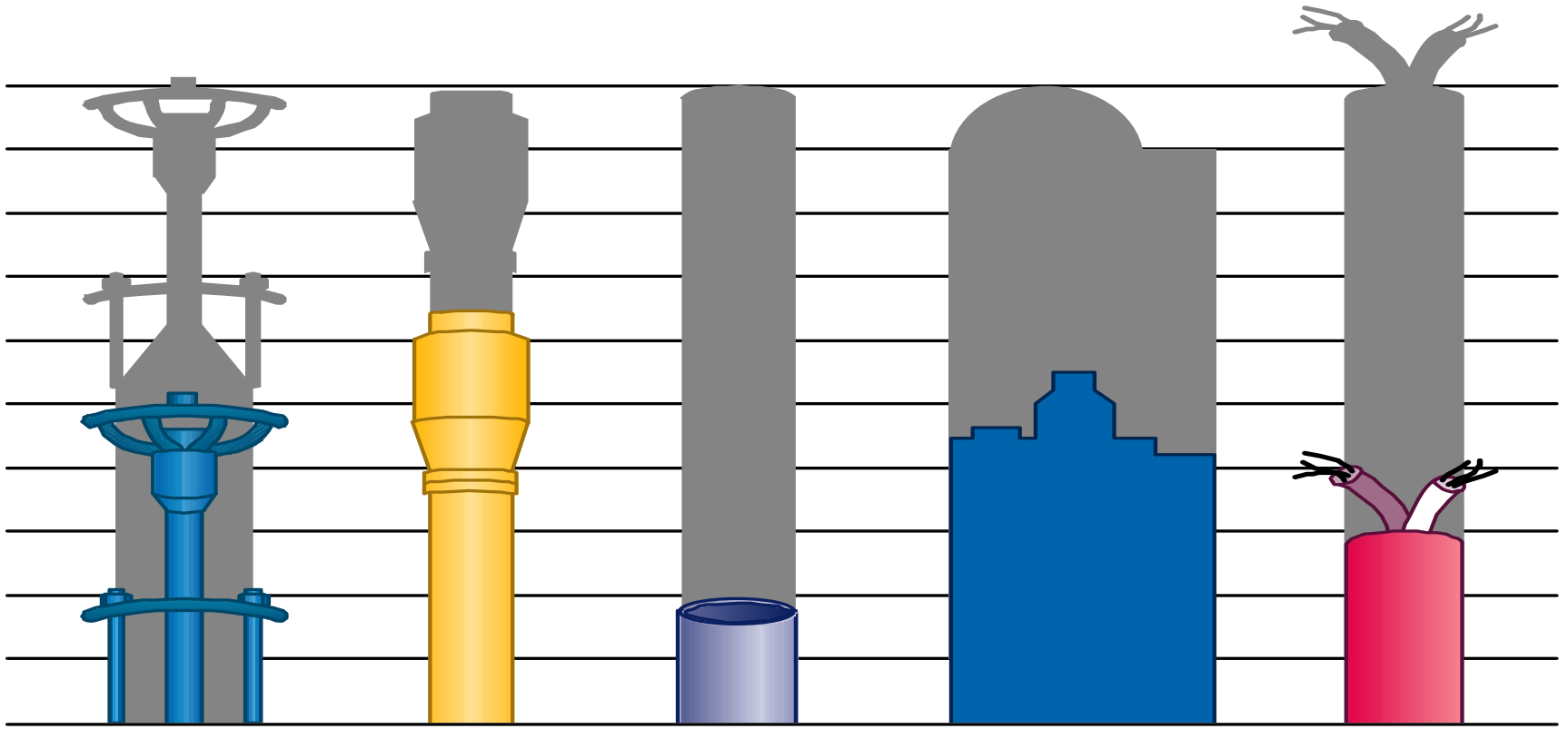
AP1000 Simplifications Drive Economics and Construction Schedule



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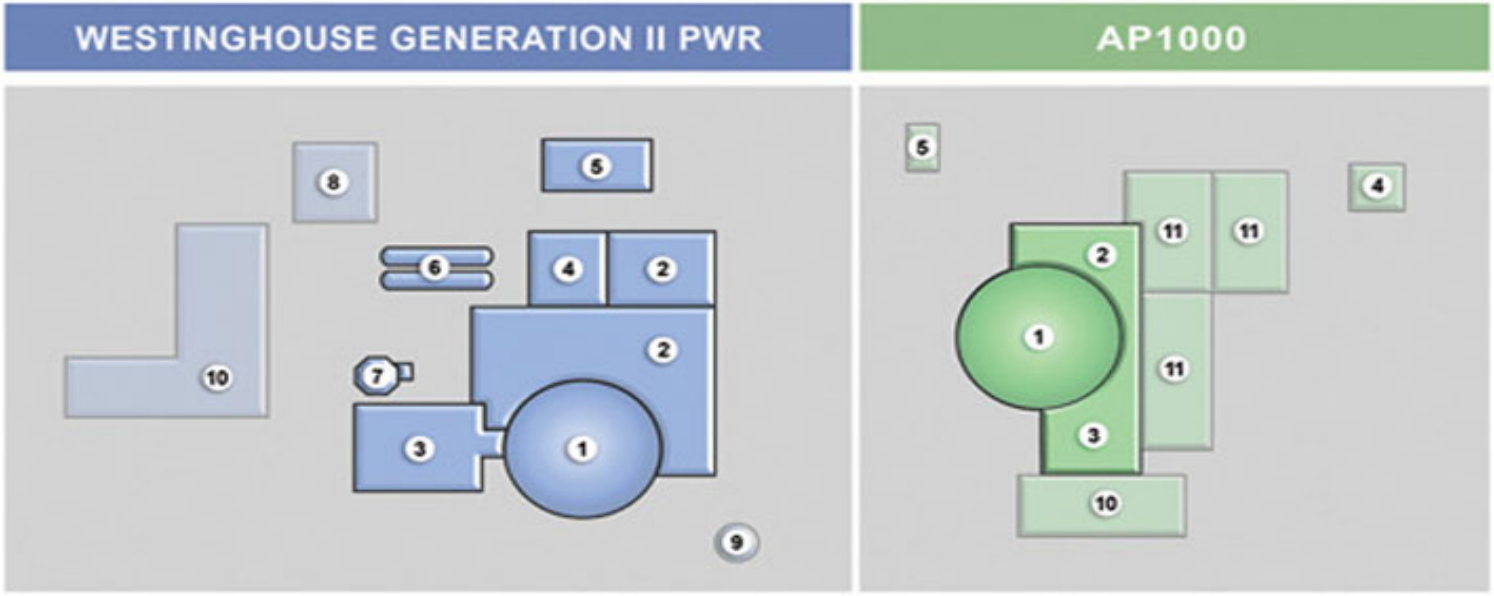
AP1000 is Smaller and Dramatically Simpler than Evolutionary Plants

Comparison of Important Nuclear Island Buildings

AP1000



Darker areas shown are Seismic I category buildings

0 20 40 60 80 100m

1. Shield / Containment
2. Auxiliary Building
3. Fuel Area
4. Diesel Generators
5. Service Water Pumphouse
6. Emergency Fuel Oil Storage
7. Refueling Water Storage Tank
8. Demineralizer / Potable Water Plant
9. Condensate Storage Tank
10. Radwaste Building
11. Annex Building

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AP1000 Design Overview

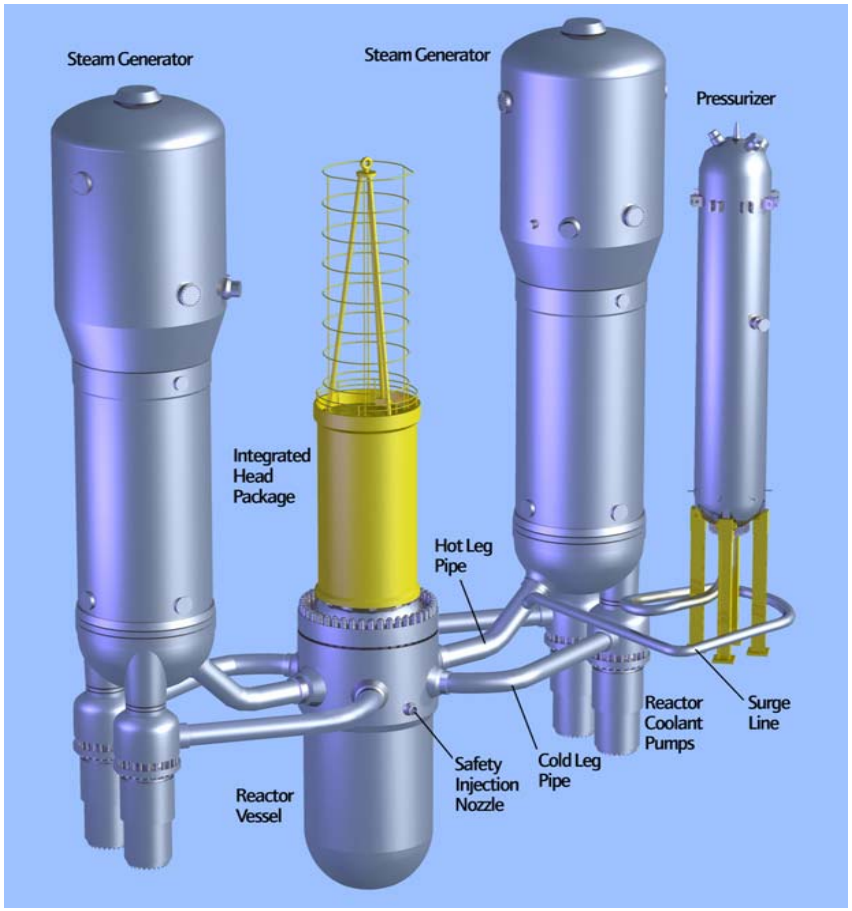
- For the Power Generation Function, AP1000 is a typical Westinghouse PWR with advances in materials and components
  - Fuel
  - Reactor Coolant Loop
  - Pumps
  - Plant Controls
  - Reactor Vessel
  - Steam Generators
  - Turbine
- Reactor Safety Functions are achieved without using any safety-related AC power (accident mitigation without diesel generator operation)
  - Battery Powered Valve Actuation
  - Natural Circulation
  - Compressed gasses (nitrogen, air)
  - Condensation
  - Evaporation
- Passive safety systems actuated by simple, reliable valve position changes. System performance was proven by extensive testing approved by the NRC

AP1000 Design Overview

- Typical PWR safety active systems and safety support systems exist as simplified non-safety systems located in non-safety building structures
  - Diesels
  - Chilled Water
  - Component Cooling
  - Spent Fuel Cooling
  - Diesel Support Systems (Fuel Oil, HVAC)
  - Instrument Air
  - Hot Water (heating)
  - Essential Service Water
  - Residual Heat Removal
  - Startup Feedwater (replaces Auxiliary Feedwater)
- There are no safety-related pumps in the plant and no safety-related ventilation systems.
- The non-safety active systems are credited in the PRA, but are not required for reactor safety and are not required to achieve NRC required CDF
- Severe accident scenarios are mitigated by In-Vessel Retention (IVR) of the melted fuel (the core is retained in a cooled reactor vessel)

Proven AP1000 Major Components

- **Fuel, Internals, Reactor Vessel**
  - 14-foot XL core (Doel / Tihange / S. Texas)
  - Gray rods / rapid power reduction system
  - 3-loop RV w/ CE shroud / 18-month cycle
  - No bottom-mounted instrumentation
- **Steam Generators (inconel 690 TT tubes)**
  - Similar to large W/CE SGs in operation
    - System 80, ANO RSG
    - 1200 MWe / 2 SGs instead of 4 SGs
- **Reactor Coolant Pumps**
  - Seal-less pumps, no shaft seals, intermittent CVS operation
    - Early commercial reactors (Shippingport, Yankee Rowe) / extensive experience
  - Variable speed (start at ~20% speed)
  - 2 RCPs per SG w/ no cross-over leg
- **Pressurizer**
  - About 50% larger than operating plants
- **Simplified Main Loop**



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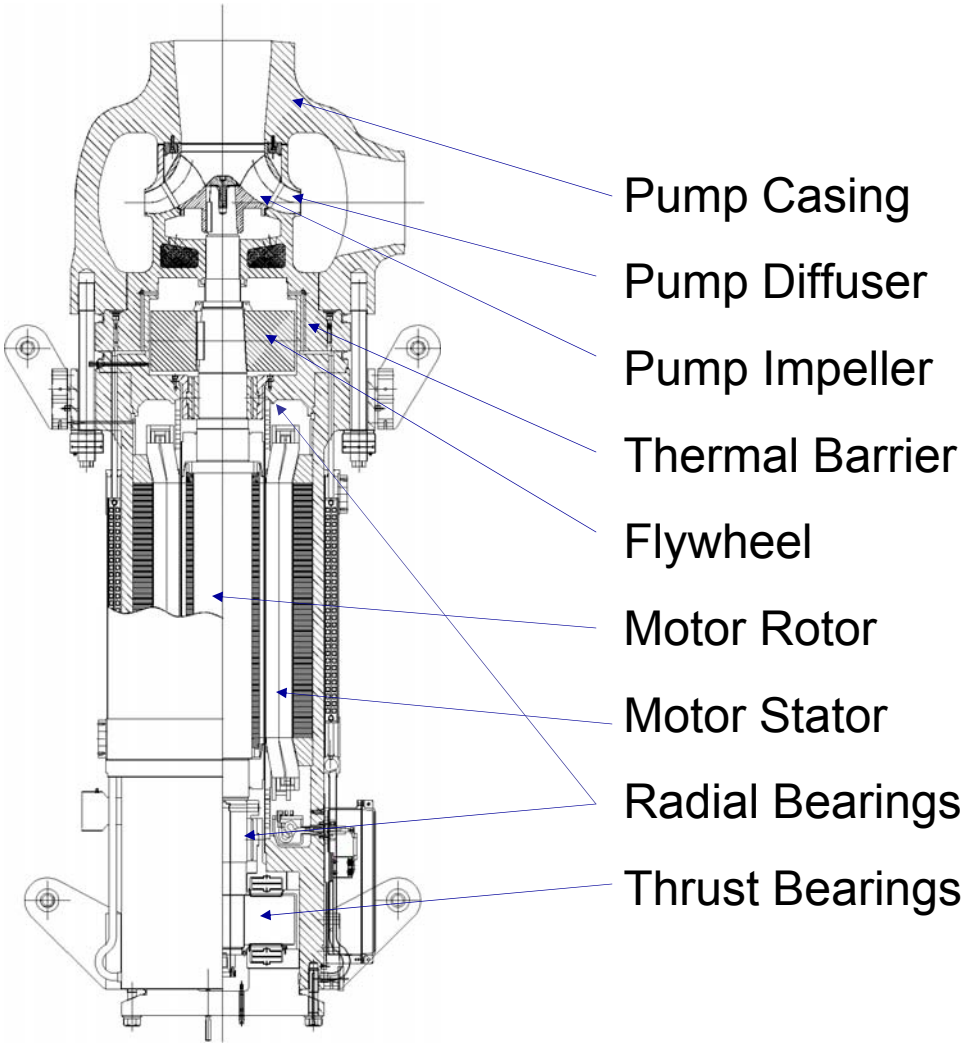
AP1000 Reactor Coolant Pump



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Passive Safety Features

- **Passive Safety Equipment Design**
  - Reliable, experienced based, nuclear grade equipment
  - Design to ASME, Seismic I, full fire / flood / wind protection
  - Availability controlled by Technical Specification with shutdown requirements
    - Technical Specification surveillance requirements reference Inservice Testing program
  - Reliability controlled by Inservice Inspection, Inservice Testing, and maintenance programs

Passive Safety Features

- **Residual Heat Removal**
  - Natural circulation heat exchanger connected to reactor coolant system
- **Safety Injection**
  - Natural circulation / gravity drain core makeup tanks (at reactor coolant system pressure)
  - Nitrogen pressurized accumulators (700 psig / ~50 Kg/cm)

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Passive Safety Features

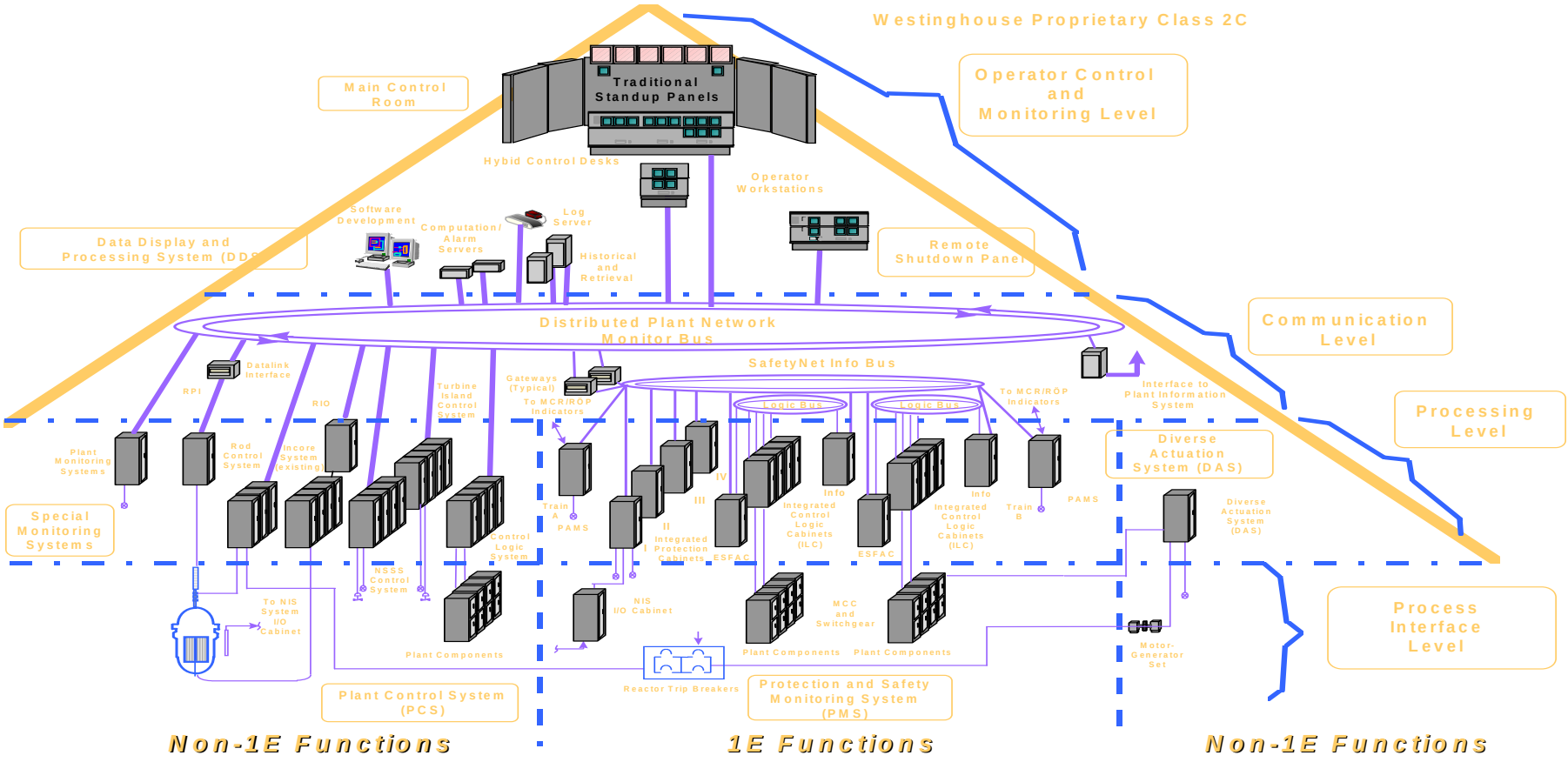
- **Containment Isolation**
  - Prevents or limits escape of fission products that may result from postulated accidents.
- **Gravity drain refueling water storage tank (at containment pressure)**
  - Automatic transition to gravity recirculation (at containment pressure)
  - Automatic depressurization valves (6 from pressurizer / 4 from hot legs)

Passive Safety Features

- **Containment Cooling**
  - Natural circulation of air / evaporation of water on outside surface of steel containment vessel
- **Radiation Removal from Containment Atmosphere**
  - Natural circulation / removal mechanisms
- **Main Control Room Habitability**
  - Compressed air pressurization of main control room envelope

AP1000 BOP Design

- Single Turbine-Generator
  - 1 - HP, 3 - LPs
  - 2 Moisture-Separator Reheaters
- 3 Condensers and 3 (50%) Condensate Pumps
  - 4 LP Feedwater Heating Stages
- 1 De-aerator / Storage Tank



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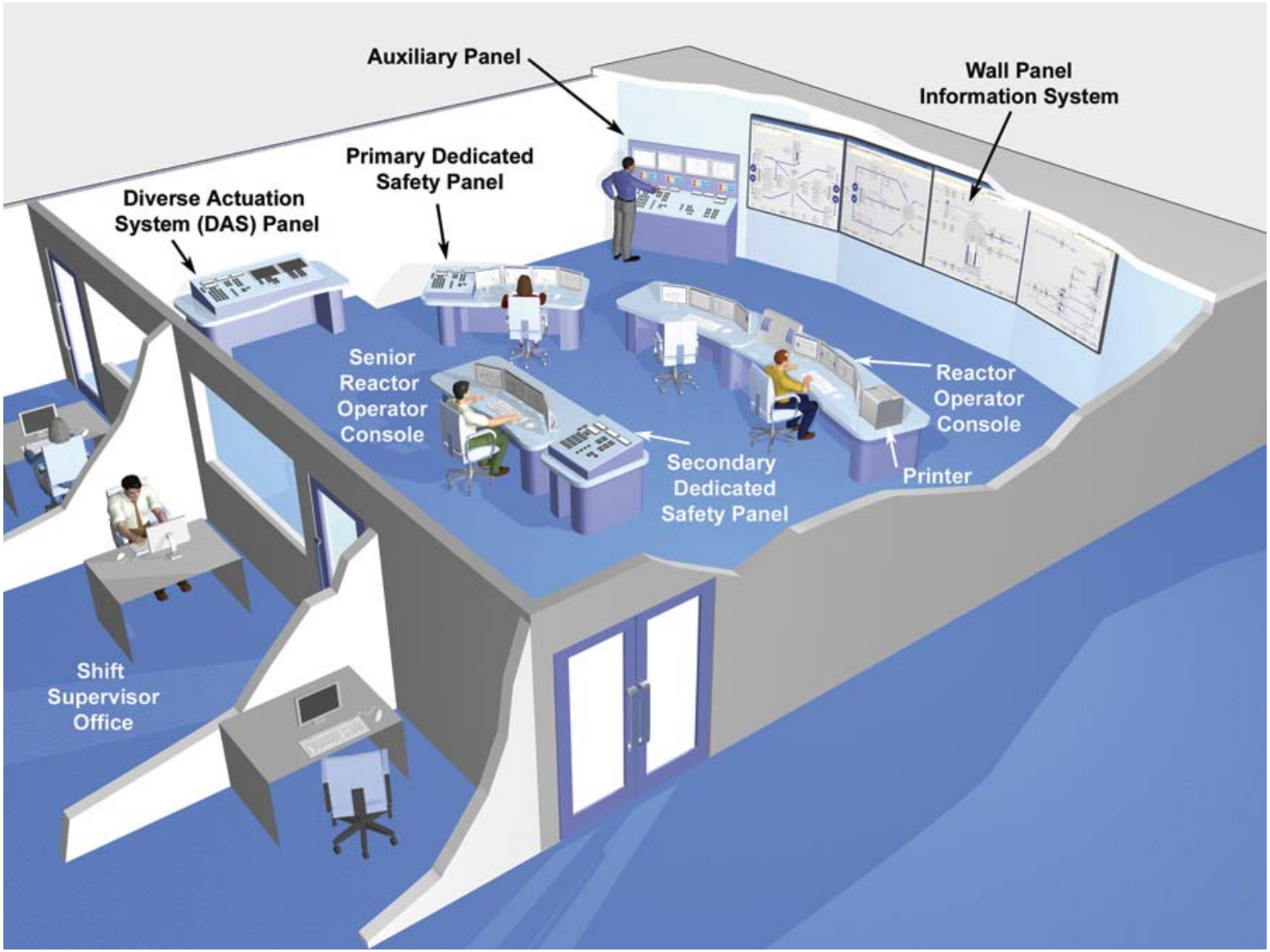
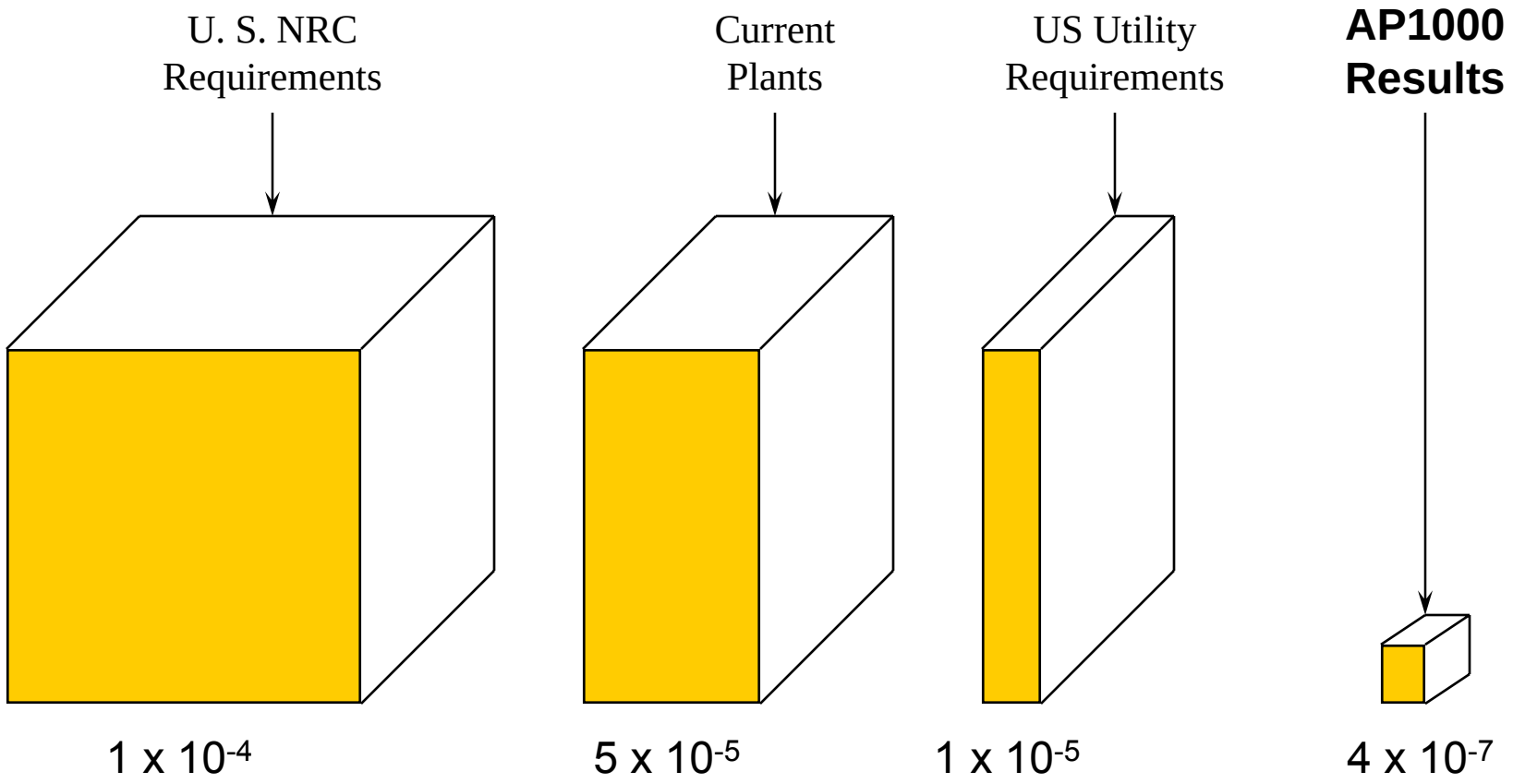
AP1000 Compact Control Room



Advanced Control Room

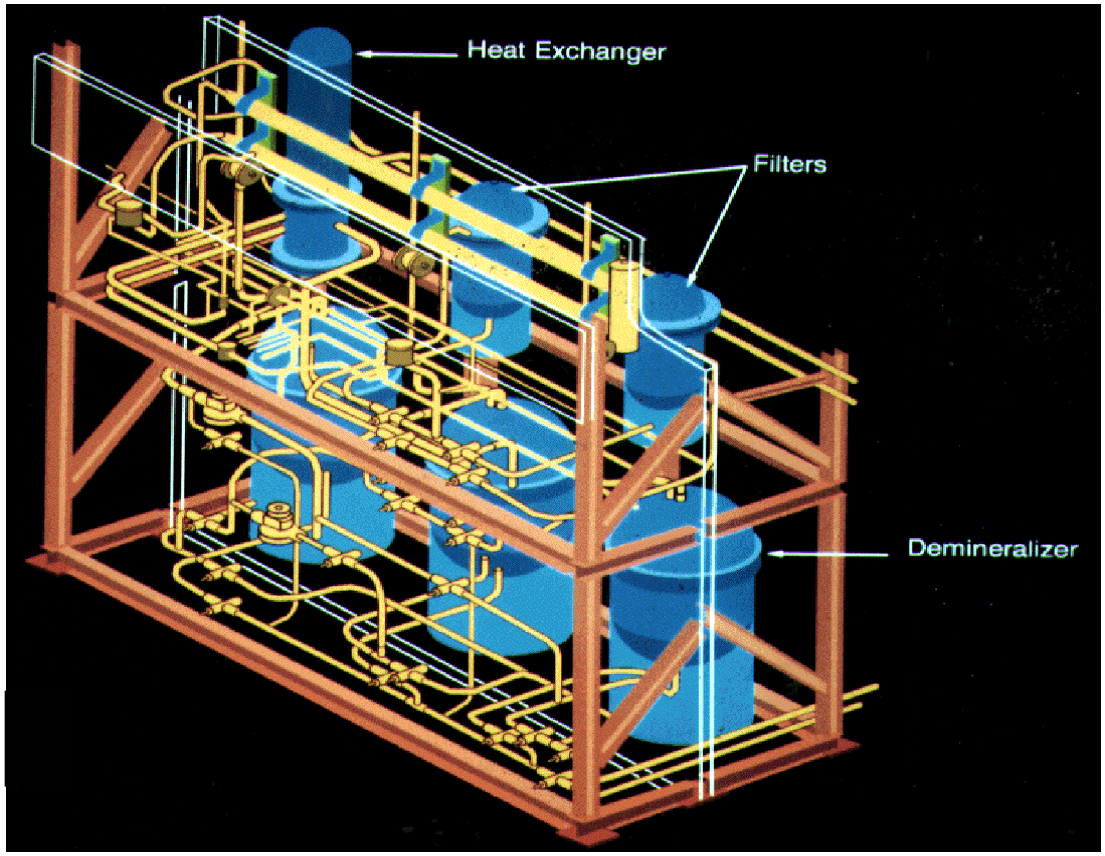
AP1000 Provides Safety Protection



AP1000 General Arrangement

- **Maintenance / Inspection**
  - Improved Larger containment diameter
  - Increased laydown area inside containment
  - Access platforms provided for equipment maintenance / inspection
- **Improved Access to Containment**
  - Equipment hatch(s) access from auxiliary building
  - Equipment hatches and personnel airlocks at both grade and operating deck levels
- **Improved Separation**
  - Radioactive vs nonradioactive
  - Fire areas, especially inside containment
  - Safety vs nonsafety

CVS Equipment Module



AP1000 Classification Overview

- Safety and seismic classification of plant structures, systems, and components (SSCs)
  - Safety-related functions are protected during design basis events
    - Maintain reactor coolant pressure boundary integrity
    - Establish and maintain safe shutdown of the reactor
    - Prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to 10 CFR 100 limits

AP1000 Seismic Classification

- Safety-Related SSCs (Seismic C-I)
  - Withstand appropriate seismic loads and other applicable loads without loss of function AND protected from adjacent non-seismic structures
- Nonsafety-Related SSCs (Seismic C-II)
  - Preclude nonsafety-related SSC structural failure or interaction with C-I SSCs which could unacceptably degrade safety-related structure SSC, or cause incapacitating injury to main control room occupants
- Nonsafety-Related SSCs (Non-Seismic)
  - Non-seismic SSCs are those that are not classified C-I or C-II

AP1000 Safety Classification

- Conforms to 10 CFR 50.55a for the development of a Quality Group classification and the use of codes and standards
- Developed considering requirements and guidelines of:
  - ANSI N18.2 (Reference 1) – Safety Classification
  - ANS 51.1 (Reference 2) – Safety Classification
  - Regulatory Guide 1.26 – Quality Groups
  - Regulatory Guide 1.97 – Instrumentation Requirements
  - 10 CFR 21, Reporting of Defects and Noncompliance

AP1000 Safety Classification

- **Safety-Related Classes A/B/C**
  - Equivalent to ANS Safety Class 1/2/3 for mechanical equipment
  - Equivalent to Class 1E for electrical equipment
  - Seismic Class C-1
- **Class A (ANS Class 1)**
  - Reactor coolant system pressure boundary
  - Includes isolation valves and mechanical supports
  - Provides highest integrity and lowest leakage probability

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AP1000 Safety Related SSCs

- **Class B (ANS Class 2)**
  - Limits leakage of radioactive material from containment following a design basis accident
  - Fission product barrier or primary containment radioactive material holdup or isolation
- **Class C (ANS Class 3)**
  - Other safety-related functions required to mitigate design basis accidents / events and NOT in Class A/B
  - Minor leakage will not prevent Class C structures, systems, and components from meeting the safety-related function

AP1000 Safety Classification

- **Class D - Nonsafety-Related SSCs**
  - SSC containing radioactivity
  - SSCs that act to prevent unnecessary actuation of passive safety systems
  - Some additional requirements on procurement, inspection, or monitoring beyond other nonsafety-related class requirements
  - 10CFR50 Appendix B / 10CFR21 do NOT apply
- **Other Nonsafety-Related SSCs**
  - SSCs NOT covered in the above classes
  - Have no safety-related functions to perform
  - Do NOT contain sufficient radioactive material that a release could exceed applicable limits

AP1000 RPV Design Requirements

- ASME and ANS codes and standards
- Electric Power Research Institute
  - ALWR Utility Requirements Document
- Welding Research Council bulletins
- ASTM Standards
- NRC requirements:
  - U.S. Code of Federal Regulations,
  - NRC Orders, NRC Regulatory Guides
  - NRC NUREG publications

AP1000 RPV Design Specification - 1

- **Sections 3.0 and 4.0 – Functional Description**
  - provide a functional description of the RPV
  - define all of the safety, design and seismic classifications
- **Sections 5.0 and 6.0 - Design and Analysis**
  - define the design and analysis boundaries for the RPV
  - establish the design requirements and parameters for completing the analysis and Design Report

AP1000 RPV Design Specification - 2

- **Section 7.0 - Material**
  - selection of ASME materials for pressure boundary, structural parts, and items of RPV
  - detailed requirements for Alloy 690 material with optimized resistance to PWSCC
  - special limits on beltline material residual elements to minimize radiation damage effects
  - other material requirements beyond Section III requirements and the requirements of the applicable ASME materials specification from Section II of the Code

AP1000 RPV Design Specification - 3

- **Sections 8.2 - Fabrication**
  - special fabrication processing requirements in more detail than provided by NB-4000
  - additional controls are imposed on:
    - welding processes
    - selection of weld filler materials
    - post-weld heat treatment requirements
    - other special processes
      - thermal cutting and cleaning procedures

AP1000 RPV Design Specification - 4

- **Section 8.3 – Examination**
  - addresses examination requirements for RPV materials and welds
    - for compliance with Code requirements
    - other industry standards for examinations in addition to the Section III examinations
- **Section 8.4 – Testing**
  - additional testing requirements include material testing beyond minimum Code requirements
  - such as fracture mechanics tests

AP1000 RPV Design Specification - 5

- **Section 8.5 – Surveillance Program**
  - defines type and quantity of materials to be provided with the RPV
    - machined into specimens
    - installed in surveillance capsule in RPV to monitor response of beltline materials to fluence over lifetime of plant
- **Section 8.6 – Archive Materials**
  - materials retained as contingency, in event that additional testing or characterization of material is needed to resolve an issue during the course of plant operation

AP1000 RPV Design Specification - 6

- **Pre-service and In-service Inspection**
  - techniques, procedures and personnel qualification requirements used to perform PSI are required to be the same as those that will be used to perform the ISI during operation
  - current Section XI performance based requirements for RPV PSI/ISI use sophisticated automated systems with computerized data acquisition systems

AP1000 RPV Design Specification - 7

- **Section 9.0 – Quality Assurance**
  - Subpart 1 of NQA-1-94
    - (equivalent to NQA-1-89 edition and up to the 1992 Addenda)
  - number of other aspects of NQA-1-94 Subpart 2 (formerly NQA-2)
    - cleaning, cleanliness criteria
    - packaging, shipping, handling requirements
  - Fabricator oversight
- **Section 10.0 – Packaging and Shipping**
  - addresses preparation for shipment of the RPV

Summary and Conclusion

- AP1000 Key Features
  - 2 Loop Reactor Coolant System
    - Seal-less pumps
  - Passive Safety Systems
  - Non-Safety Defense-in-Depth Systems
    - previously safety systems
  - Digital I&C Systems with data highway
- AP100 Meets requirements of:
  - ASME and ANS codes and standards
  - Regulatory requirements
  - Other industry requirements

Questions

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