
Westinghouse AP1000™ Technology 西屋AP1000技术

Japan-China Science and Technology Exchange

Association 中日科学技术交流协会

June 6th, 2011

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主讲：中国项目技术经理 Mostafa A. Ahmed 博士

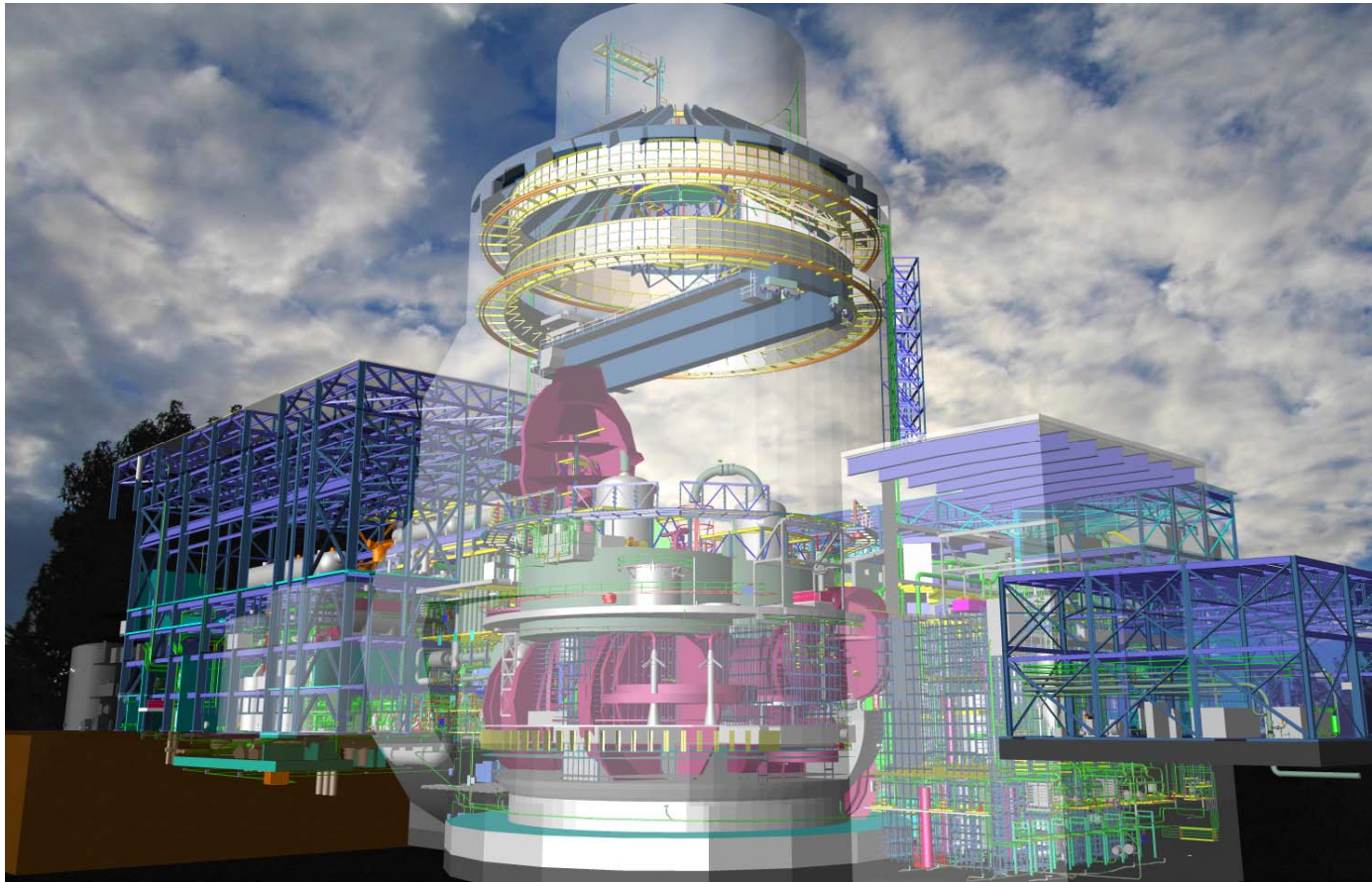


Agenda 大纲

- Introduction of AP1000™ AP1000简介
- Safety Features of AP1000™ AP1000的安全特性
- Summary 总结

AP1000 ... Simple and Safe by Design

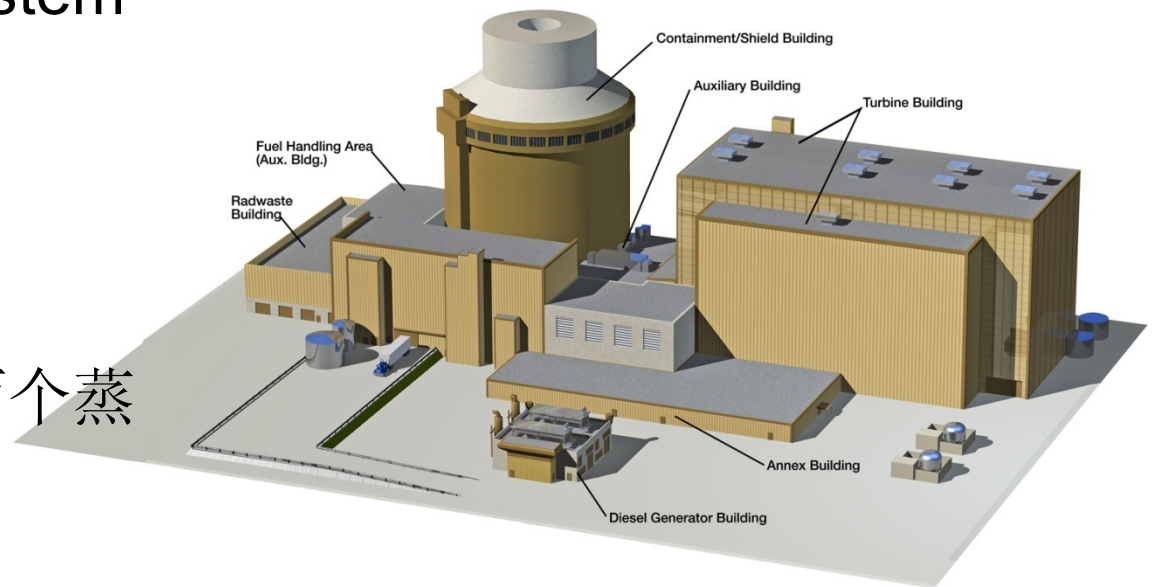
AP1000设计更为简化安全



Westinghouse AP1000 西屋AP1000技术

A Compact station 紧凑型电厂

- 3415 MWt, primary system
3415MWT 主系统
- 1117 Mwe 1117 Mwe
- Two-loops, two steam generators 双回路，两个蒸汽发生器



China Project 中国项目

AP1000 Units in China 在建AP1000机组

AP1000 selected as the Generation 3 technology for deployment in China

AP1000 中国项目选择了AP1000作为第三代技术

Construction is underway or the first four units: 在建四个机组

- Two units at Haiyang 两个海阳机组
- Two units at Sanmen 两个三门机组

First unit begins operation in 2013
第一台机组2013年开始发电

Fourth unit begins operation in 2015
2015年前四台机组均投入发电



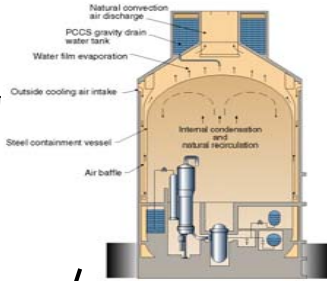
Westinghouse >20 Year of Investment in Passive Technology

西屋超过20年的非能动技术的研究

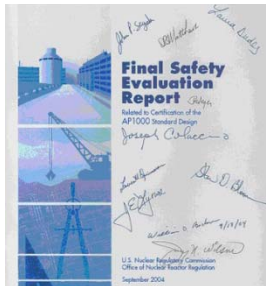
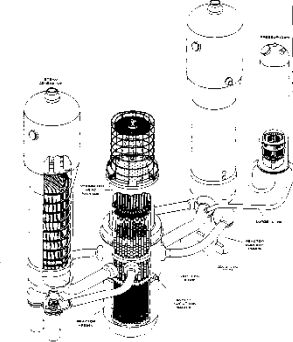
Extensive Testing of Passive Safety Systems
深入测试非能动安全系统



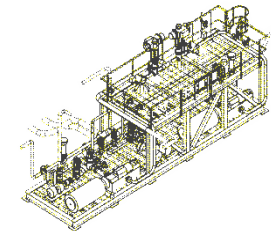
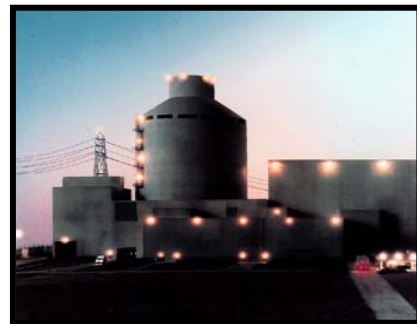
Simplified Passive Safety Systems
简化的非能动安全系统



Proven Advanced Design Features
成熟的先进设计特征

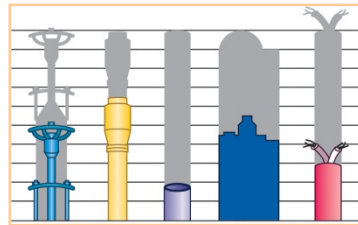
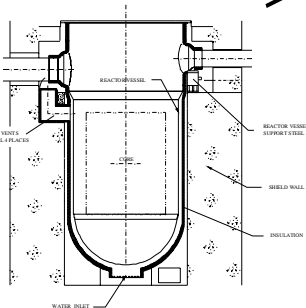


US Licensing Approval
美国取证



Modular Construction
模块化施工

PRA and Severe Accident Mitigation Features
概率风险评估和严重事故缓解特征



Reduced Components and Commodities
设备部件的简化

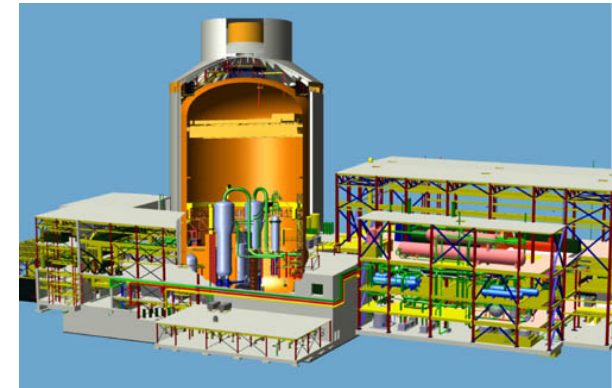
Item	Description	Quantity	Unit	Material	Notes
1	Structural Steel	1000	kg	A36	
2	Insulation	500	m ²	Rockwool	
3	Shield Wall	1	unit	Concrete	
4	Reactor Vessel	1	unit	Steel	
5	Support Steel	200	kg	A36	
6	Water Inlet	1	unit	Steel	
7	Air Baffle	1	unit	Steel	
8	Water Film Evaporator	1	unit	Steel	
9	Outside Cooling Air Intake	1	unit	Steel	
10	Natural Convection Air Discharge	1	unit	Steel	
11	PCCS Gravity Drain Water Tank	1	unit	Steel	
12	Internal Condenser	1	unit	Steel	
13	Steel Containment Vessel	1	unit	Steel	

Short Engineering and Construction Schedule
设计施工期短

Simplification and Standardization...

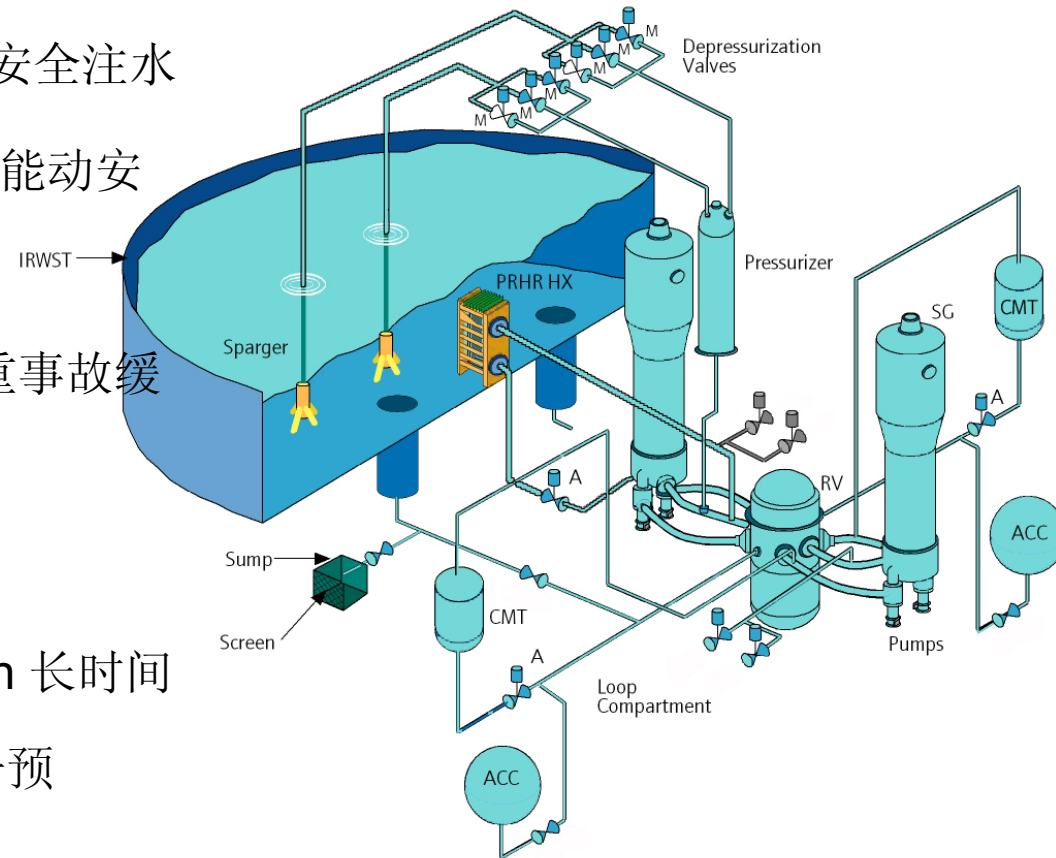
简化和标准化

- Simplicity and standardization in **Design** through reduced number of components and bulk commodities 大量部件和大宗设备的减少使得设计更加简化标准化
- Simplicity in **Safety** through use of passive safety systems 采用非能动安全系统更容易达到安全性
- Simplicity in **Construction** through modularization 模块化简化施工
- Simplicity in **Procurement** through standardization of components and plant design 标准化部件和电厂设计简化采购
- Simplicity in **Operation and Maintenance** through use of proven systems and components, and man-machine interface advancements 使用成熟系统元件，改进型人机界面使操作和维护更为简便

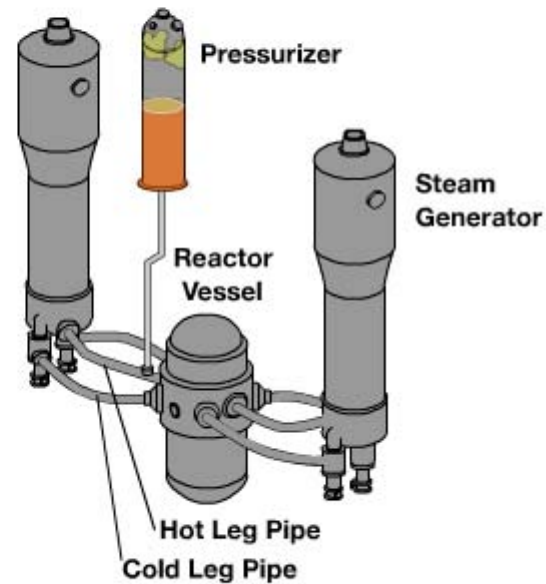


Passive Core Cooling System 非能动堆芯冷却系统

- Passive safety injection 非能动安全注水
- Passive containment cooling 非能动安全壳冷却
- Several Accident Mitigation 严重事故缓解措施
- Long term safe shutdown state:
72 hours without operator action 长时间的
安全停堆：72小时不需外界干预

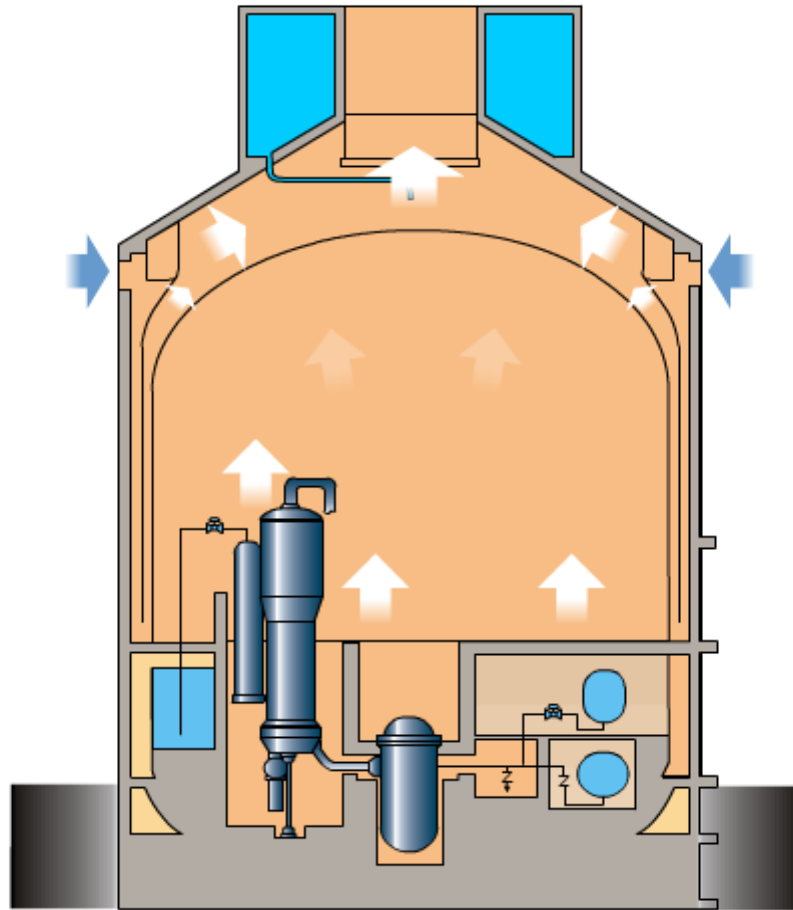


Passive Core Cooling System Operation During a Small-Break LOCA 小破裂失水事故的非能动堆芯冷却系统的运行



Passive Containment Cooling Operation During a LOCA

失水事故的非能动安全壳冷却过程



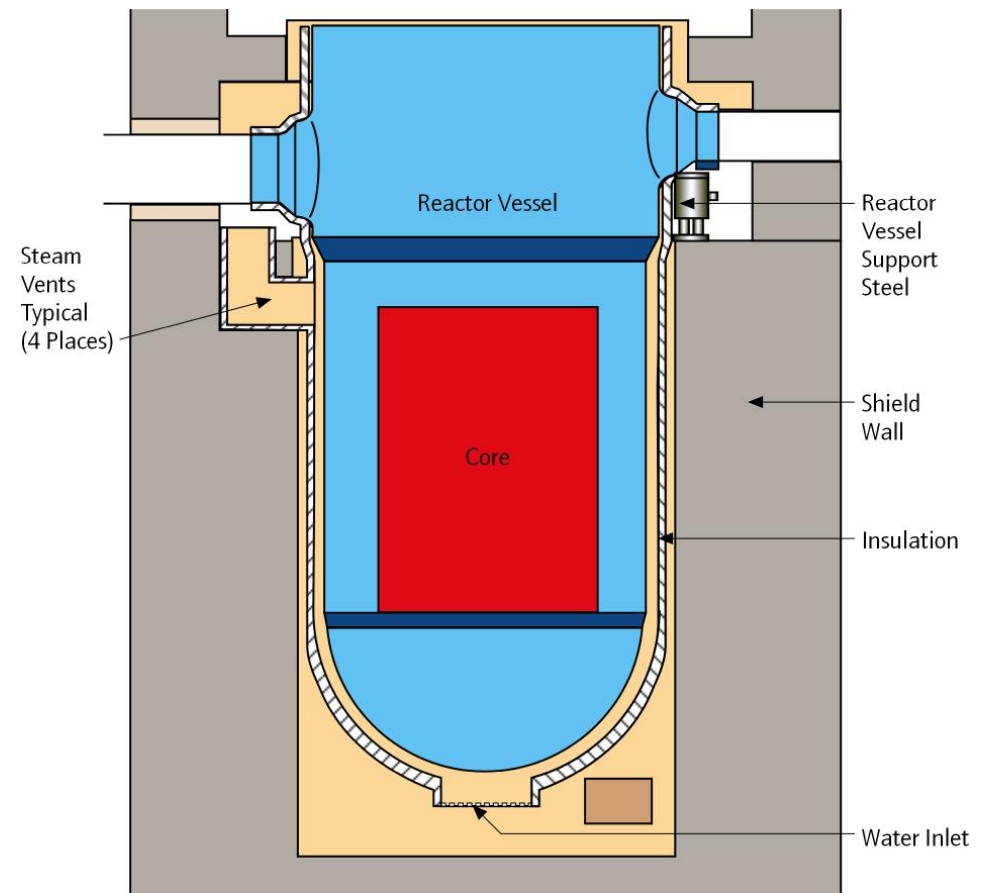
Severe Accident Mitigation Design

In-Vessel Retention

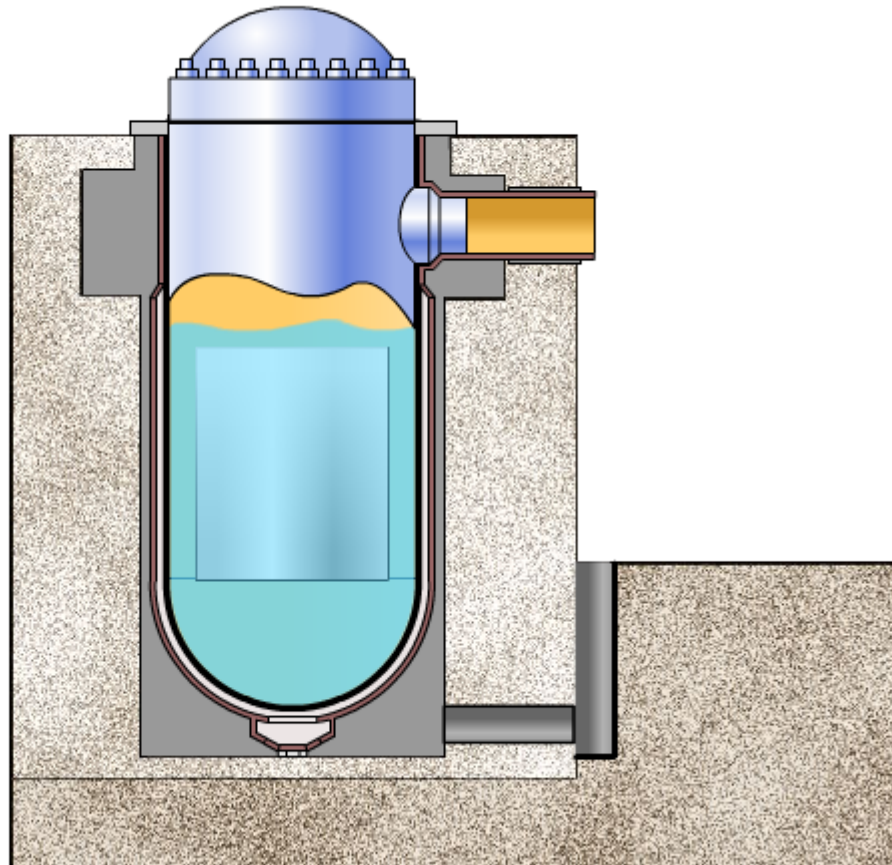
严重事故缓解设计 压力容器内滞留

In the unlikely event of core melt
在可能性不大的融堆情况下

- AP1000 designed to retain core debris within the reactor vessel AP1000的熔渣会留在反应容器内
- Large release frequency: 5.9×10^{-8} per reactor year; Utilities Requirements: $<10^{-6}$ per reactor year 大量释放频率： 5.9×10^{-8} 每堆年；美国公共事业要求： $<10^{-6}$ 每堆年



In-vessel Retention for Severe Accident Management 严重事故控制的安全壳内滞留



Safety Features of AP1000™

AP1000的安全性特征



AP1000 Station Blackout (SBO) Coping Features

AP1000对全厂断电的应对特性

- **Passive Safety Systems** 非能动安全系统
- **On-site water sources dedicated to safety** 专用于安全的厂内水源
 - **In-Containment Refueling Water, CMTs, and ACCs for core cooling** (2300 m³)
用于堆芯冷却的安全壳内换料水，堆芯补水箱以及安注箱（2300 m³）
 - **Passive Containment Cooling Water** (2900 m³)
非能动安全壳冷却水(2900 m³)
 - **Spent Fuel Pool, above top spent fuel** (900 m³)
乏燃料池，于乏燃料之上（900 m³）
 - **Ancillary Water Tank for containment and/or spent fuel cooling** (3500 m³)
用于安全壳和/或乏燃料池冷却的辅助水箱(3500 m³)

AP1000 Station Blackout (SBO) Coping Features - Cont.

AP1000对全厂断电的应对特性 – 续

- DC power sources 直流电源
 - Class 1E 24-hour capability for safety device actuation
 - 用于安全装置驱动的24小时能力的安全1E级
 - Class 1E 72 hour capability for Post Accident Monitoring (PAMS) system
 - 用于事故后监测系统的72小时能力的安全1E级
 - Non-1E batteries – for Control Room Indication, Diverse Actuation System (DAS) 2 hr, and H² Igniters (4 hr)
 - 用于控制室指示，多样化驱动系统两小时，氢气点火器 4小时的非1E级电池
 - Remote DAS - 4 hour battery
 - 远程控制多样化驱动系统-4小时电池
- Alternative AC power source, for post-72 hours support 其它交流电源，用于事故72小时后的支持
 - Two 80 kW Ancillary Diesels
 - 两台80KW辅助柴油机

AP1000 Passive Safety System Features

AP1000 非能动安全系统特性

- Core and Containment Cooling After Trip (0 to 3 days)

停堆后堆芯和安全壳的冷却（0到3天内）

- Air operated valves will move to a safe-shutdown position on PMS actuation signal or on loss of plant air or on loss of power (1E DC)

事故后由於保护及安全监测系统驱动信号起动，或失去电厂仪表压缩空气，或失去电源（1E级直流电）都会使气动阀移动到安全停堆位置

- Natural circulation cooling of the RCS via the Passive RHR Heat Exchanger.

通过非能动余热排出系统热交换器进行冷却剂系统的自然循环冷却。

- Core Makeup Tanks borate and maintain RCS inventory.

堆芯补水箱对冷却剂系统进行硼化并确保其容量。

- Passive Containment Cooling provides containment cooling.

非能动安全壳冷却系统提供安全壳冷却。

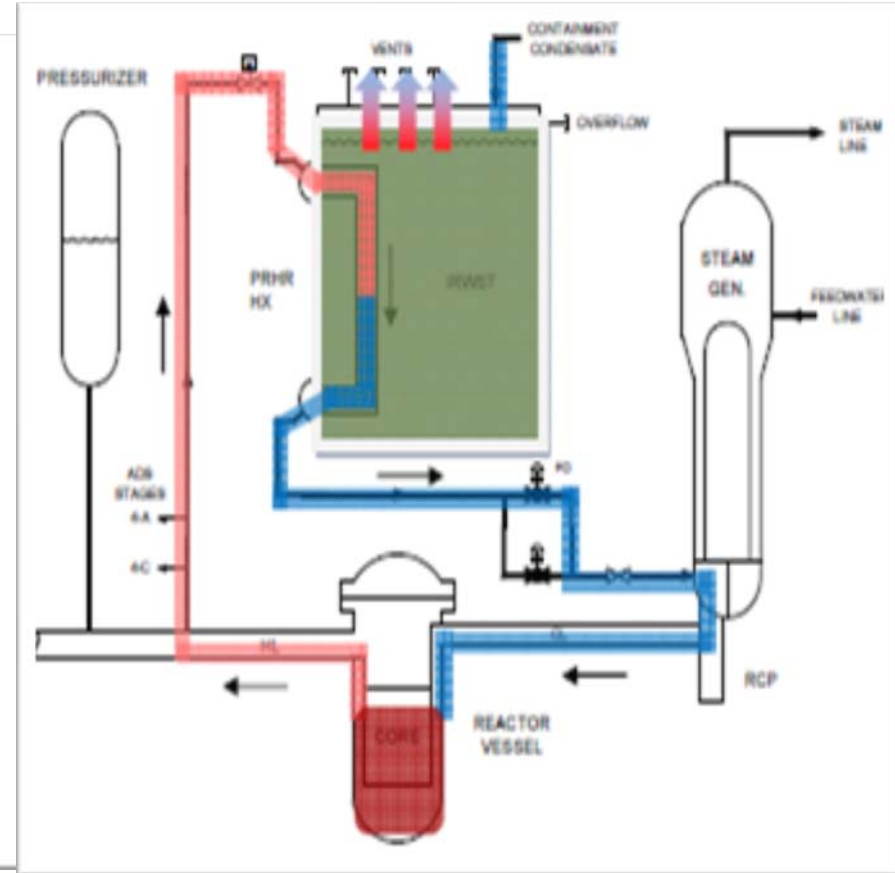
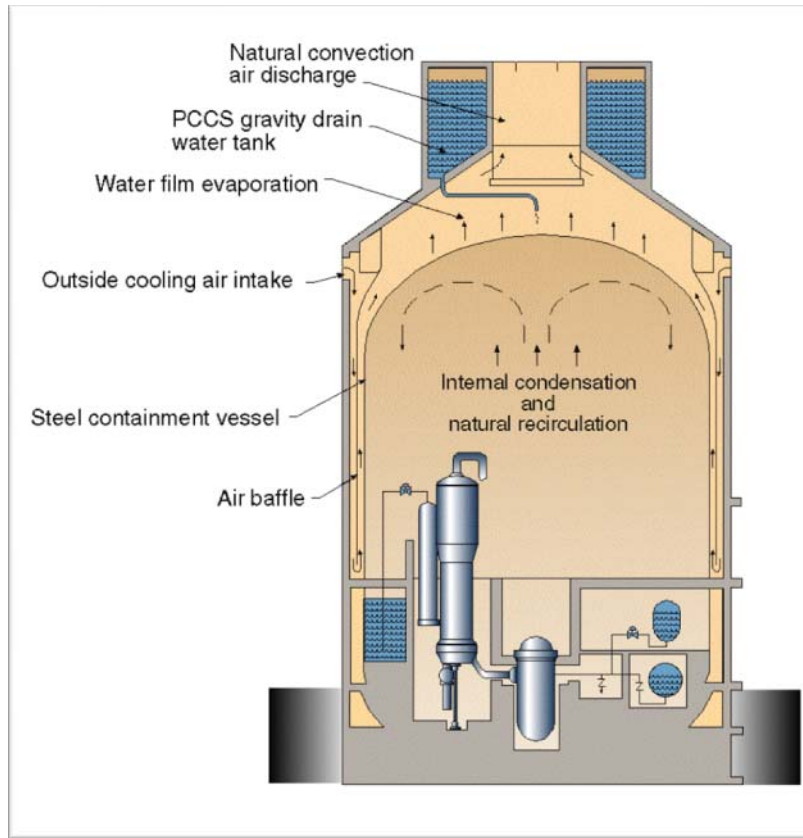
AP1000 Passive Safety System Features - Cont.

AP1000非能动安全系统特性 – 续

- Core and Containment Cooling After Trip (0 to 3 days)
 - 停堆后堆芯和安全壳的冷却（0到3天内）
 - Passive injection from ACCs, IRWST, long-term gravity recirc controlled by Automatic Depressurization System (ADS) actuation by PMS 由安注箱非能动注入，安全壳内换料水箱注入以及由保护及安全监测系统驱动的自动降压系统来控制的长期重力再循环。
 - Only required if there is a significantly loss of reactor coolant
 - 只有在严重的失去反应堆冷却水情况下需要
 - Manual actuation of ADS also possible from DAS panels (MCR or remote)
 - 可以通过多样化驱动系统盘柜进行手动驱动自动降压系统（从主控室或从远程控制）
 - Spent Fuel Cooling after loss of AC失去交流电后的乏燃料冷却
 - Water heatup and boil-off with gravity makeup from safety sources
 - 水加热或蒸发可通过安全设施进行重力补充。

Passive Core and Containment Cooling Core Decay Heat Transferred to Atmosphere

非能动堆芯和安全壳冷却系统将堆芯衰变热转移到大气中



AP1000 Post-72 Hour Features – Cont.

AP1000事故后72小时后特性 – 续

- Core Cooling maintained (PRHR and CMTs)
堆芯保持冷却（非能动余热排出和堆芯补水箱）
- Spent fuel and containment cooling (3 to 7 days)
乏燃料池和安全壳的冷却（3到7天）
 - Ancillary Diesels provide AC power for post-72 hour operations.
辅助柴油机提供72小时后运行所需交流电
 - Ancillary Water Storage Tank provides water for containment cooling and the SF pool makeup for up for 4 additional days.
辅助储水箱提供安全壳冷却和乏燃料池补水可达额外4天的冷却
 - PCS recirculation pumps provide water to the spent fuel pool and the containment outer surface.
非能动安全壳冷却系统泵给乏燃料池和安全壳外表面供水
 - Permanently installed seismic connections together with onsite or pre-defined offsite assistance provides backup to ancillary equipment.
永久安装的抗震连接可与厂内或预先确定的厂外设施提供辅助后援

AP1000 Equipment and Systems that Functions After Tsunami

AP1000 在海啸后发挥功能的设备和系统

- **Passive Core Cooling System (PXS) 非能动堆芯冷却系统**
 - ‘Fail-Safe’ Functions Operational ‘故障安全’功能可用
 - Core Make-up Tanks (Coolant Injection) 堆芯补水罐（冷却剂注入）
 - PRHR HX (Decay Heat Removal) 非能动余热排出热交换器（衰变热带出）
- **Passive Containment Cooling System (PCS) 非能动安全壳冷却系统**
 - ‘Fail-Safe’ functions intact and operational ‘故障安全’功能未受损且可用
- **Diverse Actuation System (DAS) Alternate Workstation Operational 多样化驱动系统备用工作站可用**
 - Located above flood level in Auxiliary (RCA) Building 位于辅助厂房（放射性控制区）水淹平面以上
 - 4 hour battery provides limited indication and control 4小时电池提供有限的指示和控制
 - After 4 hours can use portable meters and electro-mechanical squib actuators 4小时后可使用便携式仪表和机电爆破驱动器

Summary

总结

AP1000 Post-72 Hour Features

AP1000事故后72小时后特性

- Spent fuel and containment cooling (7 days and beyond)
乏燃料池和安全壳冷却（7天及以后）
 - Additional water sources aligned for continued spent fuel and containment cooling.
— 为持续的乏燃料和安全壳冷却设置了额外的水源

AP1000 Designed for Indefinite SBO Coping
AP1000 的设计考虑了无限期的全厂断电的应对

AP1000 Response Summary

AP1000 响应总结

- The AP1000 maintains nuclear safety throughout scenarios
在所有的方案下，AP1000都保持了核安全
 - No fuel damage is predicted in either the Core or the Spent Fuel Pool
无论在堆芯或在乏燃料池都预期不会产生燃料破损
 - No hydrogen is generated during the plant response
在电厂响应期间无氢气产生
 - Peak cladding temperature maintained below H2 generation limits on all fuel assemblies 所有燃料组件的包壳温度峰值仍保持在氢气产生的限值以下