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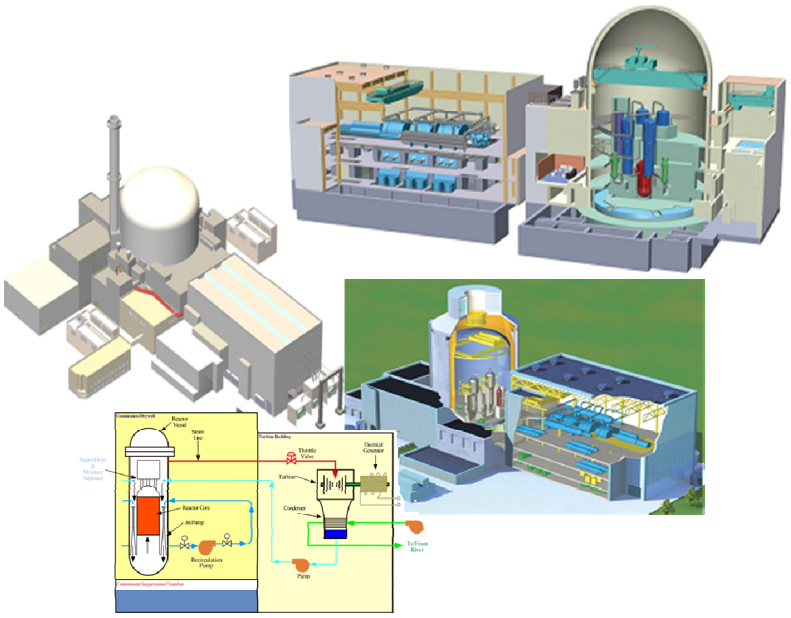

Part I

Introduction to Reactor Technology - PWR

Chapter 5.0 Advanced PWR Designs

HRTD
Human Resources
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UNITED STATES

NUCLEAR REGULATORY COMMISSION

HUMAN RESOURCES TRAINING & DEVELOPMENT

Introduction to Reactor Technology

This manual is a text and reference document for the Introduction to Reactor Technology for the media briefing. It should be used by students as a study guide during attendance at this course. This manual was compiled by staff members from the Human Resources Training & Development in the Office of Human Resources.

The information in this manual was compiled for NRC personnel in support of internal training and qualification programs. No assumptions should be made as to its applicability for any other purpose. Information or statements contained in this manual should not be interpreted as setting official policy. The data provided are not necessarily specific to any particular nuclear power plant, but can be considered to be representative of the vendor design.

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5.0 ADVANCED PWR DESIGNS

5.0.1 Introduction

Nuclear power plants generate over 20 percent of the electricity produced in this country; however, all recent electric-generating capacity additions and many projected future additions are primarily fueled by natural gas. To help meet the growing demand for new base-load electricity generation, several electric utility companies are looking to expand the role of nuclear energy as a major component of our nation's energy supply. Despite the excellent performance of current nuclear plants and decisions by power plant owners to seek license renewal and power uprates, no new plant has been ordered in this country for more than 25 years.

The Department of Energy (DOE) believes that an over-reliance on a single fuel source, like natural gas, is a potential vulnerability to the long-term security of our nation's energy supply, and new nuclear plants must be built in the next decade to address increasing concerns over air quality and to ease the pressures on natural gas supply.

The recent and expected nuclear power plant applications are listed in Table 6.0-1. These applications include five reactor plant designs, three of which are pressurized water reactors (PWRs). The majority of the sites chosen are located in the southeastern part of the United States.

Table 5.0-1, Expected New Nuclear Power Plant Applications

Expected New Nuclear Power Plant Applications
Updated December 20, 2010

Company (Project or Docket Numbers)	Date of Application	Design	Date Accepted	Site Under Consideration	Number of Units	State	Existing Operating Plant	Status
Calendar Year (CY) 2007 Applications								
NRG Energy (52-012/013)	09/20/07	ABWR	11/29/07	South Texas Project	2	TX	Y	Accepted/Docketed
NuStart Energy (52-014/015)	10/30/07	AP1000	01/18/08	Bellefonte	2	AL	N	Accepted/Docketed
UNISTAR (52-016)	07/13/07 (Envir.) 03/13/08 (Safety)	EPR	01/25/08 06/03/08	Calvert Cliffs	1	MD	Y	Accepted/Docketed Accepted/Docketed
Dominion (52-017)	11/27/07	ESBWR	01/28/08	North Anna	1	VA	Y	Accepted/Docketed
Duke (52-018/019)	12/13/07	AP1000	02/25/08	William Lee Nuclear Station	2	SC	N	Accepted/Docketed
2007 Total Number of Applications = 5 **Total Number of Units = 8**								
Calendar Year (CY) 2008 Applications								
Progress Energy (52-022/023)	02/19/08	AP1000	04/17/08	Harris	2	NC	Y	Accepted/Docketed
NuStart Energy (52-024)	02/27/08	ESBWR	04/17/08	Grand Gulf	1	MS	Y	Accepted/Docketed
Southern Nuclear Operating Co. (52-025/026)	03/31/08	AP1000	05/30/08	Vogtle	2	GA	Y	Accepted/Docketed
South Carolina Electric & Gas (52-027/028)	03/31/08	AP1000	07/31/08	Summer	2	SC	Y	Accepted/Docketed
Progress Energy (52-029/030)	07/30/08	AP1000	10/06/08	Levy County	2	FL	N	Accepted/Docketed
Detroit Edison (52-033)	09/18/08	ESBWR	11/25/08	Fermi	1	MI	Y	Accepted/Docketed
Luminant Power (52-034/035)	09/19/08	USAPWR	12/02/08	Comanche Peak	2	TX	Y	Accepted/Docketed
Entergy (52-036)	09/25/08	ESBWR	12/04/08	River Bend	1	LA	Y	Accepted/Docketed
AmerenUE (52-037)	07/24/08	EPR	12/12/08	Callaway	1	MO	Y	Accepted/Docketed
UNISTAR (52-038)	09/29/08	EPR	12/11/08	Nine Mile Point	1	NY	Y	Accepted/Docketed
PPL Generation (52-039)	10/10/08	EPR	12/19/08	Bell Bend	1	PA	Y	Accepted/Docketed
2008 Total Number of Applications = 11 **Total Number of Units = 16**								
Calendar Year (CY) 2009 Applications								
Florida Power and Light (763)	06/30/09	AP1000	09/04/09	Turkey Point	2	FL	Y	Accepted/Docketed
2009 Total Number of Applications = 1 **Total Number of Units = 2**								
Calendar Year (CY) 2010 Applications								
No Letters of Intent have been received from applicants expressing their plans to submit new COL applications in CY 2010								
2010 Total Number of Applications = 0 **Total Number of Units = 0**								
Calendar Year (CY) 2011 Applications								
Blue Castle Project		TBD		Utah	1	UT	N	
Southern		TBD		TBD	1		TBD	
Unnamed		TBD		TBD	1		TBD	
Unnamed		TBD		TBD	1		TBD	
2011 Total Number of Applications = 4 **Total Number of Units = 4**								
2007 - 2011 Total Number of Applications = 21 **Total Number of Units = 30**								

5.0.2 Plant Comparisons

This manual provides a brief description of each of the 3 different PWR designs: the AREVA US-EPR, Mitsubishi US-APWR, and the Westinghouse AP1000. A comparison of the major design features and nominal parameters for the US-APWR, US-EPR, and AP1000 is provided in Table 6.0-2. The values are nominal and provided for comparison only.

Table 5.0-2, Plant Comparisons

System/Component	US-APWR	US-EPR	AP1000
Overall Plant Information			
Design Life (years)	60	60	60
NSSS Power (MWt)	4,468	4,607	3,415
Core Power	4,451	4,590	3,400
Net MWe	1,700	1,600	1,090
RCS Operating Pressure (psia)	2,250	2,250	2,250
T_{hot} (°F)	617	624	615
SG Design Pressure (psia)	1,200	1,450	1,200
Core			
Fuel Assemblies	257	241	157
Active Fuel Length (inches)	168	165	168
Fuel Assembly Array	17x17	17x17	17x17
Number of Control Rods	69	89	53
Number of Grey Rods	0	0	16
Average Linear Power (kw/ft)	4.60	5.01	5.7
Heat Flux Hot Channel Factor (F_Q)	2.60	2.74	2.60
Reactor Vessel			
Number of Hot Leg nozzles	4	4	2
Hot Leg ID (inches)	31	30.7	31

Table 5.0-2, Plant Comparisons

System/Component	US-APWR	US-EPR	AP1000
Number of Cold Leg Nozzles	4	4	4
Cold Leg ID (inches)	31	30.7	22
Number of Direct Vessel Injection Nozzles	4[a]	0	2
Reactor Coolant Pumps			
Type	Shaft Seal with Seal Injection	Shaft Seal with Seal Injection	No Seals
Number	4	4	4
Rated HP (Rated Temp/Press)	8200	~9000	7300
Flow/Pump (gpm)	112,000	125,000	78,750
Pressurizer			
Volume (ft^3)	2900	2649	2100
PRT	Yes	Yes	No
Steam Generators			
Type	Vertical U-Tube, Recirc Design	Vertical U-Tube, Recirc Design with Axial Economizer	Vertical U-Tube, Recirc Design
Number	4	4	2
Heat Transfer Area (ft^2) per SG	91,500	85,681	123,538
Number Tubes/SG	6747	5980	10,025
Tube Material	I 690 TT	I 690 TT	I 690 TT
Separate SU FW Nozzle	No	No	Yes
Startup/Aux Feedwater			
Turbine Pumps	2	0	0

Table 5.0-2, Plant Comparisons

System/Component	US-APWR	US-EPR	AP1000
Motor Pumps	2	4	2
Safety Related	Yes	Yes	No
Containment			
Type	Post tensioned concrete with steel liner	Post tensioned concrete with 0.25" steel liner protected by a reinforced concrete shield bldg	Free Standing Steel Vessel with Reinforced Concrete Shield Bldg
Design Press (psig)	68	62	59
Post Accident Cooling	Cnmt spray (4 trains)	Cnmt spray & IRWST cooling[b]	Air & Water on outside of cnmt vessel
Safety Injection			
Accumulator #/Volume (ft^3)	4/3180	4/1942	2/2000
High Head Pumps	4	0	0
Intermediate Head Pumps	0	4	0
Low Head Pumps	0	4	0
RWST #/Volume (gal)	1/583,340	1/500,342	1/546,828
RWST Location	Inside-cnmt	Inside-cnmt	Inside-cnmt
PRA CDF	~1 x 10^{-7} (est)	~1 x 10^{-7}	~1.7 x 10^{-7}
RHR			
Design Pressure (psig)	900	1160	900
Number of Pumps	4[c]	4	2
Design Flow (gpm)	3000	2200	1500

Table 5.0-2, Plant Comparisons

System/Component	US-APWR	US-EPR	AP1000
Safety Related	Yes[c]	Yes	No
Chemical & Volume Control			
Normal Letdown (gpm)	180	160	100
Max Letdown (gpm)	180	TBD	100
System Location	Aux Bldg	Fuel Bldg	Cnmt
RCP Seal Injection	Yes	Yes	No
# Charging Pumps	2	2	2[d]
Safety Related	No	No	No
Electrical			
Number Emergency Generators	4 GTG[e]	4 DG	2 DG
Gen Capacity (kw)	4500	9500	4000
SBO Generators	2 GTG[e]	2 DG[f]	0
Safety Related	Yes	Yes	No
1E Batteries	Yes	Yes	Yes

a. SIS pumps of the US-APWR inject via direct vessel injection nozzles (4); the accumulators inject into the cold legs.
b. For US-EPR cnmt spray only needed for severe accident cnmt cooling and is not safety related.
c. US-APWR uses the safety related Containment Spray Pumps for RHR during normal shutdown operations below 400 psi and 350°F.
d. AP1000 Makeup Pumps are used for pressurizer level control and are normally off.
e. US-APWR uses safety related gas turbine generators (GTGs) for LOOP. SBO GTGs are not safety related.
f. US-EPR SBO DGs are not safety related.