Part 1 – Plant Design Information

This section summarizes bounding plant design information received from the reactor vendors.

1. Advanced Boiling Water Reactor

1.1 Introduction

General Electric's (GE's) Advanced Boiling Water Reactor (ABWR) is a 1350 MWe standardized plant that has been certified under the NRC requirements contained in 10 CFR Part 52. The certified design was initially based on the ABWR design used in the construction of the first two ABWRs built in Japan, which is described in the Standard Safety Analysis Report (SSAR) (Reference 1), Design Control Document, and the Certified Design Manual (CDM) (Reference 2), also referred to as the Tier 1 documents. A general description of the ABWR is provided in Reference 3.

Following certification of the ABWR design, GE was selected to further detail the design of the ABWR in the First-of-a-Kind Engineering (FOAKE) program. One of the primary goals of the FOAKE program was to ensure that the ABWR plant met the needs of U.S. utilities. Because of this effort, the turbine island and balance of plant design were modified significantly. Thus, the design and arrangement of the turbine, service, and radwaste buildings should be based on the design from the FOAKE program rather than the design in the SSAR.

1.2 Operating Power Level

The thermal power level of the ABWR licensed in the certified design is rated 3926 MWt with a design power level of 4005 MWt. The net electric output is 1350 MWe.

1.3 Dimensions, General Arrangement, and General Plant Description

The dimensions and size of a typical ABWR are provided in Table 1-1. See Figure 1-1 at the end of this section for the layout of a typical ABWR plant.

Table 1-1. ABWR Size Requirements

	1 Unit	2 Units
Plant Area	787 ft x 1312 ft or 1.03 million ft^2 (23.7 acres)	1574 ft x 1312 ft 2.06 million ft^2 (47.4 acres) (Based on twice shortest side)
Cooling Towers	808 ft x 808 ft 653,000 ft^2 (15 acres)	808 ft x 1616 ft 1.31 million ft^2 (30 acres) (Based on twice shortest side)

Table 1-1. ABWR Size Requirements

	1 Unit	2 Units
Ultimate Heat Sink	590 ft x 590 ft 348,000 ft^2 (8 acres)	590 ft x 1180 ft 696,000 ft^2 (16 acres) (Based on twice shortest side. Conservatively assumes 2 times accident heat load.)

Based on GE Drawing 24158-1Y99-S1001, "Site Plan, Plant Site, and Yard (PSY)." The area required for mechanical draft cooling towers is conservatively assumed to be 15 acres per unit. The area for the ultimate heat sink (UHS) is taken from the GE drawing for a spray pond; this area could be significantly reduced if mechanical draft cooling towers with integral water basins are used.

Figures in SSAR Section 1.2 provide details of the ABWR major dimensions and arrangements for the reactor and control buildings.

As previously noted, the FOAKE program significantly modified the design of the turbine, service, and radwaste buildings. GE provided the FOAKE general arrangement drawings for the turbine, radwaste, and service buildings.

1.4 Required Excavation

GE states that the extent of required excavation depends on site soil conditions and the excavation method chosen. The external building dimensions can be determined from the general arrangement drawings referenced above. For the purposes of determining the depth of the excavation, grade for the ABWR is designated as +39.4 feet.

The major excavation required is for the reactor and control buildings. The top of the basemats for these buildings is located at –26.9 feet. The exterior dimensions for these buildings are provided below:

Building	Length	Width	Top of Basemat	Basemat Thickness
Reactor Building	195.5 ft	185.7 ft	–26.9 ft	18 ft
Control Building	78.7 ft	183.7 ft	–26.9 ft	9.8 ft

Based on this information, the foundation depth is approximately 84 feet (39.4 feet + 26.9 feet + 18 feet).

1.5 Major Equipment Sizes, Weights, and Foundation Bearing Pressures

The design of the reactor and control buildings is completed in sufficient detail to determine the required soil bearing pressures. This information is provided in CDM Chapter 5.0. The soil property requirements include a minimum static bearing capacity of 15 ksf at the foundation level.

1.6 Cooling and Water Use Requirements

The largest water use in the plant is for condenser cooling. Estimating requirements for cooling water is difficult because the amount of cooling water needed is dependent on the design of the system, the site environmental requirements, and EPA limits on water use and maximum temperature rise. Heat rejection rates for the various cooling water systems are given in the SSAR.

The ABWR circulating water system reference system design and values can be found in SSAR Section 10.4, Tables 10.4–1 and 10.4–3 and Figures 10.1–2 and 10.1–3 (additional information can be found in SSAR Section 10.1). These values can be influenced by the design features of the main steam system, which may change with the selection of turbine generator vendor and designer of the system.

The turbine service water and turbine building cooling water systems provide cooling requirements for nonsafety systems and for those systems that are not potentially contaminated. Although a description of these systems is provided in SSAR Sections 9.2.16 and 9.2.14, respectively, requirements for heat removal are not available. System sizing is such that two heat exchangers (of three installed) with a capacity of 68.7 GJ/hr are used during operation.

The reactor service water and reactor building cooling water systems provide cooling requirements for safety-related systems and for those systems that are potentially contaminated. Descriptions of these systems are provided in SSAR Sections 9.2.15 and 9.2.11, respectively, and design calculations have been performed for heat removal and are available on request.

Site characteristics and utility operating patterns influence water usage, because the potability and demineralization requirements of the ABWR are not drastically different from current operating plants.

The makeup water preparation system is described in SSAR Section 9.2.8. This system provides the raw water for all internal uses in the plant. The system is sized for peak usage and is designed to provide 1000 gpm.

1.7 Routine Emissions and Expected Radiation Dose

SSAR Section 12.2 contains detailed calculations of radiation emissions and radiation exposures to the public. SSAR Section 12.4 provides an assessment of occupational doses. The SSAR values are conservative and represent an upper bound on expected actual values, appropriate for the purposes of the ESP effort. Operational data from the Japanese ABWRs has shown that the actual values are much less than those described in the SSAR.

1.8 Projected Releases from Postulated Operational Occurrences and Accidents

Radiation releases from anticipated operational occurrences are addressed by the assessment of normal operation for the ABWR. Radiation releases due to design basis accidents (DBAs) are discussed in SSAR Chapter 15, and radiation releases due to Beyond DBA events are discussed in SSAR Chapter 19.

1.9 Hazardous Chemical Usage

Operation of the ABWR does not require the use of any hazardous chemicals. Lubricating and hydraulic oils will be selected based on the requirements of equipment vendors, as well as the plant owner. Use of hazardous chemicals in the treatment systems of various raw water systems will also depend on site conditions. Although the ABWR design makes provisions for these systems, the actual design of these systems is performed during the detailed design phase. Although the radwaste system designed for the ABWR in the FOAKE design does not require the use of hazardous chemicals, alternative treatment processes selected by the utility may dictate the use of hazardous chemicals.

1.10 Required Labor Force

GE did not provide any estimates for the required labor force.

1.11 Summary of Standard Plant Site Design Parameters

Table 1-2. Summary of ABWR Standard Plant Site Design Parameters

	Parameter	Value
Plant Area	1 ABWR unit	787 ft x 1312 ft, approximately 23.7 acres
	2 ABWR units	1574 ft x 1312 ft, approximately 47.4 acres
Air Temperature	Maximum safety	115°F dry bulb/80°F coincident wet bulb, 81°F wet bulb (noncoincident)
	Minimum safety	–40°F
Wind Speed	Operating basis	122.5 mph
	Tornado	300 mph—240 mph rotational, 60 mph translational
Seismology	Safe shutdown earthquake	0.30 g peak ground acceleration
	Shear wave velocity	1000 ft/sec
Soil	Average allowable static soil bearing capacity	15 ksf
	Foundation depth	84 ft
	Liquefaction	None

Table 1-2. Summary of ABWR Standard Plant Site Design Parameters

Tornado Missiles	Spectrum	3960 lb automobile at 35% maximum horizontal windspeed of design basis tornado
		275 lb, 8-inch shell at 35% maximum horizontal windspeed of design basis tornado
		1-inch diameter steel ball at 35% maximum horizontal windspeed of design basis tornado
Flooding	Flood level	1 ft below plant grade
Groundwater	Groundwater level	2 ft below plant grade
Precipitation	Rain	19.4 in/hr
	Snow/Ice	50 psf
Atmospheric Dispersion Values (X/Q)	Maximum annual at Low Population Zone	1.17×10^{-6} sec/m^3
Exclusion Area	Exclusion Area Boundary	Not available

1.12 References

1. "ABWR Standard Safety Analysis Report," GE Nuclear Energy, GE Document 23A6100.

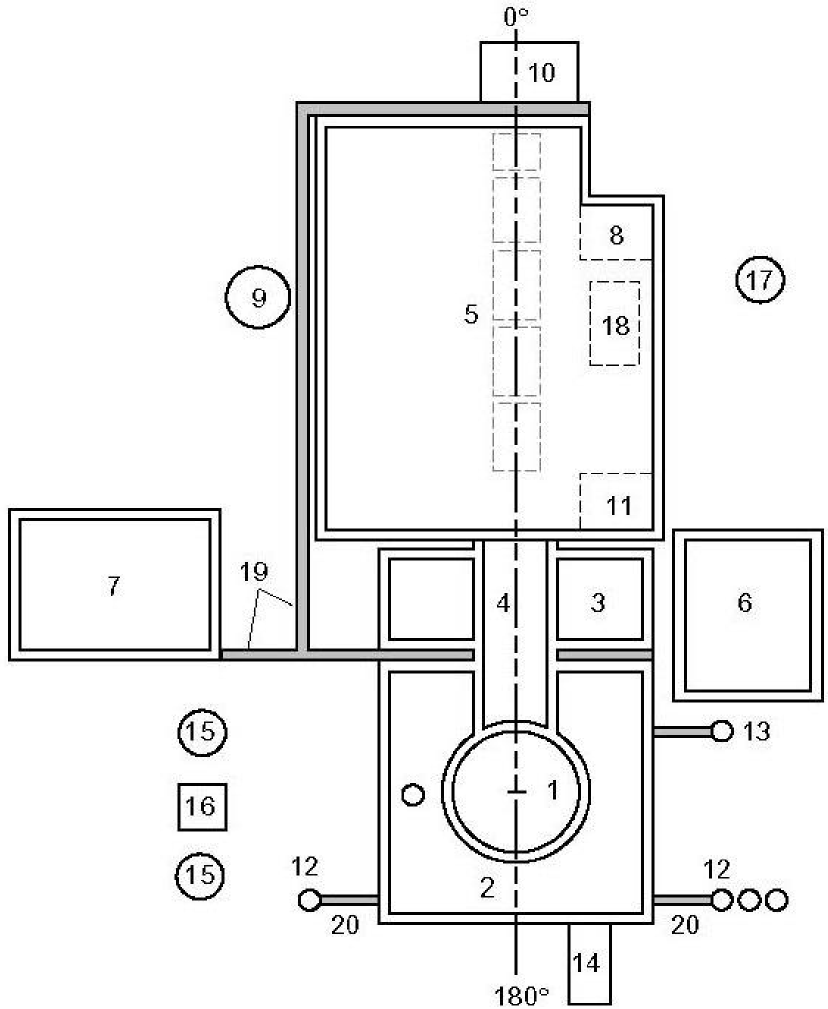
2. "ABWR Certified Design Manual," GE Nuclear Energy, GE Document 25A5447.

3. "Advanced Boiling Water Reactor Plant General Description, 'First of the Next Generation,' " GE Nuclear Energy, January 2000.

4. "Site Plan, Plant Site, and Yard (PSY)," GE Drawing 24158-1Y99-S1001

Figure 1-1. ABWR Plant Layout

No.	FACILITY
1	REACTOR CONTAINMENT
2	REACTOR BUILDING
3	CONTROL BUILDING
4	MAIN STEAM/FEEDWATER TUNNEL
5	TURBINE BUILDING
6	SERVICE BUILDING
7	RADWASTE BUILDING
8	HOUSE BOILER
9	CONDENSATE STORAGE TANK
10	UNIT AUXILIARY TRANSFORMERS
11	NORMAL SWITCHGEAR
12	DIESEL OIL STORAGE TANK (3)
13	STACK
14	EQUIPMENT ENTRY LOCK
15	FIRE PROTECTION WATER STORAGE TANK (2)
16	FIRE PROTECTION PUMPHOUSE
17	BUNKER FUEL TANK
18	COMBUSTION TURBINE GENERATOR
19	RADWASTE TUNNELS RB, CB, TB
20	DG OIL TRANSFER TUNNEL (3)



Source: Figure 8-1, ABWR Site Plan, ABWR, Advanced Boiling Water Reactor General Description, First of the Next Generation, GE Nuclear Energy, January 2000.

2. AP1000

2.1 Introduction

Westinghouse's Advanced Pressurized Water Reactor AP1000 is a standardized, two-loop, 1000 MWe PWR with passive safety features. The AP1000 is derived directly from the NRC-certified AP600, a two-loop 600 MWe PWR.

2.2 Operating Power Level

The calculated nuclear steam supply system thermal power is 3415 MWt. The operating power levels for the AP1000 are:

- Approximately 1115 MWe net @ 2.5 in. Hg absolute for a plant employing a cooling tower
- Approximately 1117 MWe net @ 2 in. Hg absolute for a plant employing a cooling tower
- Approximately 1150 MWe net @ 1.5 in. Hg absolute for a plant employing once-through cooling

2.3 Dimensions, General Arrangement, and General Plant Description

The dimensions and size of an AP1000 plant are provided in Table 2-1. See Figure 2-1 at the end of this section for the layout of a typical AP1000 plant.

Table 2-1. AP1000 Size Requirements

	1 Unit	2 Units
Plant Area	530 ft x 790 ft 419,000 ft^2 (9.6 acres)	530 ft x 1580 ft 837,000 ft^2 (19.2 acres)
Cooling Towers	808 ft x 808 ft 653,000 ft^2 (15 acres)	808 ft x 1616 ft 1.31 million ft^2 (30 acres) (Based on twice shortest side)
Ultimate Heat Sink	None. The passive cooling design of the AP1000 does not require a separate safety-grade UHS.	None. The passive cooling design of the AP1000 does not require a separate safety-grade UHS.

Based on Westinghouse Drawing APP-0000-X2-022, Revision A, "AP1000 – Twin Unit Site Plot Plan With Cooling Towers." The area required for mechanical draft cooling towers is conservatively assumed to be 15 acres per unit based on the ABWR plant layout.

2.4 Required Excavation

Based on Reference 4, the nominal excavation depth for the nuclear island is 40 feet.

2.5 Major Equipment Sizes, Weights, and Foundation Bearing Pressures

Westinghouse provided the following information:

Equipment	Outer Dimensions	Weight (tons)
Reactor Vessel	33 ft x 22 ft (diameter)	670
Steam Generators	80 ft x 20 ft (diameter)	700
Cradle for Reactor Module	145 ft (diameter) x 40 ft	350
Containment Vessel Lower Head	130 ft (diameter) x 38 ft	650
Containment Vessel Ring Section	130 ft (diameter) x 51 ft	800
Module CA–20	70 ft x 50 ft x 70 ft	850
Module CA–01	90 ft x 90 ft x 90 ft	500
IHP	62 ft x 19 ft (diameter)	150
Module CA–81	200 ft x 46 ft x 11 ft	350

Westinghouse gives the average allowable static bearing capacity of the soil as greater than or equal to 8.4 ksf over the footprint of the nuclear island at its excavation depth.

2.6 Cooling and Water Use Requirements

The AP1000 is a passive nuclear plant—it requires no safety-related heat sink to reach safe shutdown other than the water contained in its passive cooling system tank situated on top of the reactor building. Therefore, a safety-related ultimate heat sink is not required. The ultimate heat sink is air, which is motivated by natural means.

The service water system has its own cooling tower, which is separate from the condenser circulating water system. Makeup for the service water cooling tower is estimated to be 500 gpm.

Circulating water requirements can vary greatly depending on site-specific conditions and limitations. The AP1000 requires no more or no less circulating water than any other similarly sized plant. Essentially, the plant needs to reject approximately two-thirds of 3400 MWt or about 2250 MWt. If the plant uses a cooling tower, ambient air temperature, humidity, and the design temperature rise across the cooling tower/condenser are needed to estimate required flow rate. (A very rough estimate is that the required flow rate is somewhere between 450,000 gpm to 750,000 gpm.) If the plant uses once-through direct cooling, the required flow rate will generally be less, but it can also vary significantly depending on environmental temperature rise limitations.

Makeup for a circulating water system that uses a cooling tower can be estimated at up to 4 percent of the circulating water flow rate. Generally, no makeup is required for a direct cooling application.

Potable water requirements can be estimated based on the assumption that there may be up to 300 operating personnel required for the first single unit and up to 420 operating personnel required for the first twin unit.

2.7 Routine Emissions and Expected Radiation Dose

For normal operations, waste production for the AP1000 design is:

Solid Radwaste Releases	
	ft^3/year
High Integrity Containers	501
Drums	131
Boxes	1339
Total	1970

Liquid Radwaste Releases	
	Ci/year
Corrosion and Activation Products	0.0032
Fission Products	0.0882
GALE Adjustment Factor	0.1600
Total (except Tritium)	0.2514
Tritium	1139

Routine emissions are:

Airborne Releases	
	Ci/year
Noble Gases	1.16E+04
Iodines	5.43E-01
Other Radionuclides	8.32E-02

Note: Releases scaled from AP600.

Direct radiation from the containment and other plant buildings is negligible. Because refueling water is stored in the containment, it is eliminated as a site boundary radiation source.

Collective operator dose estimates are provided below for the AP600. Similar estimates for the AP1000 have not been made, but, given the similar geometry of the plants, the operator doses for the AP600 should be applied to the AP1000.

AP1000 Collective Dose Estimate (by NUREG Category)			
Category	Percent	Annual Dose	
		Man-Rem	Man-Sv
Reactor Operations and Surveillance	20.4	13.8	0.138
Routine Maintenance	18.0	12.1	0.121
In-Service Inspection	24.6	16.5	0.165
Special Maintenance	22.4	15.0	0.150
Waste Processing	7.8	5.2	0.052
Refueling	6.6	4.4	0.044
Total	100	67.0	0.670

2.8 Projected Releases from Postulated Operational Occurrences and Accidents

Detailed accident releases have not been calculated for AP1000; accordingly, the projected releases given below are based on AP600 releases (based on a ratio of AP1000 to AP600 source terms). The LOCA shown was selected as the limiting release event. The "1–3 hour" time interval is the greatest release during a two-hour time period following the accident. The selected radionuclides account for more than 80 percent of the TEDE doses offsite.

LOCA Activity Releases Projected for the AP1000		
Radionuclide	Release (in Curies)	
	1-3 hour	0-30 day
I-131	1.8E+03	3.1E+03
I-132	1.6E+03	2.0E+03
I-133	3.7E+03	5.5E+03
I-135	2.7E+03	4.2E+03
Kr-88	3.4E+03	1.1E+04
Xe-133	1.6E+04	1.7E+06
Sr-89	9.1E+01	1.5E+02
Sr-90	7.8E+00	1.3E+01
Cs-134	2.4E+02	4.4E+02
Cs-137	1.5E+02	2.6E+02

2.9 Hazardous Chemical Usage

Hazardous chemical usage for AP1000 is for water treatment only. The specific chemicals used within the plant are determined by the site water conditions, and therefore will be provided by the utility. Active chemistry management should be in accordance with the recommendations from the Steam Generator Owner's Group.

2.10 Required Labor Force

Westinghouse's estimate of the required construction labor force is provided in Attachment 5 of Reference 2.

The expected number of staff members at the time of commercial operation, for the first single-unit AP1000, is estimated to be 281. This includes: management and trainers; operators; maintenance and work control personnel; security, material, and waste services personnel; and administration and configuration control personnel. The same staff makeup for the first twin unit AP1000 would require an estimated 396 individuals.

2.11 Summary of Standard Plant Site Design Parameters

Table 2-2. Summary of AP1000 Standard Plant Site Design Parameters

	Parameter	Value
Plant Area	1 AP1000 unit	530 ft x 790 ft, approximately 9.6 acres
	2 AP1000 units	530 ft x 1580 ft, approximately 19.2 acres
Air Temperature	Maximum safety	115°F dry bulb/80°F coincident wet bulb, 81°F wet bulb (noncoincident)
	Minimum safety	–40°F
Wind Speed	Operating basis	110 mph; importance factor 1.11 (safety), 1.0 (nonsafety)
	Tornado	300 mph
Seismology	Safe shutdown earthquake	0.30 g peak ground acceleration
	Shear wave velocity	1000 ft/sec
Soil	Average allowable static soil bearing capacity	8.4 ksf
	Foundation depth	40 ft
	Liquefaction	None
Tornado Missiles	Spectrum	4000 lb automobile at 105 mph horizontal, 74 mph vertical
		275 lb, 8-inch shell at 105 mph horizontal, 74 mph vertical
		1-inch diameter steel ball at 105 mph horizontal and vertical
Flooding	Flood level	Less than plant elevation 100 ft
Groundwater	Groundwater level	Less than plant elevation 98 ft
Precipitation	Rain	19.4 in/hr
	Snow/Ice	75 psf on ground with exposure factor of 1.0 and importance factor of 1.2 (safety) and 1.0 (nonsafety)
Atmospheric Dispersion Values (X/Q)	Site Boundary (0-2 hour)	$\leq 0.6 \times 10^{-3}$ sec/m^3
	Site Boundary (annual avg)	$\leq 2.0 \times 10^{-5}$ sec/m^3
	0–8 hour	$\leq 1.35 \times 10^{-4}$ sec/m^3
	8–24 hour	$\leq 1.0 \times 10^{-4}$ sec/m^3
	24–96 hour	$\leq 5.4 \times 10^{-5}$ sec/m^3
	96–720 hour	$\leq 2.2 \times 10^{-5}$ sec/m^3
Exclusion Area	Exclusion Area Boundary	2640 ft

2.12 References

1. Dominion Letter ESP-002, "Siting Study: Surry and North Anna Power Stations," dated August 16, 2001.

2. Westinghouse letter DCP/MIS0216, "Dominion Resources Early Site Study: Information Package," dated August 24, 2001.

3. WCAP-15612, "AP1000 Plant Description and Analysis Report," Westinghouse Electric Company, LLC, December 2000.

4. GW-GCL-001, Section 6.2.1, "1000.XE Excavation Plan," Westinghouse.

5. Westinghouse Drawing APP-0000-X2-022, Revision A, "AP1000 – Twin Unit Site Plot Plan With Cooling Towers."

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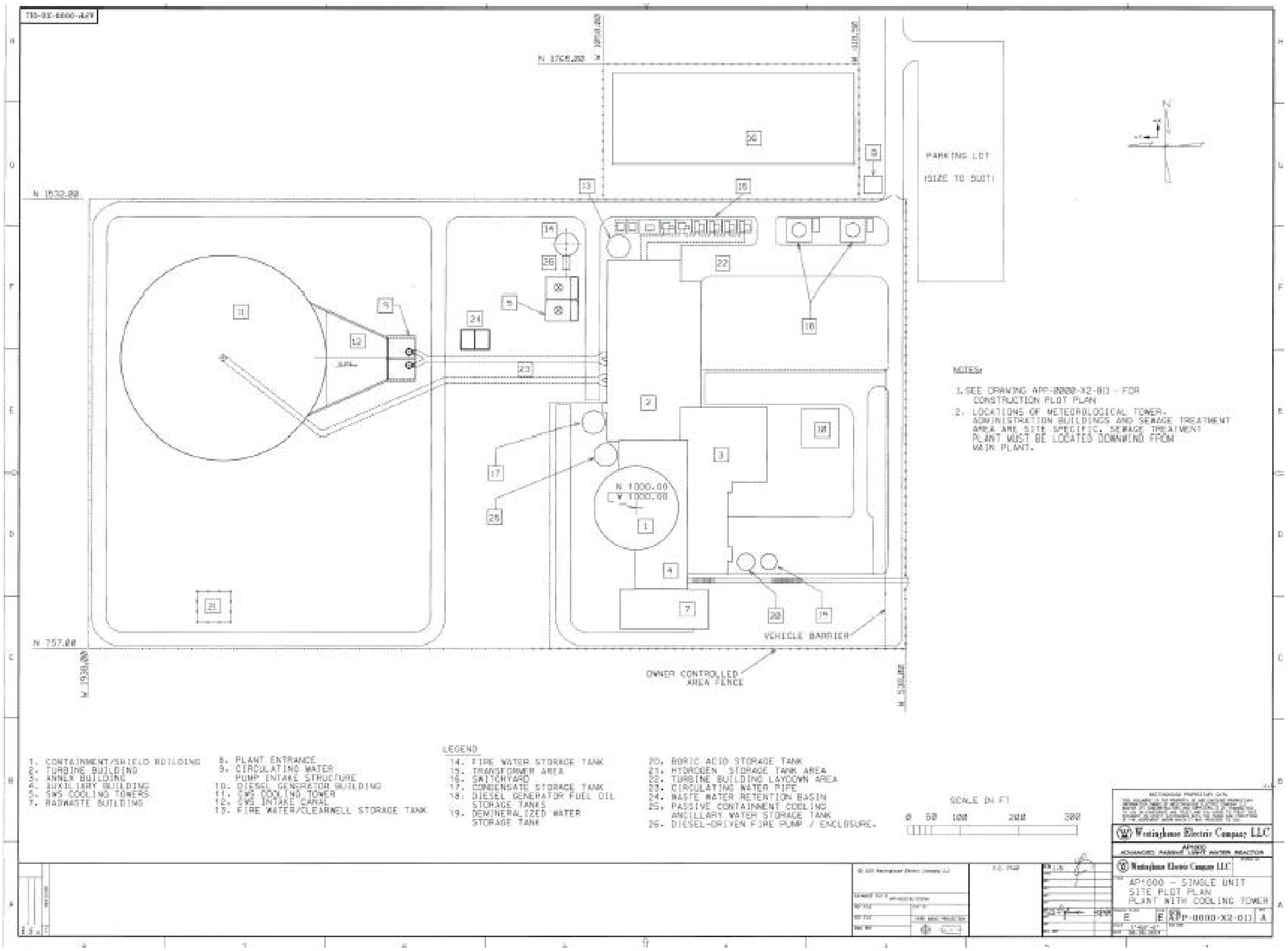
Figure 2-1. AP1000 Plant Layout



SOURCE: Drawing APP-0000-X2-011, AP1000 – Single Unit, Site Plot Plan, Plant with Cooling Tower, Westinghouse Electric Company, LLC, Revision A.

3. Gas Turbine – Modular Helium Reactor

3.1 Introduction

General Atomics' Gas Turbine – Modular Helium Reactor (GT-MHR) is a modular integrated direct-cycle nuclear power facility. In the GT-MHR, the high temperature helium coolant directly drives a gas turbine coupled to an electric generator. The efficiency of the system is about 48 percent. This is about 50 percent more efficient than today's first generation reactors. A typical GT-MHR module, rated at 600 MWt, yields a net output of about 286 MWe. The reactor can be fueled with uranium or plutonium. This system permits sequential construction of modules to match the user's growth requirements.

3.2 Operating Power Level

Each module has an operating power level of 600 MWt, and a net electrical output of 286 MWe.

3.3 Dimensions, General Arrangement, and General Plant Description

The dimensions and size of a GT-MHR plant are provided in Table 3-1. See Figure 3-1 at the end of this section for the layout of a typical GT-MHR plant.

Table 3-1. GT-MHR Size Requirements

	4 Modules	8 Modules
Plant Area	1200 ft x 1660 ft 2 million ft^2 (44 acres)	1200 ft x 3320 ft 4 million ft^2 (91 acres) (Based on twice longest side)
Cooling Towers	808 ft x 808 ft 653,002 ft^2 (15 acres)	808 ft x 1616 ft 1.31 million ft^2 (30 acres) (Based on twice shortest side)
Ultimate Heat Sink	590 ft x 590 ft 348,000 ft^2 (8 acres)	590 ft x 1180 ft 696,000 ft^2 (16 acres) (Based on twice shortest side. Conservatively assumes 2 times 4-module accident heat load.)

Based on General Atomics Figure 3.2-1 of Reference 1. The plant area assumed is conservative but should be considered preliminary because the plant and site layout has not been finalized or optimized. The area required for mechanical draft cooling towers is conservatively assumed to be 15 acres for a 4-module plant based on the ABWR plant layout. It is expected that this area will be less considering the higher plant efficiency of the GT-MHR and, therefore, the lower heat rejection rate. The area for the UHS is consistent with that assumed for a spray pond for 1 ABWR unit; this area could be significantly reduced if mechanical draft cooling towers with integral water basins are used.

3.4 Required Excavation

Figure 4.22–2 of Reference 1 indicates that the bottom of the reactor building basemat is at –148 feet.

3.5 Major Equipment Sizes, Weights, and Foundation Bearing Pressures

Major Equipment Sizes, Weights, and Foundation Bearing Pressures		
Equipment	Outer Dimensions	Weight
Reactor Vessel	27.6 ft (diameter at flange), 101.9 ft high	540 tons (closure head) 925 tons (vessel assembly)
Cross Vessel	7.75 ft (diameter), ~9.35 ft long	Not provided
Power Conversion Vessel	27.9 in. (diameter at flange), 115.55 in. high	197 tons (ellipsoidal head) 532 tons (upper vessel assembly) 791 tons (lower vessel assembly)
Turbomachine (turbine and compressor)	11 in. (diameter), 88.5 in. long	58 tons

Per General Atomics, the foundation material is assumed to have an allowable static bearing capacity of 10 ksf.

3.6 Cooling and Water Use Requirements

Cooling water use requirements is limited to the makeup and blowdown requirements for a 300 MW heat rejection cooling tower, plus minor heat loads associated with the routine process operations of the plant. General Atomics provided no specific flow rates.

3.7 Routine Emissions and Expected Radiation Dose

No information was provided with respect to routine emissions. Expected radiation doses are summarized below.

Occupational Dose Assessment			
		Dose	
Category	Percent	Man-Rem	Man-Sv
Routine Operations	7.4	11	0.11
Preventive Maintenance	15	22	0.22
In-Service Inspection	46	68	0.68
Refueling	2.7	4	0.04
Waste Processing	1.3	2	0.02
Corrective Maintenance	8.0	12	0.12
Contingency	20	30	0.30
Total	**100**	**149**	**1.49**

3.8 Projected Releases from Postulated Operational Occurrences and Accidents

The design of the GT-MHR is obviously different from the existing and advanced light water reactors. For this primary reason, the most limiting accident is different than those for the ABWR, AP1000, and IRIS designs. No information was provided for projected releases (in Curies) from postulated operational occurrences and accidents. However, General Atomics did provide values for the offsite doses from operational occurrences and accidents.

Because of the GT-MHR's design, the potential offsite releases for many of the postulated accidents are insignificant. The postulated accident of primary concern to the GT-MHR is a depressurized conduction cooldown (with moderate moisture ingress). The resulting doses (95th percentile) are 3.8 rem thyroid and 0.045 rem whole body.

3.9 Hazardous Chemical Usage

Hazardous chemical usage is basically limited to that required for water quality maintenance. Since there is no need to maintain the water quality for a high-pressure steam system, the chemical requirements are modest and apply, principally, to those of the cooling tower. Other chemical usage of a similar nature is specified for other closed-loop, low-temperature cooling systems.

3.10 Required Labor Force

General Atomics provided no information on the required construction labor force or the labor force required to decommission the plant.

For operation of a four-module plant, General Atomics estimates that approximately 241 to 300 employees will be required.

3.11 Summary of Standard Plant Site Design Parameters

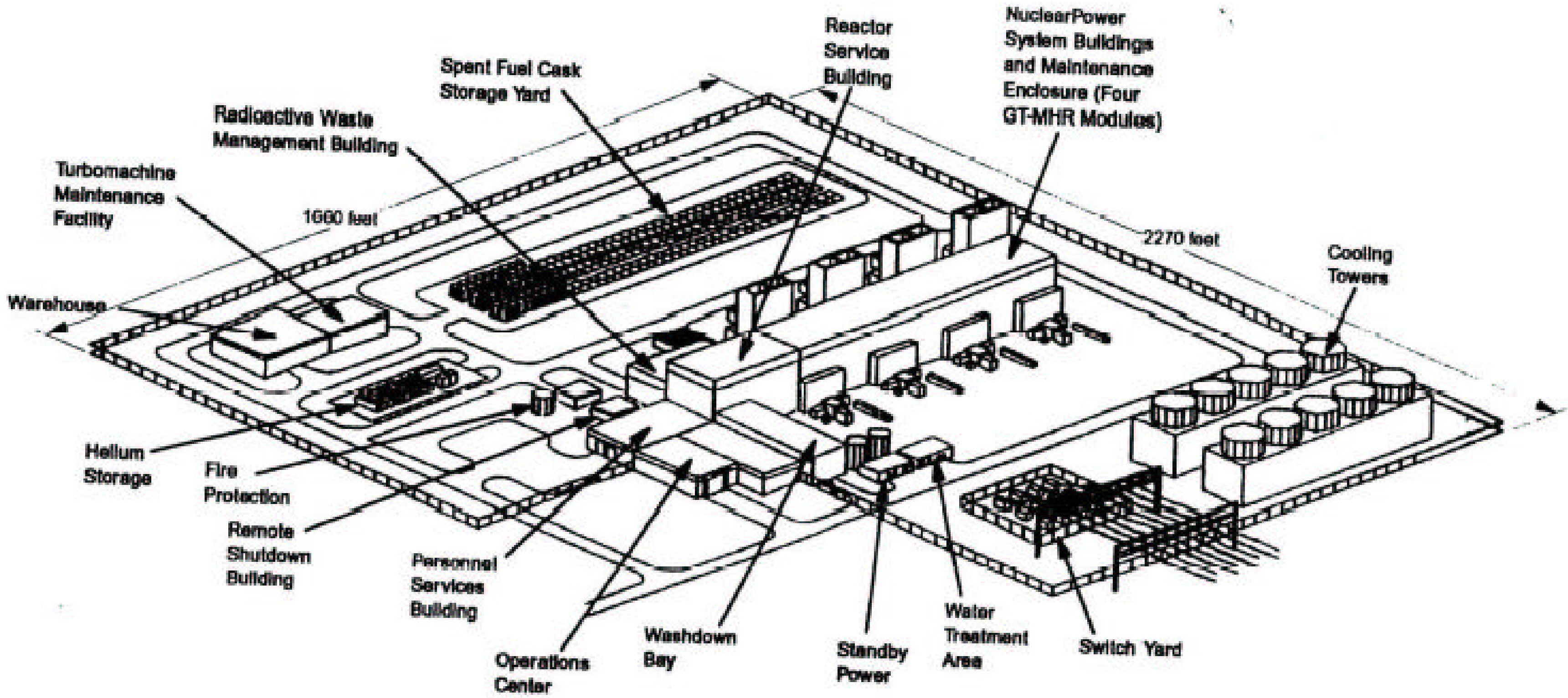
Table 3-2. Summary of GT-MHR Standard Plant Site Design Parameters

	Parameter	Value
Plant Area	4-module plant	1200 ft x 1660 ft, approximately 44 acres
	8-module plant	1200 ft x 3320 ft, approximately 91 acres
Air Temperature	Maximum safety	110°F dry bulb/82°F wet bulb
	Minimum safety	–45°F
Wind Speed	Operating basis	110 mph at 10 meters
	Tornado	360 mph (290 mph rotational, 70 mph translational)
Seismology	Safe shutdown earthquake	0.30 g peak ground acceleration
	Shear wave velocity	Not available
Soil	Average allowable static soil bearing capacity	10 ksf
	Foundation depth	40 ft
	Liquefaction	Not available
Tornado Missiles	Spectrum	Not available
Flooding	Flood level	Not available
Groundwater	Groundwater level	Less than plant elevation –8 ft
Precipitation	Rain	Not available
	Snow/Ice	50 psf
Atmospheric Dispersion Values (X/Q)	Annual average at exclusion area boundary	2.0×10^{-5} sec/m^3
	Low population zone boundary 0–8 hour	1.21×10^{-3} sec/m^3
	8–24 hour	6.34×10^{-4} sec/m^3
	24–96 hour	2.30×10^{-4} sec/m^3
	96–720 hour	5.22×10^{-5} sec/m^3
Exclusion Area	Exclusion Area Boundary	1390 ft

3.12 References

1. General Atomics Letter GA/ESPP-198-2001, "Early Site Permitting Project," dated August 30, 2001.

Figure 3-1. GT-MHR Plant Layout



SOURCE: Figure 3.2–1, Isometric of four-module GT-MHR plant, Letter from A. Shenoy, General Atomics, to S. Semmes, Dominion Resources Services, August 30, 2001.

4. International Reactor Innovative and Secure

4.1 Introduction

Westinghouse's International Reactor Innovative and Secure (IRIS) is a modular, pressurized light water reactor of medium power (335 MWe). The IRIS module features a 1000 MWt thermal core with standard commercial fuel assemblies that is designed to operate over a five-year long straight burn fuel cycle, and an integral reactor vessel which contains all the reactor coolant system components, including the pressurizer, steam generators, and reactor coolant pumps, as well as radiation shields.

The information provided in the following sections is based on two plant configurations:

- Three single units, 335 MWe each, 1005 MWe total
- Two twin units, 670 MWe for each twin, 1340 MWe total

The independent multiple single-unit arrangement (Option 1) includes three independent IRIS modules that only share nonsafety-related service water and main circulating water cooling towers. This arrangement is based on the assumption that the units would be constructed in series in a "slide-along" manner. The two twin-unit arrangement (Option 2) maximizes the shared components between the two modules. This arrangement maintains the ability to begin operations on the completed twin-unit, while construction of subsequent twin units proceeds in a "slide along" manner.

4.2 Operating Power Level

The operating power level for the plant configurations is:

Option 1: 3 x 335 MWe = 1005 MWe @ 2.5 in. Hg absolute condenser vacuum
Option 2: 2 x 2 x 335 MWe = 1340 MWe @ 2.5 in. Hg absolute condenser vacuum

4.3 Dimensions, General Arrangement, and General Plant Description

The dimensions and size of an IRIS plant are provided in Table 4-1. See Figure 4-1 at the end of this section for the layout of a typical IRIS plant.

Table 4-1. IRIS Size Requirements

	3 Modules	6 Modules
Plant Area	733 ft x 1167 ft 855,000 ft^2 (19.6 acres)	800 ft x 1267 ft 1.01 million ft^2 (23.3 acres)
Cooling Towers	808 ft x 808 ft 653,000 ft^2 (15 acres)	808 ft x 1616 ft 1.31 million ft^2 (30 acres) (Based on twice shortest side)
Ultimate Heat Sink	None. The passive cooling design of the IRIS does not require a separate safety-grade UHS.	None. The passive cooling design of the IRIS does not require a separate safety-grade UHS.

Based on Westinghouse Figure 1-3, "IRIS, Three Single Unit Site, Plot Plan," and Figure 1–4, "IRIS, Two Twin-Unit Site Plot Plan." The plant area assumed is conservative but should be considered preliminary because the plant and site layout has not been finalized or optimized. The area required for mechanical draft cooling towers is conservatively assumed to be 15 acres for a 3-module plant based on the ABWR plant layout.

The dimensions and general arrangement of major structures is provided in Reference 1.

4.4 Required Excavation

The site excavation requirements are given in the table below for each of the two plant arrangements provided by General Atomics.

Building Structure	Option 1 Three Single Units	Option 2 Two Twin Units
Nuclear Island	3 x (200 ft x 150 ft x 40 ft deep)	2 x (250 ft x 200 ft x 40 ft deep)
Turbine Building	3 x (260 ft x 118 ft x 20 ft deep*)	2 x (290 ft x 170 ft x 20 ft deep*)
Radwaste Building	At grade	At grade
Annex Building	At grade	At grade

** The Turbine Buildings could be constructed at grade. The 20-ft depth for excavation provides improved steam and feed line routing and improved heater drain operation.*

An excavation depth of 43 feet has been assumed for evaluation purposes.

4.5 Major Equipment Sizes, Weights, and Foundation Bearing Pressures

Dimensions and weights for IRIS major components are reported in the following table.

Equipment	Outer Dimensions	Weight
Reactor Vessel	21 ft – 9 in. (diameter) x 69 ft – 6 in. long	780 tons
Steam Generators	5 ft – 4 in. (diameter) x 37 ft – 6 in. long	38.5 tons (each)
Reactor Vessel Head	24 ft (diameter at flange) x 10 ft – 6 in. high	112.5 tons
Containment Vessel Lower Half	Hemisphere, 82 ft diameter	771 tons
Containment Vessel Upper Half	Hemisphere, 82 ft diameter, with closure flange	776 tons
Containment Vessel Closure Head	32 ft – 10 in. (diameter), 29 ft – 6 in. high	175 tons

Westinghouse gives the average allowable static bearing capacity of the soil as greater than or equal to 8 ksf over the footprint of the nuclear island at its excavation depth.

4.6 Cooling and Water Use Requirements

IRIS requires approximately the same circulating water requirements as other, similarly sized light water reactors. Each unit rejects approximately two-thirds of its 1000 MWt rating (or 665 MWt). Circulating water requirements will vary depending on site conditions and limitations. In Reference 1, Figures 6–1 and 6–2, Westinghouse provided cooling water usage values, based on a cooling tower arrangement. Actual values will depend on the site ambient air temperature, humidity, and temperature rise across the cooling tower/condenser. If once-through cooling is used, the amount of water required will be generally less, but will depend on environmental temperature rise limitations. Makeup water for a circulating water system using a cooling tower will be approximately 4 percent of the circulating water flow rate.

Because of its design, a safety-related ultimate heat sink system is not required for IRIS. However, IRIS does employ small, dedicated, nonsafety-related mechanical draft cooling towers for the service water system (separate from the main condenser circulating water requirements discussed above). These service water towers operate only during plant cooldown operations when the normal residual heat removal system is operating. Makeup water for the service water cooling system is approximately 250 gpm for a single unit, 500 gpm for a twin unit.

4.7 Routine Emissions and Expected Radiation Dose

Detailed calculations of routine emissions and dose estimates have not been performed for the IRIS. Westinghouse believes that IRIS plant releases can be conservatively bounded by those estimated for the AP600, adjusting for the power sizes of the IRIS plant options. These estimates are provided below. Because the IRIS is being designed with a low (or possibly no) boron core, thereby reducing tritium generation, and a less extended primary coolant boundary, the AP600 gaseous and liquid effluent emissions will exceed those expected for the IRIS.

	Three Single IRIS Units	Two Twin IRIS Units
Solid Radwaste, ft^3/yr	2600	3400
Liquid Releases—excluding Tritium, Ci/yr	<0.1600	<0.1600
Tritium Releases, Ci/yr with low boron core	<690	<690
Airborne Releases		
Noble gases, Ci/yr	10,000	13,000
Iodines, Ci/yr	0.45	0.60
Other Radionuclides, Ci/yr	0.07	0.09
Tritium, Ci/yr	<100	<100

Likewise, the expected radiation doses for IRIS are based on estimates for the AP600. It is important to note that there are major differences between AP600 and IRIS designs that are expected to affect radiation doses. However, at the preliminary stage, dose estimates for the AP600 will conservatively bound those for IRIS plant operators. These expected radiation doses (by NUREG category) are provided below:

Category	Percent	Annual Dose (Man-Sv)
Reactor Operations and Surveillance	20.4	0.138
Routine Maintenance	18.0	0.121
In-Service Inspection	24.5	0.165
Special Maintenance	22.4	0.150
Waste Processing	7.8	0.052
Refueling	6.6	0.044
Total	100	0.670

4.8 Projected Releases from Postulated Operational Occurrences and Accidents

The design of the IRIS reactor eliminates or reduces the consequences of serious design basis accidents that can result in core damage. Additionally, the design reduces the releases from operational occurrences and accidents for an IRIS unit such that releases should be significantly less than that for the AP600. The table below lists the LOCA activity releases for the AP600, which provide a temporary and conservative upper bound for the IRIS until design-specific release analyses are performed.

Radionuclide	AP600 Releases (in Curies)	
	1–3 hour	0–30 day
I-131	9.5E+02	1.7E+03
I-132	8.4E+02	1.1E+03
I-133	2.0E+03	3.1E+03
I-135	1.4E+03	2.3E+03
Kr-88	1.8E+03	5.6E+03

Radionuclide	AP600 Releases (in Curies)	
	1–3 hour	0–30 day
Xe-133	9.0E+03	9.7E+03
Sr-89	4.9E+01	7.9E+01
Sr-90	5.5E+00	8.8E+00
Cs-134	1.5E+02	2.5E+02
Cs-137	1.1E+02	1.8E+02

4.9 Hazardous Chemical Usage

The hazardous chemical usage for IRIS, like the AP600, is for water treatment only. The specific chemicals used within the plant are determined by the site water conditions.

4.10 Required Labor Force

Westinghouse provided no information on the required construction labor force or the labor force required to decommission the plant.

Based on the estimate of 229 total employees (150 to 200 full-time) to operate a single, stand-alone unit (with 50 percent uncertainty), the staffing for a three-unit plant is conservatively estimated to range from 250 to 300, and for two twin units from 280 to 350. Note that site management, security, administrative services, training, engineering, health physics, and other departments would share their services over multiple units.

4.11 Summary of Standard Plant Site Design Parameters

Table 4-2. Summary of IRIS Standard Plant Site Design Parameters.

	Parameter	Value
Plant Area	Three single unit configuration (3 modules)	733 ft x 1167 ft, approximately 19.6 acres
	Two twin unit configuration (6 modules)	800 ft x 1267 ft, approximately 23.3 acres
Air Temperature	Maximum safety	115°F dry bulb/80°F coincident wet bulb, 81°F wet bulb (non-coincident)
	Minimum safety	–40°F
Wind Speed	Operating basis	110 mph; importance factor 1.11 (safety), 1.0 (nonsafety)
	Tornado	300 mph
Seismology	Safe shutdown earthquake	0.30 g peak ground acceleration
	Shear wave velocity	1000 ft/sec
Soil	Average allowable static soil bearing capacity	8 ksf
	Foundation depth	43 ft
	Liquefaction	None

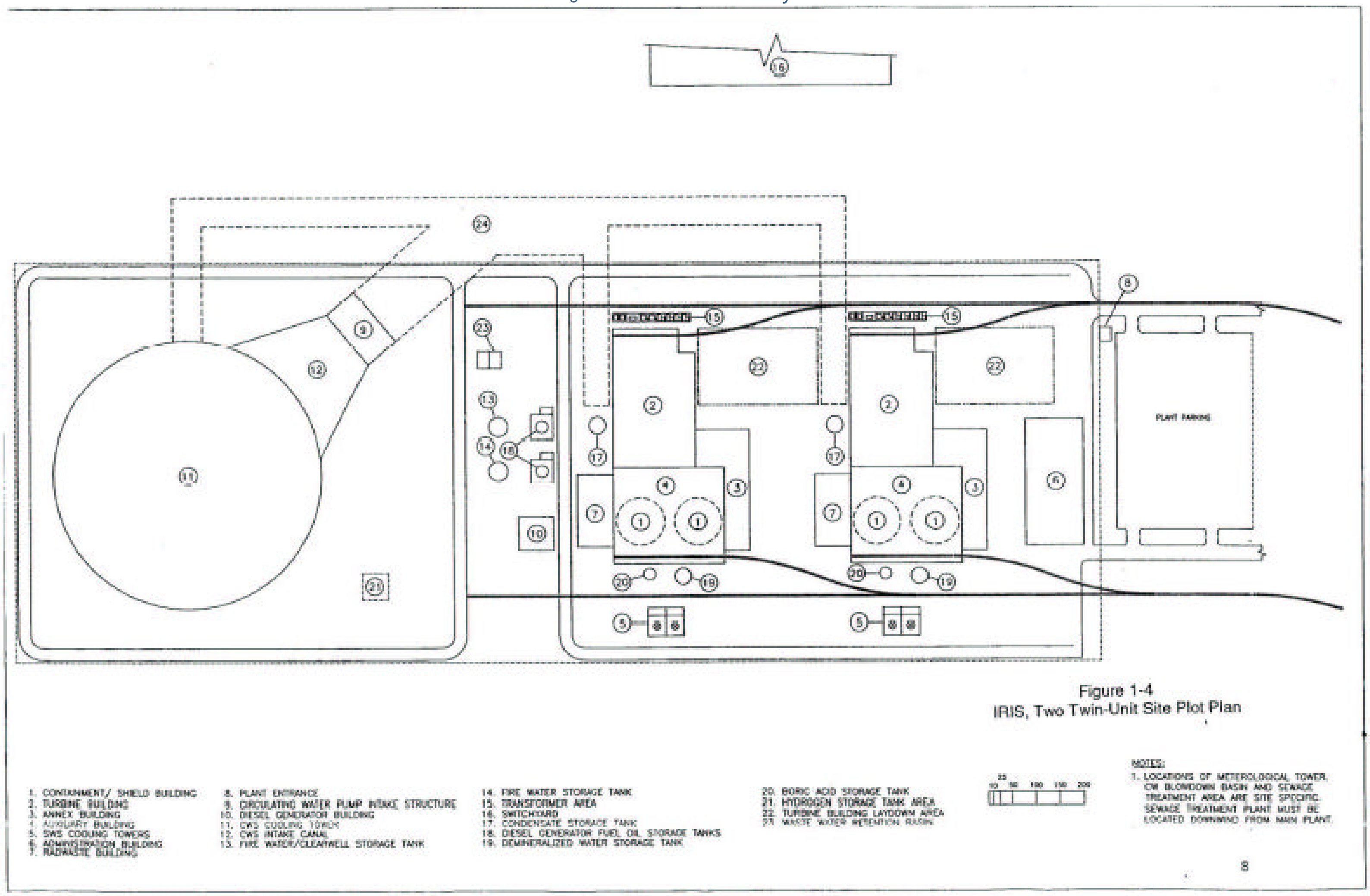
Table 4-2. Summary of IRIS Standard Plant Site Design Parameters.

	Parameter	Value
Tornado Missiles	Spectrum	4000 lb automobile at 105 mph horizontal, 74 mph vertical
		275 lb, 8-inch shell at 105 mph horizontal, 74 mph vertical
		1-inch diameter steel ball at 105 mph horizontal and vertical
Flooding	Flood level	Less than plant grade elevation
Groundwater	Groundwater level	Less than − 3.3 ft plant elevation
Precipitation	Rain	19.4 in./hr
	Snow/Ice	75 psf on ground with exposure factor of 1.0 and importance factor of 1.2 (safety) and 1.0 (nonsafety)
Atmospheric Dispersion Values (X/Q)	Site Boundary (0-2 hour)	$\leq 1.0 \times 10^{-3}$ sec/m^3
	Site Boundary (annual avg)	$\leq 2.0 \times 10^{-5}$ sec/m^3
	0–8 hour	$\leq 1.35 \times 10^{-4}$ sec/m^3
	8–24 hour	$\leq 1.0 \times 10^{-4}$ sec/m^3
	24–96 hour	$\leq 5.4 \times 10^{-5}$ sec/m^3
	96–720 hour	$\leq 2.2 \times 10^{-5}$ sec/m^3
Exclusion Area	Exclusion Area Boundary	2640 ft

4.12 References

1. Westinghouse letter STD-ES-01-0036, "Dominion Resources Early Site Study," dated August 31, 2001.

Figure 4-1. IRIS Plant Layout



SOURCE: Figure 1–4, IRIS, Two Twin-Unit Site Plot Plan, Letter from M. Carelli, Westinghouse Electric Company, LLC, to S. Semmes, Dominion Resources Services, August 31, 2001.

5. Pebble Bed Modular Reactor

5.1 Introduction

PBMR Pty. Ltd's Pebble Bed Modular Reactor (PBMR) is a high temperature gas-cooled reactor with a graphite moderator. It is a small-sized, nuclear power plant that uses coated uranium particles encased in graphite to form a fuel sphere. The plant can be configured in a variety of sizes by combing one or more stand-alone modules together to form a single plant. According to Reference 1, each PBMR consists of a vertical steel pressure vessel, 19.7 feet in diameter and about 65 feet high. It is lined with a 39-inch-thick layer of graphite blocks, which serves as a reflector and a passive heat transfer medium. The graphite brick lining is drilled with vertical holes to house the control rods.

The PBMR uses silicon carbide and pyrolitic carbon-coated particles of enriched uranium oxide encased in graphite to form a fuel sphere, or pebble, about the size of a tennis ball. Helium is used as the coolant and energy transfer medium to a closed-cycle gas turbine and generator system.

5.2 Operating Power Level

The standard core is rated at 400 MWt. The electrical output of each module is approximately 160 MWe resulting in a gross electrical output of 1280 MWe for an 8-module plant.

5.3 Dimensions, General Arrangement, and General Plant Description

The dimensions and size of a PBMR plant are provided in Table 5-1.

Table 5-1. PBMR Size Requirements

	8 Modules	**16 Modules**
Plant Area	180 ft x 1804 ft 325,000 ft^2 (7.5 acres)	360 ft x 1804 ft 649,000 ft^2 (15 acres) (Based on twice shortest side)
Cooling Towers	18 acres	36 acres (Based on twice shortest side)
Ultimate Heat Sink	None. The passive cooling design of the PBMR does not require a separate safety-grade UHS.	None. The passive cooling design of the PBMR does not require a separate safety-grade UHS.

The plant area assumed is conservative but should be considered preliminary because the plant and site layout has not been finalized or optimized. The area required for mechanical draft cooling towers is conservatively assumed to be 18 acres for an 8-module plant based on data provided in Reference 2. It is expected that this area will be less considering the higher plant efficiency of the PBMR and, therefore, the lower heat rejection rate.

5.4 Required Excavation

Based on Reference 2, the nominal excavation depth for the foundation embedment is 32.8 feet.

5.5 Major Equipment Sizes, Weights, and Foundation Bearing Pressures

Based on Reference 2, the estimate of the bearing pressure of the structure is less than 11 ksf. The stated minimum bearing capacity is 10.2 ksf. The single heaviest construction shipment to the site is 26 ft x 33 ft x 66 ft with a weight of 882 tons.

5.6 Cooling and Water Use Requirements

The PBMR is a gas-cooled plant has no ultimate heat sink requirements. The PBMR cycle does not require steam to condense, and is able to reject heat at a higher temperature. However, the PBMR operating regime is limited by the design of the helium-to-water heat exchangers. These components are inside the helium coolant pressure boundary, and it is not prudent to over-design them for abnormally high temperature conditions. The PBMR cycle is optimized for a closed cooling system inlet temperature of 25ºC (77ºF). This temperature is determined by the water temperature in an ocean or lake, for once-through cooling, or by the temperature and humidity of the air (the wet-bulb temperature) for cooling by cooling towers.

If the plant uses mechanical draft cooling towers, cooling water flow is estimated at 260,991 gpm and makeup flow is estimated at 15,659 gpm for an 8-module plant. Once-through cooling flow is estimated at 724,974 gpm for an 8-module plant.

The PBMR has no need for containment heat removal systems.

Maximum raw water use is estimated at 23,775 gpd, with potable water consumption dependent on local water quality and site characteristics.

5.7 Routine Emissions and Expected Radiation Dose

Routine gaseous emissions are estimated not to exceed 400 Ci/yr for an 8-module plant with tritium releases estimated below 1720 Ci/yr (from Reference 2).

5.8 Projected Releases from Postulated Operational Occurrences and Accidents

PBMR Lty. Ltd., has developed estimated releases from design basis events (from Reference 2). Post-accident emissions will not exceed the requirements of 10 CFR 20 and 10 CFR 100.

Radionuclide	Design Basis Event Releases (in Curies/yr) for 8-module plant	
	0–2 hour	8–720 hour
C-14	387	0
H-3	129	0
Noble Gases	143	488
I-131	0	24
Other Halogens	1	9
Metallic FPs	0.0001	0

5.9 Hazardous Chemical Usage

No information was provided by PBMR Pty. Ltd.

5.10 Required Labor Force

An estimated peak construction labor force of 1200 persons will be required for an 8-module plant.

5.11 Summary of Standard Plant Site Design Parameters

Table 5-2. Summary of PBMR Standard Plant Site Design Parameters.

	Parameter	Value
Plant Area	10 module plant	180 ft x 1804 ft, approximately 7.5 acres
	20 module plant	360 ft x 1804 ft, approximately 15 acres
Air Temperature	Maximum safety	115°F dry bulb/80°F coincident wet bulb, 81°F wet bulb (noncoincident)
	Minimum safety	–40°F
Wind Speed	Operating basis	110 mph; importance factors per ACI 349
	Tornado	300 mph – 240 mph rotational, 60 mph translational
Seismology	Safe shutdown earthquake	0.30 g peak ground acceleration
	Shear wave velocity	1000 ft/sec
Soil	Average allowable static soil bearing capacity	10.2 ksf
	Foundation depth	32.8 ft
	Liquefaction	None
Tornado Missiles	Spectrum	Spectrum II from NUREG-0800, SRP Section 3.5.1.4
Flooding	Flood level	Less than 1 foot below site grade
Groundwater	Groundwater level	Less than 2 feet below site grade
Precipitation	Rain	19.4 in/hr or 6.2 in/5 mins.
	Snow/Ice	50 lb/ft^2
Atmospheric Dispersion Values (X/Q)	Maximum annual at Low Population Zone	2.7E-5 at 0.25 mi
Exclusion Area	Exclusion Area Boundary	Less than 1312 ft

5.12 References

1. "Due to Design Issues, Decision on PBMR Prototype Pushed Back," Nucleonics Week, October 11, 2001.

2. "PBMR Site Envelope for Early Site Permitting," Document Number 011847-425 Revision 1, May 2001.

6. Bounding Plant Design

Based on the information presented in Sections 1 through 5, Table 6-1 presents plant parameters that bound the 5 reactor types being evaluated.

Table 6-1. Summary of Bounding Plant Design Information

Row	Plant Parameter	ABWR	AP1000	GT-MHR	IRIS	PBMR	Bounding Plant
1	MWe per module/unit	1350	1117	286	335	160	---
2	Number of modules/units per "plant" arrangement	1	1	4	3	8	---
3	MWe per "plant" arrangement	1350	1117	1144	1005	1280	---
4	Number of "plants" for up to 3000 MWe per site (without exceeding 3000 MWe)	2	2	2	2	2	---
5	Number of modules/units for up to 3000 MWe per site (without exceeding 3000 MWe)	2	2	8	6	16	---
6	MWe per site	2700	2234	2288	2010	2560	2700
7	Thermal efficiency	0.34	0.32	0.48	0.335	0.45	---
8	MWt per module/unit	3926	3415	600	1000	400	---
9	MWt per site	7852	6830	4800	6000	6400	---
10	Heat load to the environment for all modules/units, MW	5152	4596	2510	3990	3840	5152
11	"Plant" area	787 ft x 1312 ft	530 ft x 790 ft	1200 ft x 1660 ft	733 ft x 1167 ft	180 ft x 1804 ft	---
12	Total acres needed per "plant"	23.7	9.6	44	19.6	7.5	---
13	Total size needed at site for all "plants"	1574 ft x 1312 ft	530 ft x 1580 ft	1200 ft x 3320 ft	800 ft x 1267 ft	360 ft x 1804 ft	1200 ft x 3320 ft
14	Total acres needed at site for all "plants"	47.4	19.2	91	23.3	15	91
15	Required excavation, ft	84	40	148	43	32.8	148
16	Bearing pressure, ksf	15	8.4	10	8	10.2	15
17	Maximum air temperature	115°F dry bulb 80°F coincident wet bulb, 81°F wet bulb noncoincident	115°F dry bulb 80°F coincident wet bulb, 81°F wet bulb noncoincident	110°F dry bulb, 82°F wet bulb	115°F dry bulb, 80°F wet bulb	115°F dry bulb 80°F coincident wet bulb, 81°F wet bulb noncoincident	110°F dry bulb 82°F wet bulb
18	Minimum air temperature	–40°F	–40°F	–45°F	–40°F	–40°F	–40°F
19	Operating basis wind speed	122.5 mph	110 mph; importance factor 1.11 (safety), 1 (nonsafety)	110 mph at 10 meters	110 mph; importance factor 1.11 (safety), 1 (nonsafety)	110 mph; importance factor per ACI 349	110 mph
20	Tornado wind speed	300 mph	300 mph	360 mph	300 mph	300 mph	300 mph

Table 6-1. Summary of Bounding Plant Design Information

Row	Plant Parameter	ABWR	AP1000	GT-MHR	IRIS	PBMR	Bounding Plant
21	Safe shutdown earthquake	0.30 g PGA	0.30 g PGA	0.30 g PGA	0.30 g PGA	0.30 g PGA	0.30 g PGA
22	Shear wave velocity	1000 ft/sec	1000 ft/sec	N/A	1000 ft/sec	1000 ft/sec	1000 ft/sec
23	Liquefaction	None	None	N/A	None	None	None
24	Tornado missiles	Full spectrum	Full spectrum	N/A	Full spectrum	Full spectrum	Full spectrum
25	Flood level	1 ft below plant grade	Less than plant elevation 100 ft	N/A	Less than plant grade elevation	1 ft below plant grade	1 ft below plant grade
26	Groundwater level	2 ft below plant grade	Less than plant elevation 98 ft	Less than plant elevation –8 ft	Less than –3.3 ft plant elevation	2 ft below plant grade	3.3 ft below plant grade
27	Rain	19.4 in./hr	19.4 in/hr	N/A	19.4 in./hr	19.4 in/hr	19.4 in./hr
28	Snow/ice	50 psf	75 psf on ground with exposure factor of 1 and importance factor of 1.2 (safety) and 1 (nonsafety)	50 psf	75 psf on ground with exposure factor of 1 and importance factor of 1.2 (safety) and 1 (nonsafety)	50 psf	50 psf
29	Site exclusion area	N/A	2640 ft	1390 ft	2640 ft	<1312 ft	2640 ft