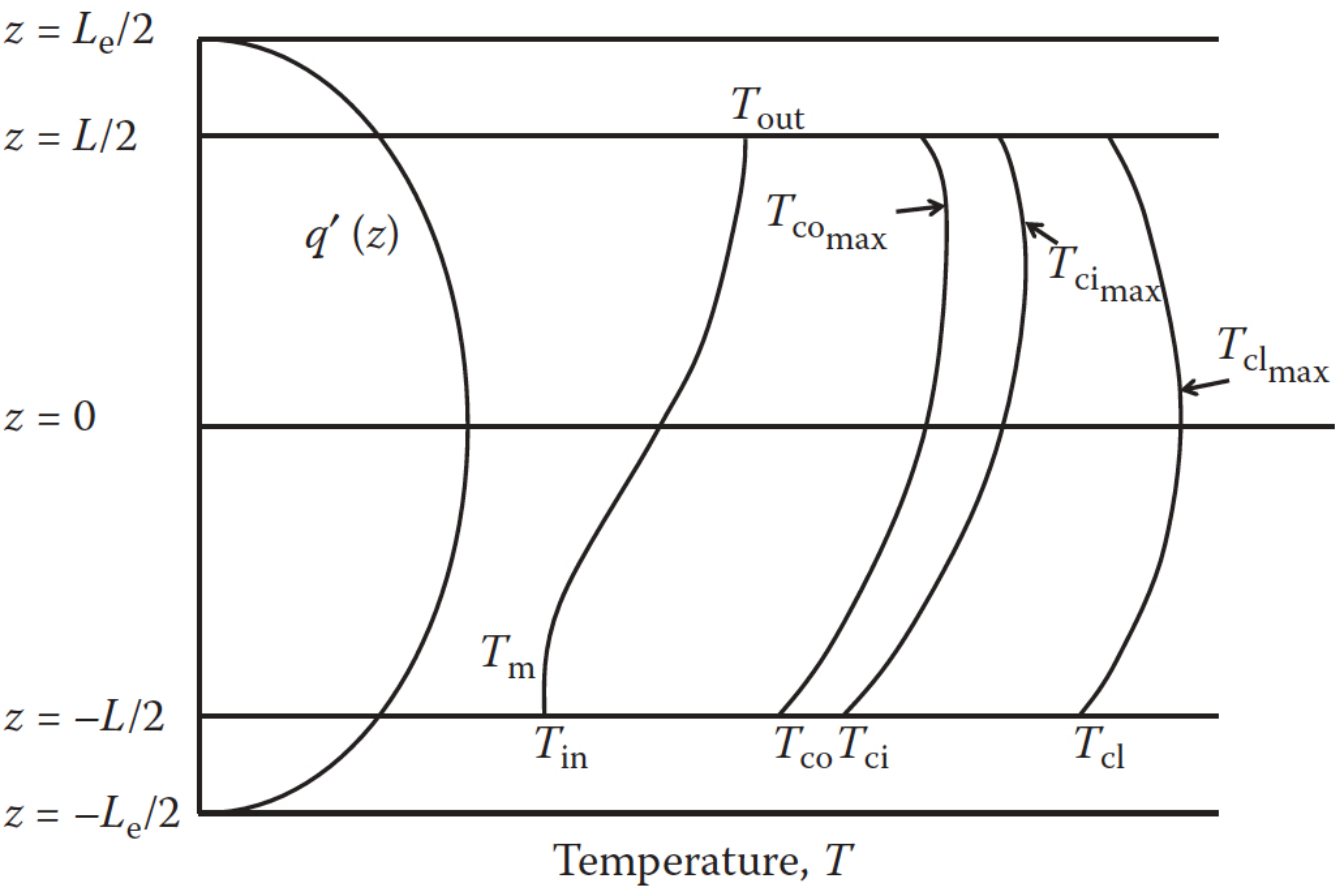

$z = L_e/2$
$z = L/2$
$z = 0$
$z = -L/2$
$z = -L_e/2$
$q'(z)$
T_{out}
$T_{co_{max}}$
$T_{ci_{max}}$
$T_{cl_{max}}$
T_m
T_{in}
T_{co}
T_{ci}
T_{cl}
Temperature, T

Appendix K: Parameters for Typical BWR-5 and PWR Reactors

TABLE K.1
Key Characteristics of the Nine Mile Point 2 General Electric BWR-5 with GE11 Fuel and of the Seabrook Station PWR

Parameters	Units	BWR	Sources	PWR	Sources
Reactor General Parameters		**Nine Mile Point 2, GE BWR-5**		**Seabrook Station Reactor**	
Thermal power, $\dot{Q}_{th}$	MWth	3323	A	3411	G
Net electric power, $\dot{Q}_{e}$	MWe	1062	B	1148	B
Efficiency, η	%	32.0	(1)	33.7	(1)
Nominal pressure, p	MPa	7.14	A	15.51	G
Steam dome pressure, p_{dome}	MPa	7.03	A	—	—
Total core pressure drop, Δp_{core}	MPa	0.171	A	0.197	G
Final feedwater temperature	°C	215.6	A	226.7	G
Core inlet temperature, T_{in}	°C	278.3	A	293.1	G
Core exit temperature, T_{exit}	°C	286.1	(2)	326.8	(12)
Core average exit quality, x	%	14.6	C	—	—
Total steam flow rate, $\dot{m}_{steam}$	kg/s	1798	A	1905.1	G
Core coolant flow rate, $\dot{m}_{core}$	kg/s	13671	A	17476[a]	G
Number of assemblies, N_a	—	764	B	193	G
Active core equivalent diameter	m	4.75	B	3.37	B
Coolant mass in primary circuit	t	260	B	354	B
Fuel enrichment (initial core), r	%	0.7/1.8/2.2	B	1.6/2.4/3.1	B
Fuel enrichment (reloads), r	%	3.5	B	3.1/3.4/4.2[c]	B
Number of loops	—	2	B	4	B
Cycle length	months	16[d]	B	12[d]	B
Average discharge burnup	MWd/tU	32300	B	33000	B
Fuel inventory	tHM	141	B	89	(4)
	$t(UO_2)$	160	(4)	101	G
Average core power density	kW_{th}/L	52.3	(3)	104.5	(3)
Average core specific power	kW_{th}/kg_{HM}	23.6	(15)	38.3	(15)

continued

TABLE K.1 (continued)
Key Characteristics of the Nine Mile Point 2 General Electric BWR-5 with GE11 Fuel and of the Seabrook Station PWR

Parameters	Units	BWR	Sources	PWR	Sources
Reactor General Parameters		**Nine Mile Point 2, GE BWR-5**		**Seabrook Station Reactor**	
Configuration	—	9 × 9	D	17 × 17	G
Fuel rods per assembly, N_{rods}	—	74	D	264	G
Number of part length fuel rods	—	8	D	—	—
Number of full length fuel rods	—	66	D	—	—
Number of water rods, N_{wr}	—	2	E	—	—
Channel width, l_{ch}	mm	134.1 (inside)	E	214.0	G
		138.6 (outside)	H		
Assembly pitch, l	mm	152.4	B	215.0	G
Core average flow rate per assembly, $\dot{m}_a$	kg/s	15.4	(5)	89.8	(13)
Assembly flow area, A_{fa}	m^2	9.718×10^{-3}[b]	(6)	2.444×10^{-2}	(14)
Core average assembly mass flux, G_a	$kg\ m^{-2}\ s^{-1}$	1584[b]	(7)	3675.4	G
Fuel Rods		**GE11, 9 × 9 fuel**		**Seabrook Station Reactor**	
Pellet percent of theoretical density	—	97	D	95	G
Rod-to-rod pitch, P	mm	14.37	D	12.6	G
Fuel rod outside diameter, D	mm	11.20	D	9.5	G
Cladding thickness, t_{clad}	mm	0.71	D	0.572	G
Fuel-cladding gap (cold), t_{gap}	mm	0.09	(8)	0.0826	G
Fuel pellet diameter, D_f	mm	9.60	D	8.192	G
Fuel pellet length, L_f	mm	10	D	9.8	G
Diameter of water rods, D_{wr}	mm	24.9	E	—	—
Total fuel rod height	m	4.09	D	3.876	G
Heated fuel height, L	m	3.588	D	3.658	G
Part length rod length	m	2.286	D	—	—
% of energy deposited in the fuel rods	%	96.5	I	97.4	G
Peak LHGR, q'_0	kW/m	47.24	D	44.62	G
Core average LHGR, $\langle q' \rangle$	kW/m	17.6	F	17.86	G
Core average subchannel flow rate, $\dot{m}_{ch}$	kg/s	0.175 (interior)	(9)	0.335 (interior)	(9)
		0.134 (edge)		0.159 (edge)	
		0.0922 (corner)		0.0759 (corner)	
Subchannel flow area, A_{fch}	m^2	1.08×10^{-4} (int)	(10)	8.79×10^{-5} (int)	(10)
		8.83×10^{-5} (edg)		4.27×10^{-5} (edg)	
		6.70×10^{-5} (cor)		2.07×10^{-5} (cor)	

continued

TABLE K.1 (continued)

Key Characteristics of the Nine Mile Point 2 General Electric BWR-5 with GE11 Fuel and of the Seabrook Station PWR

Parameters	Units	BWR	Sources	PWR	Sources
Core average subchannel mass flux, G_{ch}	kg m^{-2} s^{-1}	1625 (int) 1514 (edg) 1378 (cor)	(11)	3807 (int) 3734 (edg) 3661 (cor)	(11)

[a] Effective flow rate for heat transfer (total minus: flow through thimble tubes, leakage from barrel-baffle into core, head cooling flow, leakage to the vessel outlet nozzle).

[b] Assuming all the fuel rods being full-length rods.

[c] Many PWRs now reload about 4.5%

[d] Typically USA BWRs and PWRs now operate on 24- and 18-month cycle lengths.

References

A Nine Mile Point 2 Nuclear Plant, Updated Safety Analysis Report, Table 4.4-1, USAR Revision 8, Oswego, New York, November 1995.

B *2009 World Nuclear Industry Handbook*, Wilmington Media, Kent, United Kingdom, 2009.

C Typical BWR value.

D Anonymous, Fuel design data, *Nuclear Engineering International*, 52, 638, Sciences Module, p.32, Sept 2007.

E General Electric Company, Retransmittal of Response to Request for Additional Information (RAI) for ESBWR Pre-application Review, San Jose, CA, 2003.

F Watford, G. A., GE 10 × 10 Advanced BWR fuel design, ANS topical meeting on Advances in Nuclear Fuel Management II, Myrtle Beach, SC, 1997.

G Ferroni, P., Hejzlar, P., and Todreas N., Compilation of Thermal–hydraulic and geometric data of the Seabrook Nuclear Power Plant, Unpublished, 2006.

H BWR/6, General Description of a Boiling Water Reactor, General Electric Co., San Jose, CA, revised 1980.

I Author's best estimate.

Calculations

(1) $\eta = \dfrac{\text{Net electric power}}{\text{Thermal power}}$

(2) $T_{exit} = T_{sat}\ (p = 7.03\ MPa)$. Saturation temperature of water at the steam dome pressure.

(3) $$\text{Average core power density} = \frac{\text{Thermal power}}{L\dfrac{\pi}{4}\left(\text{active core equivalent diameter}\right)^2}$$

(4) $t\left(UO_2\right) = \dfrac{t\left(HM\right)}{f_{HM}}$

The heavy metal fraction is given by Equation 2.21:

$$f_{HM} = \frac{rM_{ff} + (1-r)M_{nf}}{rM_{ff} + (1-r)M_{nf} + M_{O_2}} \tag{2.21}$$

The values in Table K.1 are obtained using the average reload enrichments for BWRs and PWRs.

continued

TABLE K.1 (continued)
Key Characteristics of the Nine Mile Point 2 General Electric BWR-5 with GE11 Fuel and of the Seabrook Station PWR

(5) $\dot{m}_a = \frac{(1-0.10-0.04)\times \dot{m}_{core}}{N_a} = \frac{0.86\times \dot{m}_{core}}{N_a} = \frac{0.86\times 13671}{764} = 15.39\,\text{kg/s},$

assuming 10% core bypass flow and 4% flow through the water rods.

(6) $A_{fa} = (l_{ch})^2 - N_{wr}\frac{\pi(D_{wr})^2}{4} - N_{rods}\frac{\pi(D)^2}{4}$

$$= 0.1341^2 - 2\frac{\pi 0.0249^2}{4} - 74\frac{\pi 0.0112^2}{4} = 9.718\times 10^{-3}\text{ m}^2$$

(7) $G_a = \frac{\dot{m}_a}{A_{fa}} = \frac{15.39}{9.718\times 10^{-3}} = 1584\frac{\text{kg}}{\text{m}^2\text{ s}}$

(8) $t_{gap} = \frac{D - D_f - 2t_{clad}}{2} = \frac{11.20 - 9.60 - 2\times 0.71}{2} = 0.09\text{ mm}$

(9) Calculated using equation 4.114 (*Nuclear Systems Vol. II,* p. 154), using $n = 0.2$ and considering for BWR four different types of channels (50 interior channels, 32 edge, 4 corner and 1 near water rods) and for PWR five types (156 interior, 64 edge, 4 corner, 4 near the instrumentation tube, 96 near the 24 guide tubes). From source G, the instrumentation tube diameter is 12.29 mm and the guide tube diameter is 11.58 mm.

(10) $A_{fch} = P^2 - \frac{\pi D^2}{4}$

(11) $G_{ch} = \frac{\dot{m}_{ch}}{A_{fch}}$

(12) $T_{exit} = T_{in} + \Delta T_{core} = 293.1 + 33.7 = 326.8°C$, where $\Delta T_{core} = 33.7°C$ from source G.

(13) $\dot{m}_a = G_a A_{fa} = 3675.4\times 2.444\times 10^{-2} = 89.83\text{ kg/s}$

Note: $\dot{m}_a N_a = 89.83\times 193 = 17365\,\text{kg/s} \cong 99\%\ \dot{m}_{core}$. The two core flows are different because of the water flow between the assemblies.

(14) Using the data about guide tubes and the instrumentation tube cited in (9):

$$A_{fa} = l_{ch}^2 - \frac{\pi}{4}\left(N_{gt}D_{gt}^2 + N_{it}D_{it}^2 + N_{rods}D^2\right)$$

$$= 0.214^2 - \frac{\pi}{4}\left(24\times 0.01158^2 + 1\times 0.01229^2 + 264\times 0.0095^2\right)$$

$$= 2.444\times 10^{-2}\text{ m}^2$$

(15) $Q^M = \frac{\dot{Q}_{th}}{f_{HM}M_{fc}}$

where $\dot{Q}_{th}$ = reactor thermal power
f_{HM} = heavy metal fraction of core fuel material
M_{fc} = mass of fuel material in the core