3 PLANT DESCRIPTION

3.1 GENERAL PLANT DESCRIPTION

The reference design for the BWR is derived from data related to the Peach Bottom-2 BWR/4 Nuclear Power Plant and it is based on the information provided in the EPRI reports [13] and some additional sources such as the PECo Energy Topical Report [14]. This chapter specifies also the plant and neutronic data to be used in all the calculations.

Peach Bottom-2 is a single–cycle boiling water reactor (BWR/4) supplied by General Electric Company. The plant is owned and operated by Philadelphia Electric Company. The plant is located on the Susquehanna River, Pennsylvania.

The reactor vessel has a diameter of 6.37 m, and contains 764 fuel bundles. The active core length is 3.66 m (12 ft). The vessel also contains 172 local power range detectors (LPRM) 4 source range detectors, 8 intermediate range detectors, and 5 traversing in-core probes.

The total core flow is 12915 kg/s; the licensed power is 3293 MWt and 1098 MWe. The plant was accepted by Philadelphia Electric in July 1974.

The reactor vessel and the internals are shown in figure 3.1; whereas reactor vessel and reference design data are provided respectively in table 3-1 and table 3-2.

The recirculation system is responsible of maintaining active circulation of the coolant inside the reactor core; it includes two recirculation loops, each one driving 10 jet pumps (see figure 3.2); the reactor recirculation system design characteristics are collected in table 3-3

In the Peach Bottom-2 reactor there are four main steam lines as shown in figure 3.3. They connect the upper part of the reactor vessel and route steam generated in the core to the turbine. Along the steam line there are 11 Safety Relief Valves (SRV). A bypass system is connected to the main steam line and can route steam directly to the condenser.

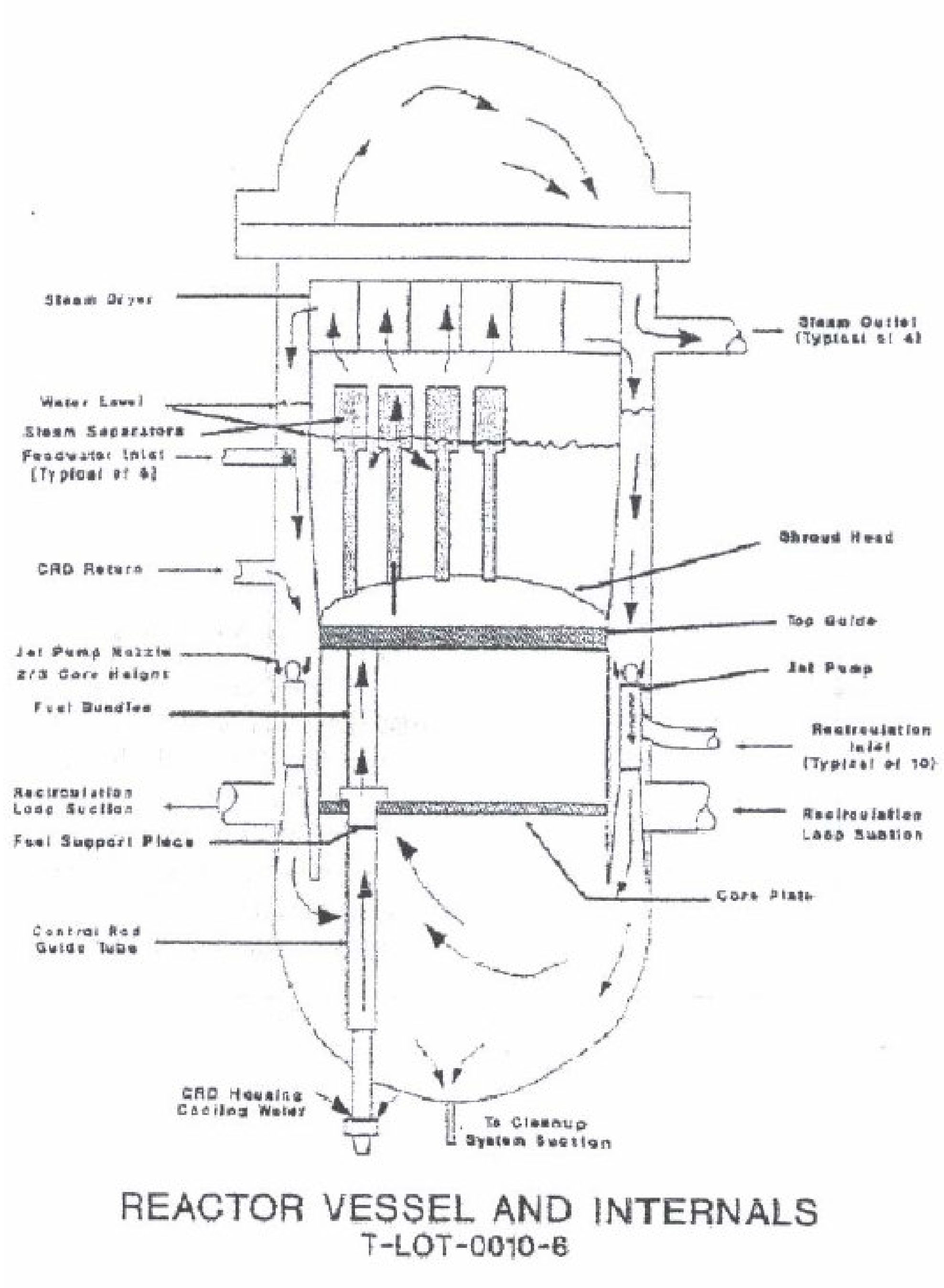

Figure 3.1: Peach Bottom-2 reactor vessel and internals

Table 3-1: Peach Bottom-2 reference design information

Parameter	Value
Rated core thermal power, MWt	3293
Rated core total flowrate, (Mlb/hr) / (kg/s)	102.5 / 12915
Bypass flowrate, fraction of total core flow	Ref [15], Figs. 54-55
Fraction of core thermal power passing through fuel cladding	.96
Approximate bypass coolant total power fraction	.02
Approximate active coolant total power fraction	.02
Approximate channel wall direct heating fraction	.0075
Design minimum critical power ratio 7x7 assemblies (Cycle 2)	≥1.28
Design minimum critical power ratio 8x8 assemblies (Cycle 2)	≥1.31
Design overpower for turbine-generator system	105% rated steam
Turbine inlet pressure, (psia) / (Pa)	965 / 6.653E06
Rated reactor dome pressure, (psia) / (Pa)	1020 / 7.033E06
Rated steam flowrate, (Mlb/hr) / (kg/s)	13.381 / 1685.98
Steam moisture content, fraction	.001
Rate steam dryer and separator pressure drop, (psia) / (Pa)	15 / 103421
Rated core pressure, (psia) / (Pa)	1035/ 7.1361E06
Core pressure drop at rated conditions, (psia) / (Pa)	22 / 151685
Approximate core inlet pressure, (psia) / (Pa)	1060 / 7.3084E06
Core inlet enthalpy, (Btu/lb) / (J/kg)	521.3 / 1.2125 E06
Enthalpy rise across core (average), (Btu/lb)/ (J/kg)	109.6 / 2.5491 E05
Core support plate pressure drop, (psia) / (Pa)	18 / 1.24105 E05
Core orifice and lower tie pressure drop	Ref [15], Figs. 48-53
Fuel bundle pressure drop	Ref [15], Figs. 44-47
Reactor average exit quality at rated conditions	.129
Design hot channel active coolant exit quality	.25
Design bypass coolant exit quality	.0
Total feedwater flowrate, (Mlb/hr) / (kg/s)	13.331 / 1679.1
Feedwater temperature, (ºF) / (K)	376.1 / 464.32
Control rod drive flowrate, (lb/hr) / (kg/s)	50000 / 6.2999
Control rod drive flow temperature, (ºF) / (K)	80 / 299.82
Cleanup demineralizer flowrate, (lb/hr) / (kg/s)	133300 / 16.7958
Cleanup demineralizer inlet temperature, (ºF) / (K)	528 / 548.7
Cleanup demineralizer outlet temperature, (ºF) / (K)	431 / 494.82
Location of demineralized water return	Feedwater line
Jet pump design M ratio	1.96
Jet pump design N ratio	.16
Number of recirculation pumps	2
Recirculation pump type	Centrifugal
Recirculation pump rated flow, (Mlb/hr) / (kg/s)	17.1 / 2154.56
Total developed pump head , (ft) / (m)	710 / 216.41
Recirculation pump efficiency, percent	87
Head loss from vessel recirculation outlet to vessel inlet, (ft) / (m)	59 / 17.98
Head loss from vessel recirculation inlet to jet pump 180º bend entrance, (ft) / (m)	11 / 3.353

Table 3-2: Reactor vessel design data

ITEM	DATA
Reactor vessel	
Operating temperature (° F)/ (K)	575 / 574.82
Inside length (in) / (m)	875.125 / 22.228
Design pressure (psia) / (Pa)	1250 / 8719771
Vessel nozzles (number-size, in / cm)	
Recirculation outlet	2- 28 / 71.12
Steam outlet	4- 26 /66.04
Recirculation inlet	10- 12 / 30.48
Feedwater inlet	6- 12 / 30.48
Core spray inlet	2- 10 / 25.4
Instrument (one of these is head spray)	2- 6 / 15.24
CRD	185- 6 / 15.24
Jet pump instrumentation	2- 4 / 10.16
Vent	1- 4 / 10.16
Instrumentation	2- 6 / 15.24
CRD hydraulic system return	1- 4 / 10.16
Core differential pressure and liquid control	1- 2 / 5.08
Drain	1- 2 / 5.08
In-core flux instrumentation	55- 2 / 5.08
Head seal leak detection	2- 1 / 2.54
Weights (lb / kg)	
Bottom head	207500 / 94120.4
Vessel shell	842300 / 382061
Vessel flange	105800 / 47990.1
Support skirt	28200 / 12791
Other vessel components	65000 / 29484
Total vessel without top head	1248800 / 566446.2
Top head	252200 / 114396
Total vessel	1501000 / 680842.1

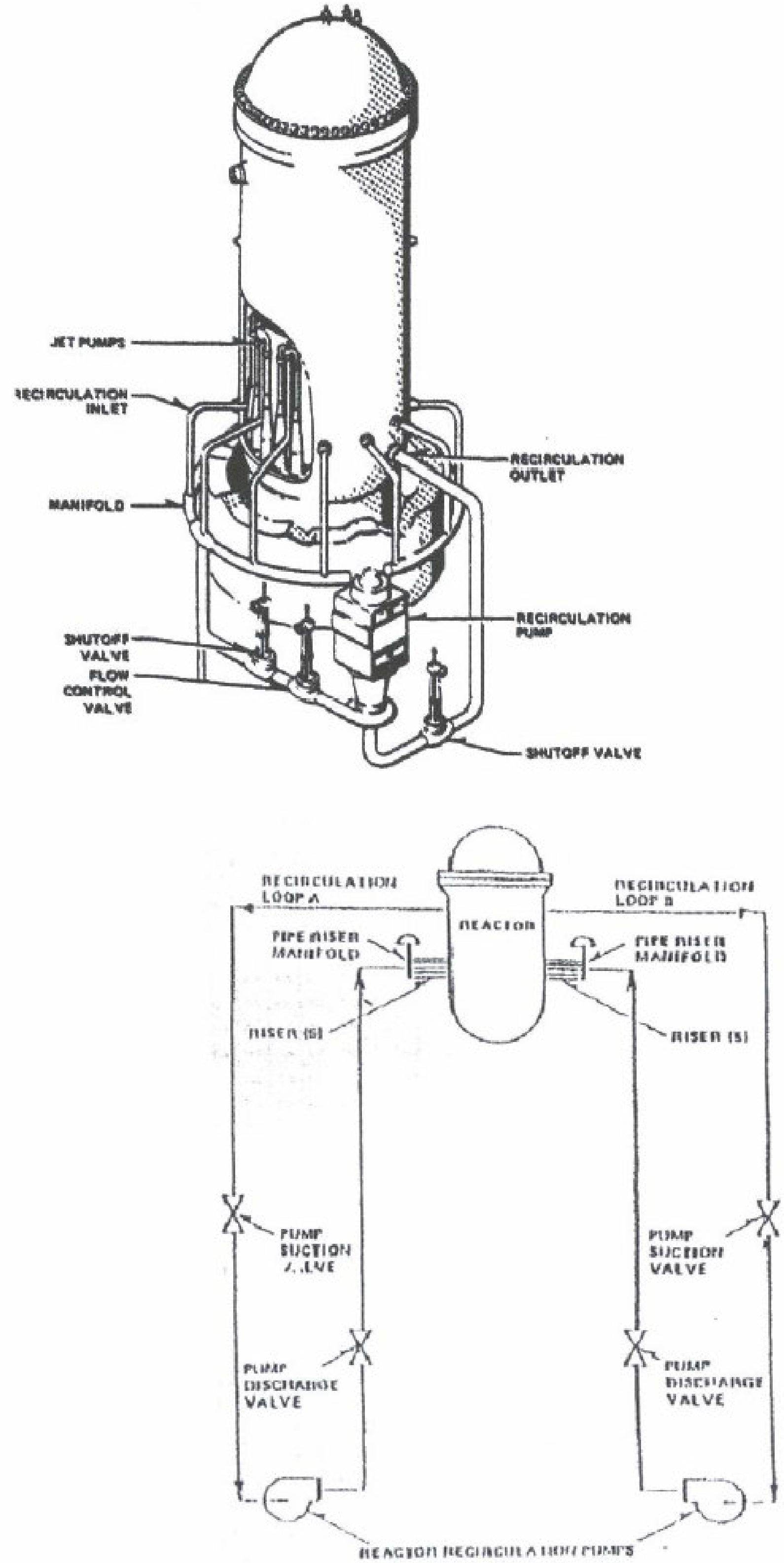

Figure 3.2: Peach Bottom-2 recirculation system

Table 3-3: Reactor recirculation system design characteristics

ITEM	DATA
External loops	
Number of loops	2
Pipe sizes (nominal O.D.)	
Pump suction, (in) / (cm)	28/71.12
Pump discharge, (in) / (cm)	28/71.12
Discharge manifold, (in) / (cm)	22/55.88
Recirculation inlet line, (in) / (cm)	12/30.48
Cross-tie line, (in) / (cm)	22/55.88
Design pressure (psig/Pa), design temperature (°F, K)	
Suction piping	1148/8016506, 562/567.59
Discharge piping	1326/9243773, 562/567.59
Pumps	1500/1.044346E07, 575/574.82
Operation at Rated Conditions	
Recirculation pump	
Flow gpm/(m^3/s) (approximate)	45200/2.851677
Flow, (lb/hr) / (kg/s)	1.71E07/2154.56
Total developed head, (ft) / (m)	710/216.408
Suction pressure (static),(psia) / (Pa)	1032/7115389
Available NPSH (min), (hp) / (W)	500/373000
Water temperature (max.), (°F) / (K)	528/548.71
Pump hydraulic HP (min.), (hp) / (W)	6130/4572980
Flow velocity at pump suction, (fps) / (m/s) (approximate)	27.5/8.382
Drive motor and power supply	
Frequency (at rated), (Hz)	56
Frequency (operating range), (Hz)	11.5/57.5
Total required power to M-G set	
KW/set	6730
KW/total	13460
Jet pumps	
Number	20
Total jet pumps flow, (lb/h) / (kg/s)	1.025E08/12915
Throat I.D., (in) / (cm)	8.18/20.7772
Diffuser I.D., (in) / (cm)	19.0/48.26
NozzleI.D., in / cm (representative)	3.14/7.9756
Differ exit velocity, fps / (m/s)	15.3/4.6634
Jet pump head, (ft) / (m)	76.1/23.195

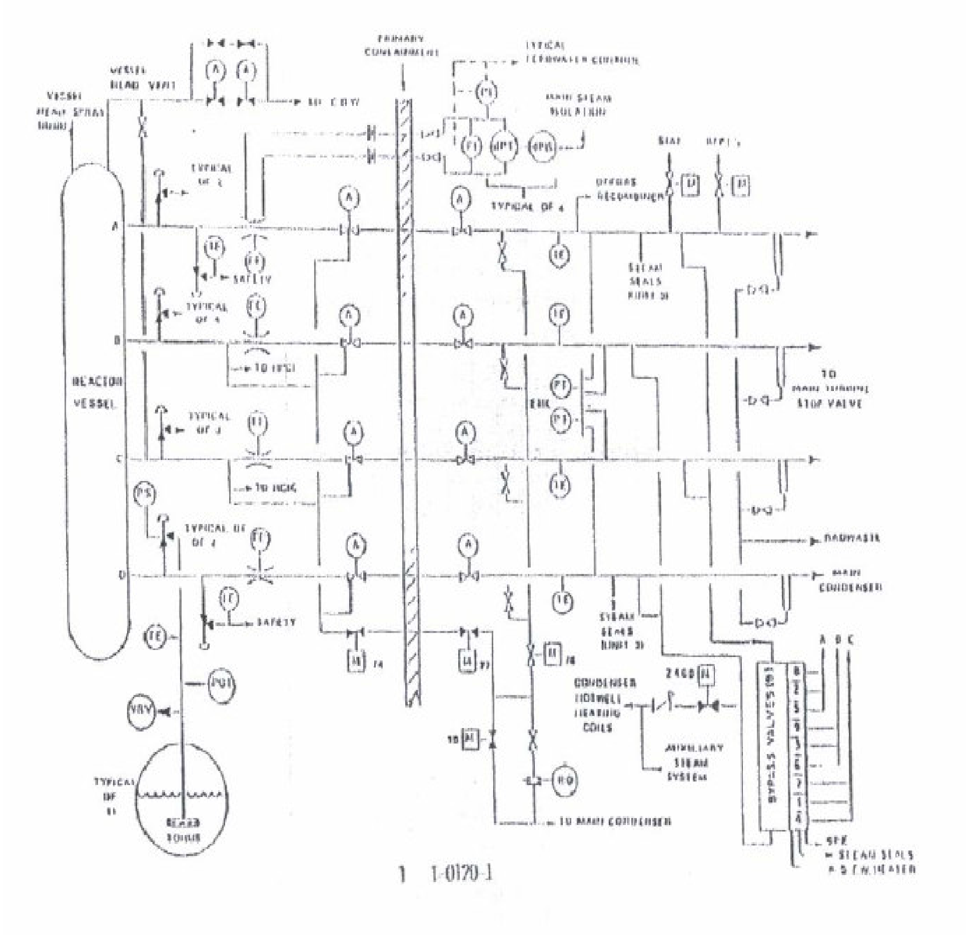

Figure 3.3: Peach Bottom-2 main steam lines system

3.2 CORE GEOMETRY AND FUEL ASSEMBLY

The radial distribution in the reactor core is shown in figure 3.4. Radially, the core is divided into cells 15.24 cm wide, each corresponding to one fuel assembly (FA), plus a radial reflector of the same cells dimensions. There are a total of 912 assemblies, 764 FA and 124 reflector assemblies. Axially, the reactor core is divided into 26 layers (24 core layers plus top and bottom reflectors) with a constant height of 15.24 cm (including reflector nodes). The total active core height is 365.76 cm. The axial nodalization accounts for material changes in the fuel design and for exposure and history variations. Geometric data for the FA and fuel rod is provided in table 3-4.

Table 3-4: Peach Bottom-2 fuel assembly data

	Initial load			Reload	Reload	LTA special
Assembly type	1	2	3	4	5	6
No. of assemblies	168	263	333	0	0	0
INITIAL CORE						
No. of assemblies,C2	0	261	315	68	116	4
Geometry	7x7	7x7	7x7	8x8	8x8	8x8
Assembly Pitch,in	6.0	6.0	6.0	6.0	6.0	6.0
Fuel Rod Pitch	0.738	0.738	0.738	0.640	0.640	0.640
Fuel Rod per Assembly	49	49	49	63	63	62
Water Rods per Assembly	0	0	0	1	1	2
Burnable Poison Positions	0	4	5	5	5	5
No. of Spacer Grids	7	7	7	7	7	7
Inconel per Grid, lb	0.102	0.102	0.102	0.102	0.102	0.102
Zr-4 per Grid, lb	0.537	0.537	0.537	0.614	0.614	0.614
Spacer Width, in	1.625	1.625	1.625	1.625	1.625	1.625
ASSEMBLY AVERAGE FUEL COMPOSITION:						
Gd_2O_3, g	0	441	547	490	328	313
UO_2, kg	222.44	212.21	212.06	207.78	208.0	207.14
Total fuel, kg	222.44	212.65	212.61	208.27	208.33	207.45

The core loading during the tests was as follows: 576 fuel assemblies were the original 7x7 type from cycle 1 (C1), and the remaining 188 were a reload of 8x8 fuel assemblies; 185 control rods provided reactivity control.

Nineteen assembly types are contained within the core geometry. There are 435 compositions. Each composition is defined by material properties (due to changes in the fuel design) and burn-up[8]. Control rod geometry data are provided in table 3-5. The definition of assembly types is shown in table 3-6.

[8] The burn-up dependence is a three-component vector of variables: exposure (GWd/t), spectral history (void fraction), and control rod history.

Table 3-5: Definition of assembly types

Assembly Type	Assembly Design (see tables 2.4.1.1 through 2.4.1.6 ref [16])
1	5
2	4
3	5
4	6
5	2
6	2
7	2
8	2
9	2
10	3
11	2
12	3
13	2
14	3
15	2
16	3
17	2
18	3
19	reflector

Table 3-6: Control rod data (movable control rod)

CONTROL ROD DATA	
Shape	Cruciform
Pitch, (cm)	30.48
Stroke, (cm)	365.76
Control length, (cm)	B_4C granules in Type-304, stainless steel tubes and sheath
Control material	70% of theoretical
Material density	84
Number of control material tubes per rod	0.47752 cm outer diameter by 0.635 cm wall
Tube dimensions	12.3825
Control blade full thickness, (cm)	0.79248
Control blade tip radius, (cm)	0.39624
Sheath thickness, (cm)	0.14224
Central structure wing length, (cm)	1.98501
Blank tubes per wing	None

The radial distribution of these assembly types, within the reactor geometry is shown in figure 3.4 and figure 3.5. The axial locations of compositions for each assembly type are shown in table 3-7.

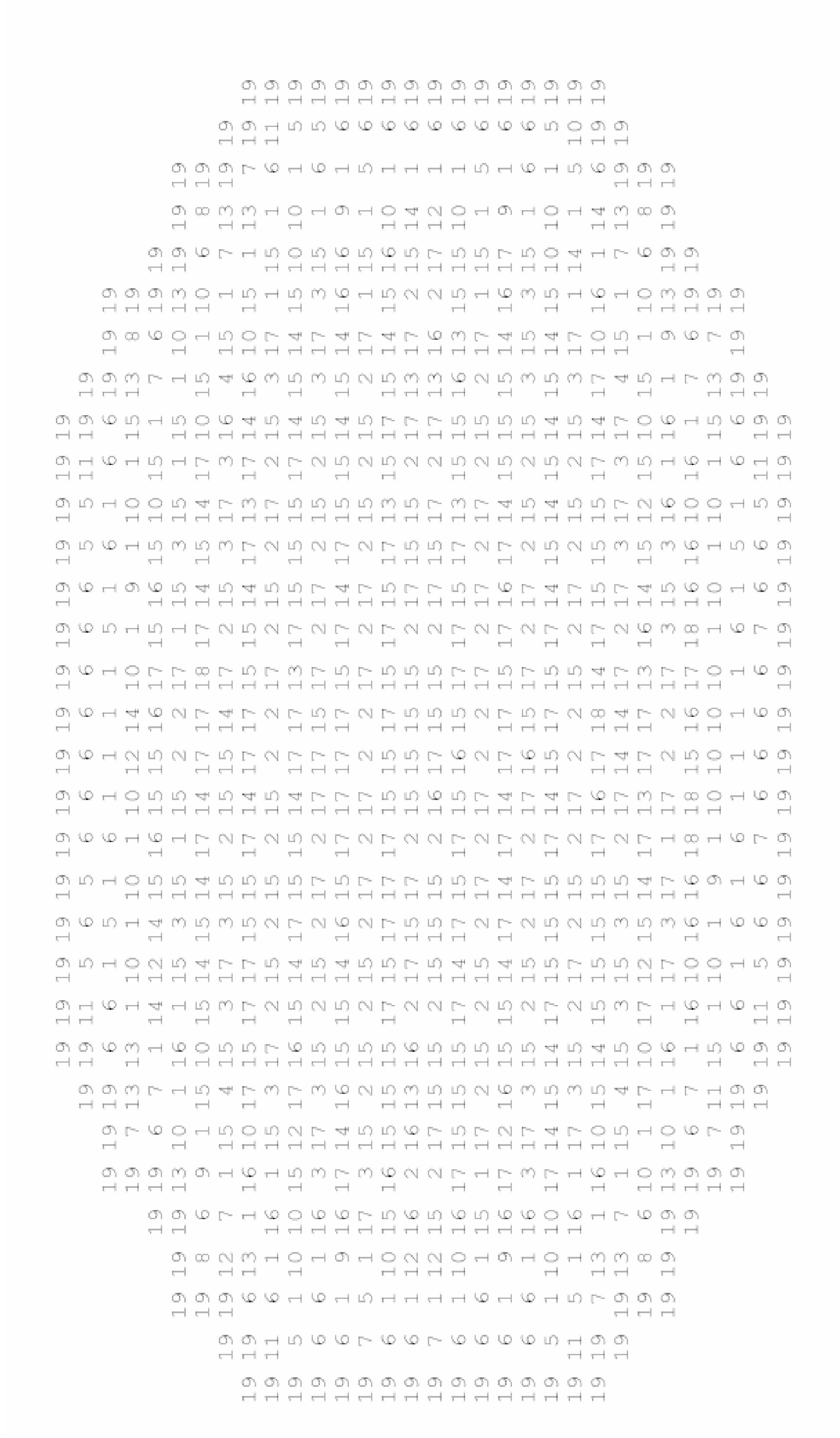

Figure 3.4: Radial distribution of assembly types

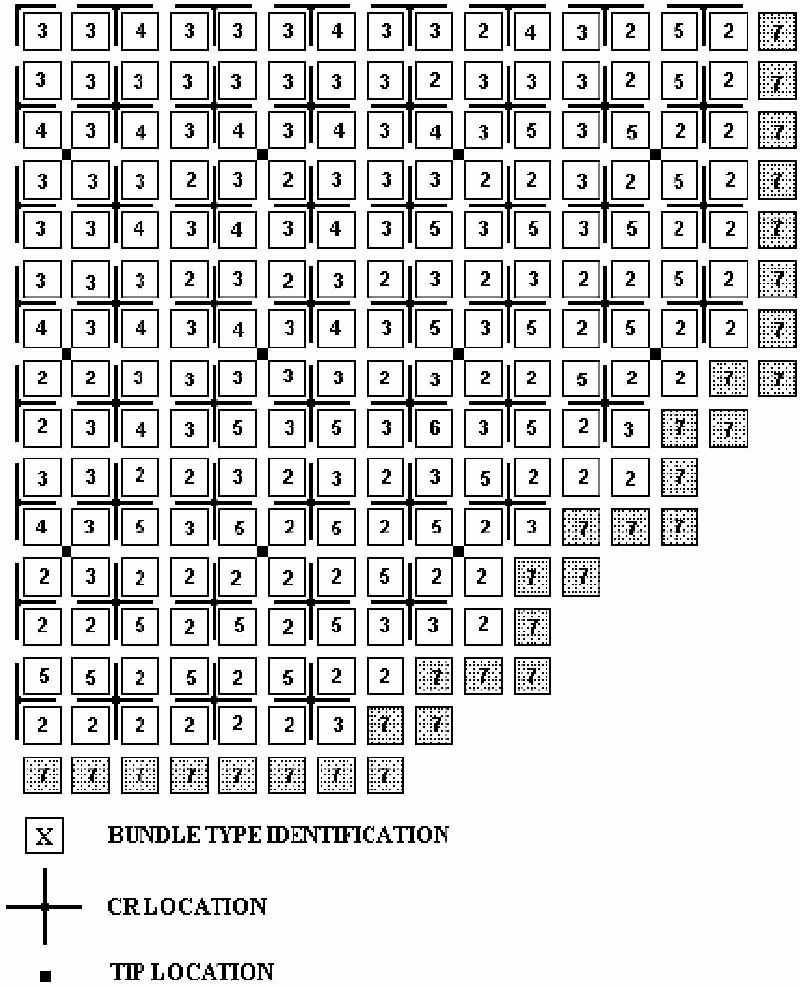

Figure 3.5: Assembly type identification, TIP and Control rod location

Table 3-7: Composition numbers in axial layer for each assembly type

Bottom

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	433	433	433	433	433	433	433	433	433	433	433	433	433	433	433	433	433	433	433
2	1	25	49	73	97	121	145	169	193	217	241	265	289	313	337	361	385	409	435
3	2	26	50	74	98	122	146	170	194	218	242	266	290	314	338	362	386	410	435
4	3	27	51	75	99	123	147	171	195	219	243	267	291	315	339	363	387	411	435
5	4	28	52	76	100	124	148	172	196	220	244	268	292	316	340	364	388	412	435
6	5	29	53	77	101	125	149	173	197	221	245	269	293	317	341	365	389	413	435
7	6	30	54	78	102	126	150	174	198	222	246	270	294	318	342	366	390	414	435
8	7	31	55	79	103	127	151	175	199	223	247	271	295	319	343	367	391	415	435
9	8	32	56	80	104	128	152	176	200	224	248	272	296	320	344	368	392	416	435
10	9	33	57	81	105	129	153	177	201	225	249	273	297	321	345	369	393	417	435
11	10	34	58	82	106	130	154	178	202	226	250	274	298	322	346	370	394	418	435
12	11	35	59	83	107	131	155	179	203	227	251	275	299	323	347	371	395	419	435
13	12	36	60	84	108	132	156	180	204	228	252	276	300	324	348	372	396	420	435
14	13	37	61	85	109	133	157	181	205	229	253	277	301	325	349	373	397	421	435
15	14	38	62	86	110	134	158	182	206	230	254	278	302	326	350	374	398	422	435
16	15	39	63	87	111	135	159	183	207	231	255	279	303	327	351	375	399	423	435
17	16	40	64	88	112	136	160	184	208	232	256	280	304	328	352	376	400	424	435
18	17	41	65	89	113	137	161	185	209	233	257	281	305	329	353	377	401	425	435
19	18	42	66	90	114	138	162	186	210	234	258	282	306	330	354	378	402	426	435
20	19	43	67	91	115	139	163	187	211	235	259	283	307	331	355	379	403	427	435
21	20	44	68	92	116	140	164	188	212	236	260	284	308	332	356	380	404	428	435
22	21	45	69	93	117	141	165	189	213	237	261	285	309	333	357	381	405	429	435
23	22	46	70	94	118	142	166	190	214	238	262	286	310	334	358	382	406	430	435
24	23	47	71	95	119	143	167	191	215	239	263	287	311	335	359	383	407	431	435
25	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	435
26	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434

Top

3.3 NUCLEAR INSTRUMENTATION DATA

Peach Bottom-2 is equipped with a system of Travelling In-Core Probe (TIP) detectors and fixed Local Power Range Monitor (LPRM) detectors designed to provide an accurate representation of a spatial distribution of the neutron flux. The TIP detectors[9] travel through a set of 43 vertical tubes which are distributed uniformly throughout the core with the planar density of one detector per 0.37 m^2. Figure 3.6 shows the core location and coordinate identification of the tip strings.

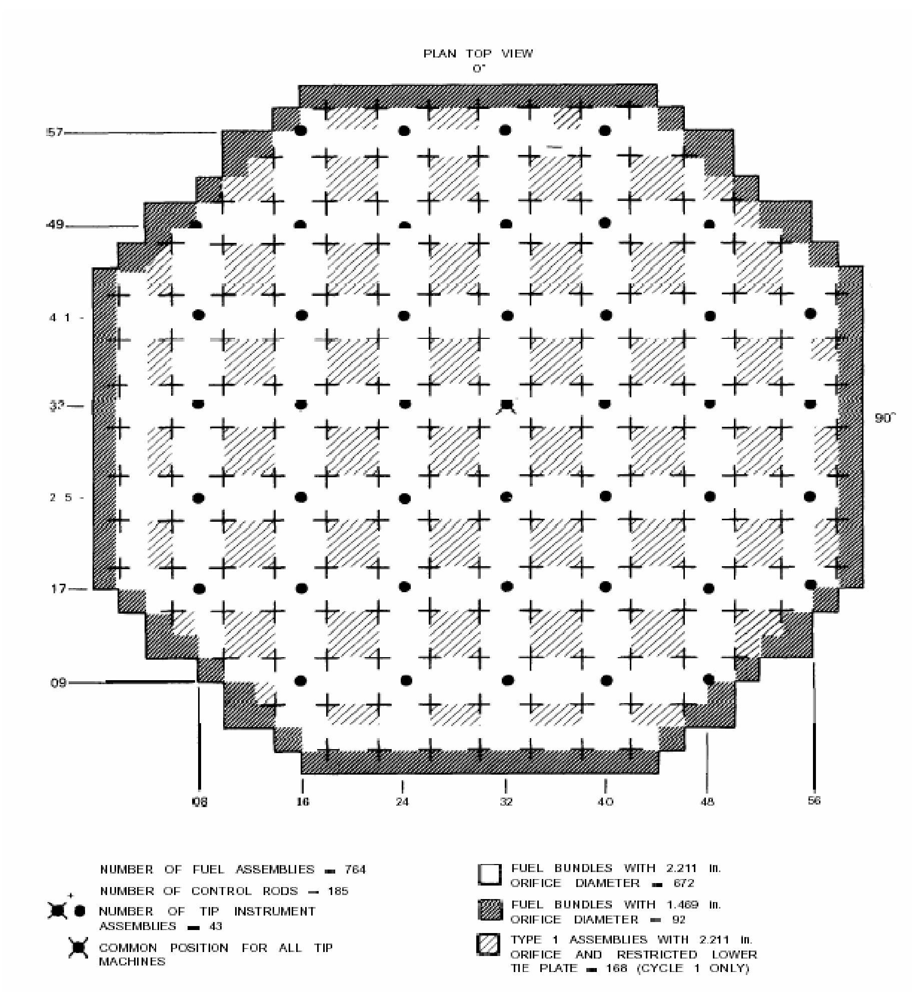

Figure 3.6: Core orificing and TIP system arrangement

[9] The TIP measures the axial neutron flux distribution in the water gap by use an 1-in. long U-235 fission chamber attached to a cable and motor which allows the chamber to be positioned at any point along the axial length of up to 10 core positions for each TIP machine. There are five TIP machines in the Peach Bottom-2 reactor.

Within each instrument tube, the LPRM's are located at 4 axial levels: Level A, Level B, Level C, and Level D which are axially located from bottom to top of the active fuel length at 45.7, 137.2, 228.6, and 304.8 cm respectively. The axial location of the above levels is shown in figure 3.7.

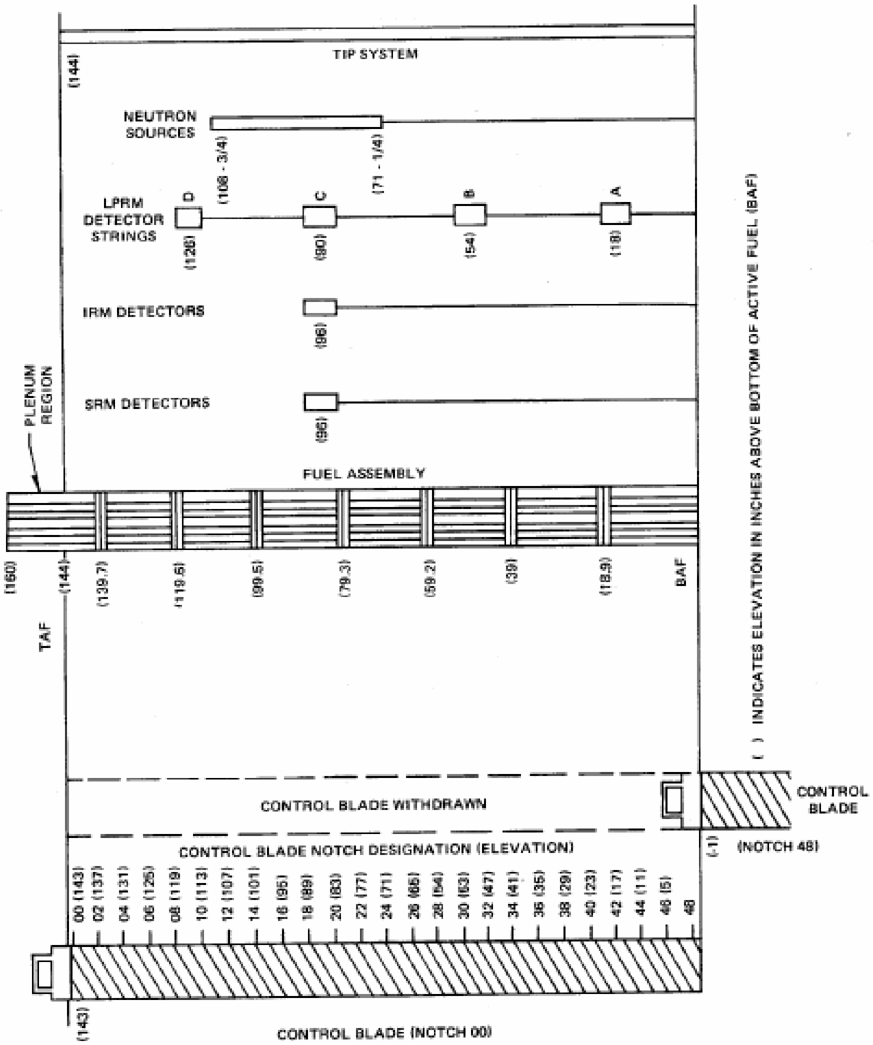

Figure 3.7: Elevation of core components