

## Session 9

### 1. Reactor Types

*[Unlocking, Chapter 7, pp. 89-99 and Chapter 6, pp. 73-88]*

*[Supplementary Material -attached]*

- chart of various families (power, research, propulsion, other)
- types by fuel, moderator, coolant
  - LWR - PWR
  - LWR - BWR
  - RBMK
  - AGR
  - Magnox
  - Fast breeders
  - CANDU
- world population of reactor types

Table 6 Nuclear power's role in electricity production

Country	Nuclear electricity generation 1999		Reactors operating/ operable August 2000		Reactors building August 2000		Uranium required 2000
	%	TWh	No.	MWe	No.	MWe	tonnes U
Argentina	9	6.6	2	935	1	692	146
Armenia	36	2.1	1	376	0	0	67
Belgium	58	47	7	5680	0	0	1020
Brazil	1.1	4.0	1	626	1	1245	292
Bulgaria	47	14.5	6	3538	0	0	615
Canada	12.4	70	18	12058	0	0	1326
China	1.2	14.1	3	2079	8	6320	418
Czech Republic	21	13.4	4	1648	2	1824	349
Finland	33	22	4	2656	0	0	558
France	75	375	59	63203	0	0	10513
Germany	31	160	20	22326	0	0	3707
Hungary	38	14.1	4	1742	0	0	354
India	2.7	11.5	12	2144	4	1304	312
Iran	0	0	0	0	1	950	0
Japan	36	307	53	43505	1	796	7334
Korea RO (South)	43	98	16	12970	4	3800	2480
Lithuania	73	9.9	2	2370	0	0	359
Mexico	5.2	10.0	2	1308	0	0	231
Netherlands	4.0	3.4	1	452	0	0	105
Pakistan	0.12	0.07	2	425	0	0	56
Romania	10.7	4.8	1	650	1	620	90
Russia	14.4	111	29	19843	3	2825	3213
Slovakia	47	13.1	6	2472	0	0	531
Slovenia	37	4.5	1	620	0	0	132
South Africa	7.1	13.5	2	1842	0	0	366
Spain	31	56.5	9	7345	0	0	1538
Sweden	47	70	11	9445	0	0	1539
Switzerland	36	23.5	5	3170	0	0	602
Taiwan	25	37	6	4884	2	2600	971
Ukraine	44	67	14	12120	2	1900	1878
United Kingdom	29	91	33	12518	0	0	2578
USA	20	728	104	98015	0	0	17496
<b>WORLD</b>	<b>16</b>	<b>2401</b>	<b>438</b>	<b>352,965</b>	<b>30</b>	<b>24,926</b>	<b>61,176</b>

Sources: the nuclear power reactor data files of ANSTO, based on information to 31 May, updated to 31 July 2000.

total includes 4 Canadian (Pickering A) reactors which are laid up, total 2080 MWe.

Brazil's second reactor started up in July 2000 but was not connected to the grid by 31 July.

IAEA- for electricity production.

Uranium Institute 2000: (reference case) - for U

Note: 61,176 tU = 72,145 t U<sub>3</sub>O<sub>8</sub>

**Table 5 Nuclear power plants in commercial operation**

Reactor type	Main countries	Number	Fuel	Coolant	Moderator
Pressurised Water Reactor (PWR)	US, France, Japan, Russia	251	enriched $UO_2$	water	water
Boiling Water Reactor (BWR)	US, Japan, Sweden	95	enriched $UO_2$	water	water
Gas-cooled Reactor (Magnox & AGR)	UK	35	natural U, enriched $UO_2$	$CO_2$	graphite
Pressurised Heavy Water Reactor "CANDU" (PHWR)	Canada	34	natural $UO_2$	heavy water	heavy water
Light Water Graphite Reactor (RBMK)	Russia	14	enriched $UO_2$	water	graphite
Fast Neutron Reactor (FBR)	Japan, France, Russia	7	$PuO_2$ and $UO_2$	liquid sodium	none
other	Russia, Japan	12			
<b>Total</b>		<b>448</b>			

Fuels are oxide, except Magnox: metal. The FBRs are, strictly, prototypes

Source: *Nuclear Engineering International handbook 1997.*

**MAGNOX**

Fuel rod casing material	Magnesium - 0.8% Al
Tonnes of fuel (U) per reactor (approx)	230-595
Fuel Enrichment % U-235	Metallic natural U
Output per reactor MWe	50-420
Typical thermal Efficiency %	27
Moderator	graphite
Coolant	carbon dioxide
Coolant pressure bar	10-27
Coolant outlet temperature C	360
Mean fuel burnup at discharge MW(th)d/tU	4,000
Fuel loading arrangements	On load
How many operating UK	20
How many operating - world (1998 excluding China)	20

**PWR**

Fuel rod casing material	Zircaloy
Tonnes of fuel (U) per reactor (approx)	90 (for 1150 MWe)
Fuel Enrichment % U-235	Uranium oxide 1.6-4.5%
Output per reactor MWe	160-1380
Typical thermal Efficiency %	32
Moderator	water
Coolant	water
Coolant pressure bar	150
Coolant outlet temperature C	324
Mean fuel burnup at discharge MW(th)d/tU	40,000
Fuel loading arrangements	Off load
How many operating UK	1
How many operating - world (1998 excluding China)	c.250

**RBMK 1000**

Fuel rod casing material	Zr-1%Nb
Tonnes of fuel (U) per reactor (approx)	180 (for 1500 MWe)
Fuel Enrichment % U-235	Uranium dioxide 2.0-2.4
Output per reactor MWe	1000 & 1500
Typical thermal Efficiency %	31
Moderator	graphite
Coolant	water
Coolant pressure bar	75
Coolant outlet temperature C	350 max
Mean fuel burnup at discharge MW(th)d/tU	22,000
Fuel loading arrangements	On load
How many operating UK	0
How many operating - world (1998 excluding China)	15

**AGR**

Fuel rod casing material	20%Cr/25%Ni/Nb stainless steel
Tonnes of fuel (U) per reactor (approx)	130
Fuel Enrichment % U-235	Uranium oxide 2.7-3.4%
Output per reactor MWe	600-625
Typical thermal Efficiency %	41
Moderator	graphite
Coolant	carbon dioxide
Coolant pressure bar	30-40
Coolant outlet temperature C	640
Mean fuel burnup at discharge MW(th)d/tU	27,000
Fuel loading arrangements	On load
How many operating UK	14
How many operating - world (1998 excluding China)	14

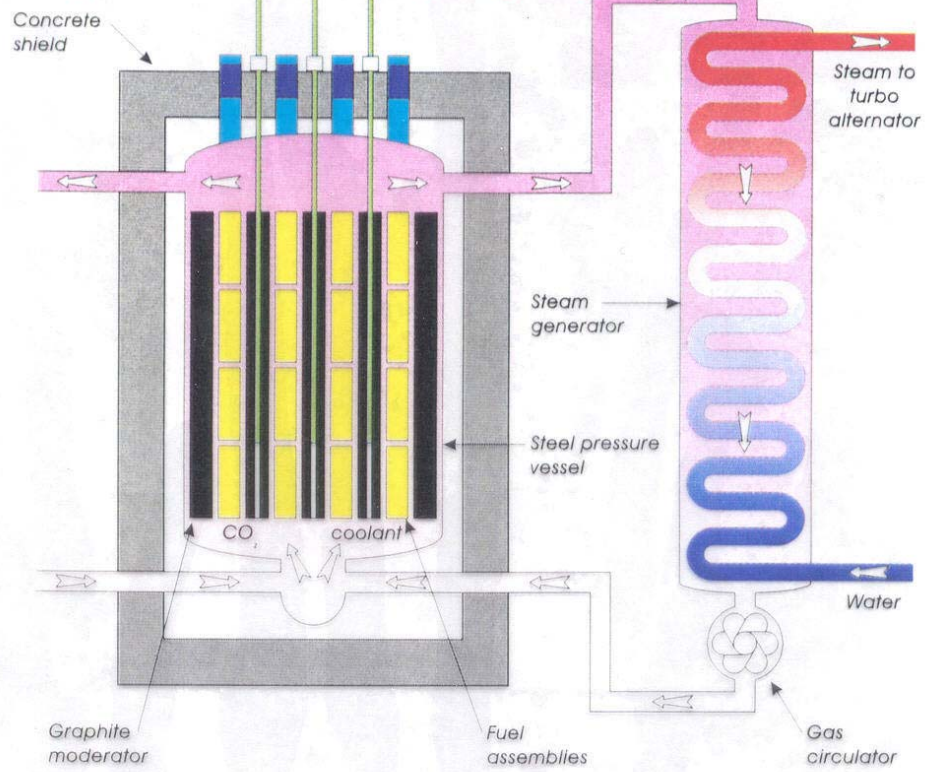
**BWR**

Fuel rod casing material	Zircaloy
Tonnes of fuel (U) per reactor (approx)	140 (for 1200 MWe)
Fuel Enrichment % U-235	Uranium dioxide 1.6-4.5%
Output per reactor MWe	75-1300
Typical thermal Efficiency %	32
Moderator	water
Coolant	water
Coolant pressure bar	70(GE BWR-6)
Coolant outlet temperature C	300
Mean fuel burnup at discharge MW(th)d/tU	35,000
Fuel loading arrangements	Off load
How many operating UK	0
How many operating - world (1998 excluding China)	c.93

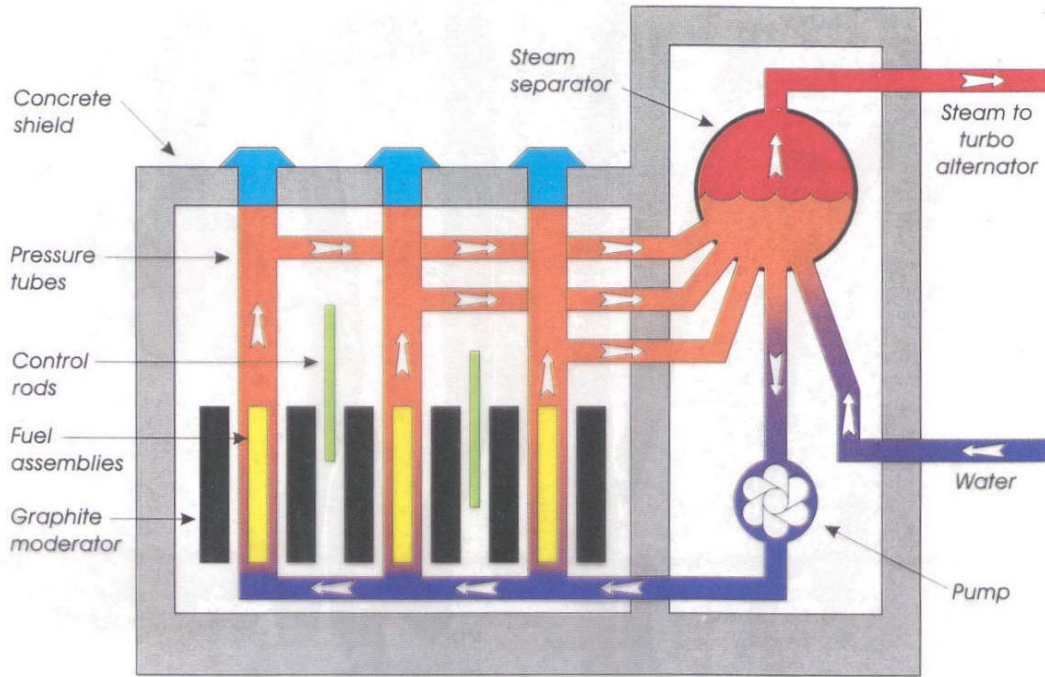
**CANDU**

Fuel rod casing material	Zircaloy-4
Tonnes of fuel (U) per reactor (approx)	110 (935 MWe)
Fuel Enrichment % U-235	Uranium dioxide non-enriched
Output per reactor MWe	220-935
Typical thermal Efficiency %	34
Moderator	heavy water
Coolant	heavy water
Coolant pressure bar	110
Coolant outlet temperature C	318
Mean fuel burnup at discharge MW(th)d/tU	7,000
Fuel loading arrangements	On load
How many operating UK	0
How many operating - world (1998 excluding China)	28

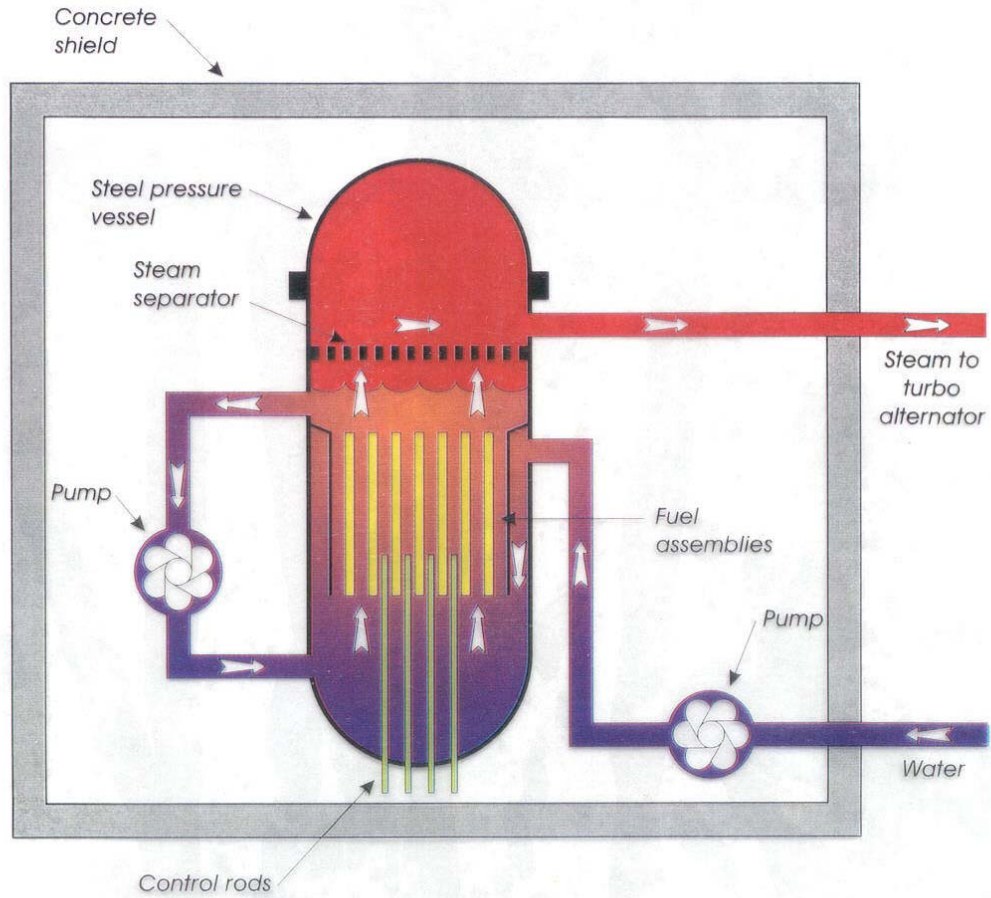
**Basic gas cooled reactor (Magnox)**



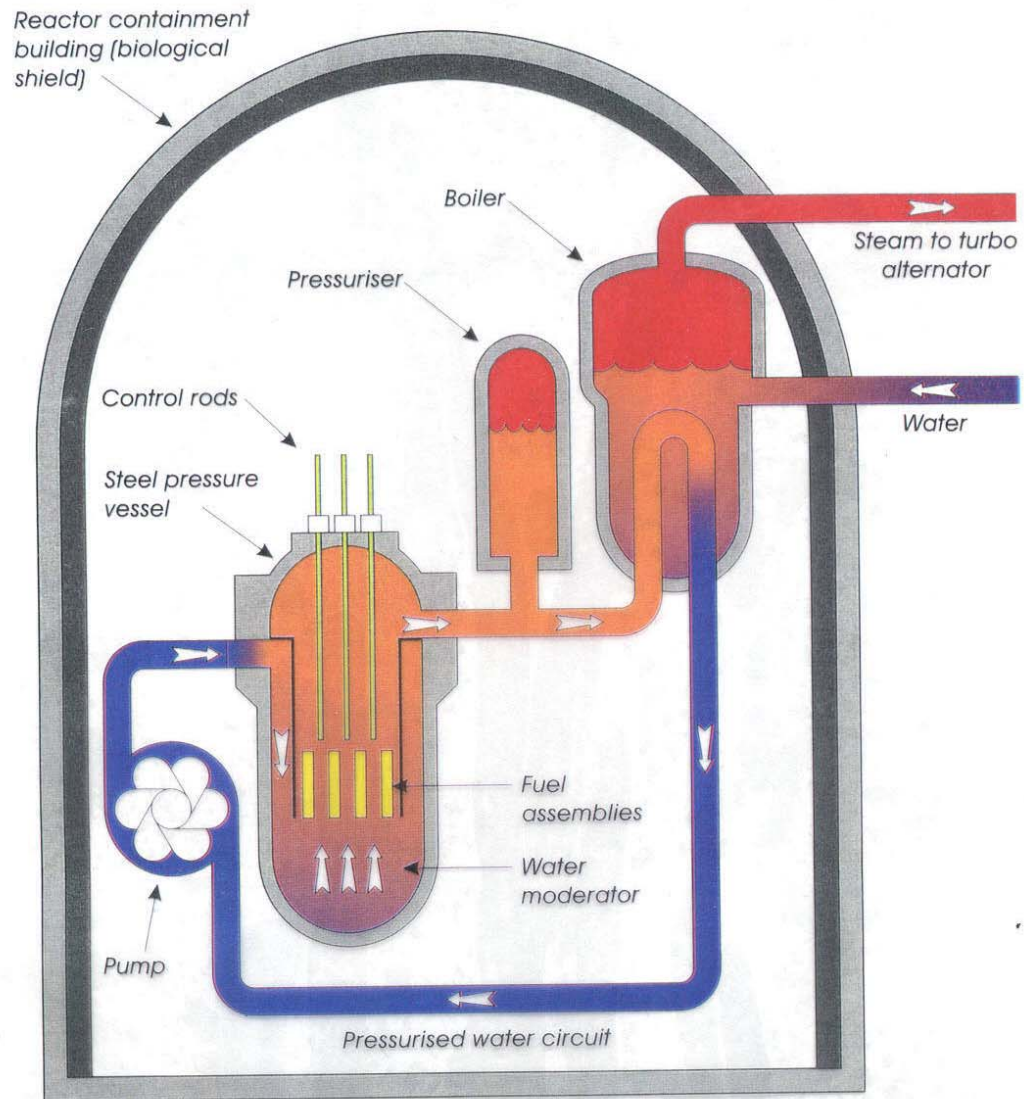
Graphite-moderated water cooled reactor ( RBMK 1000)



### Boiling water reactor (BWR)

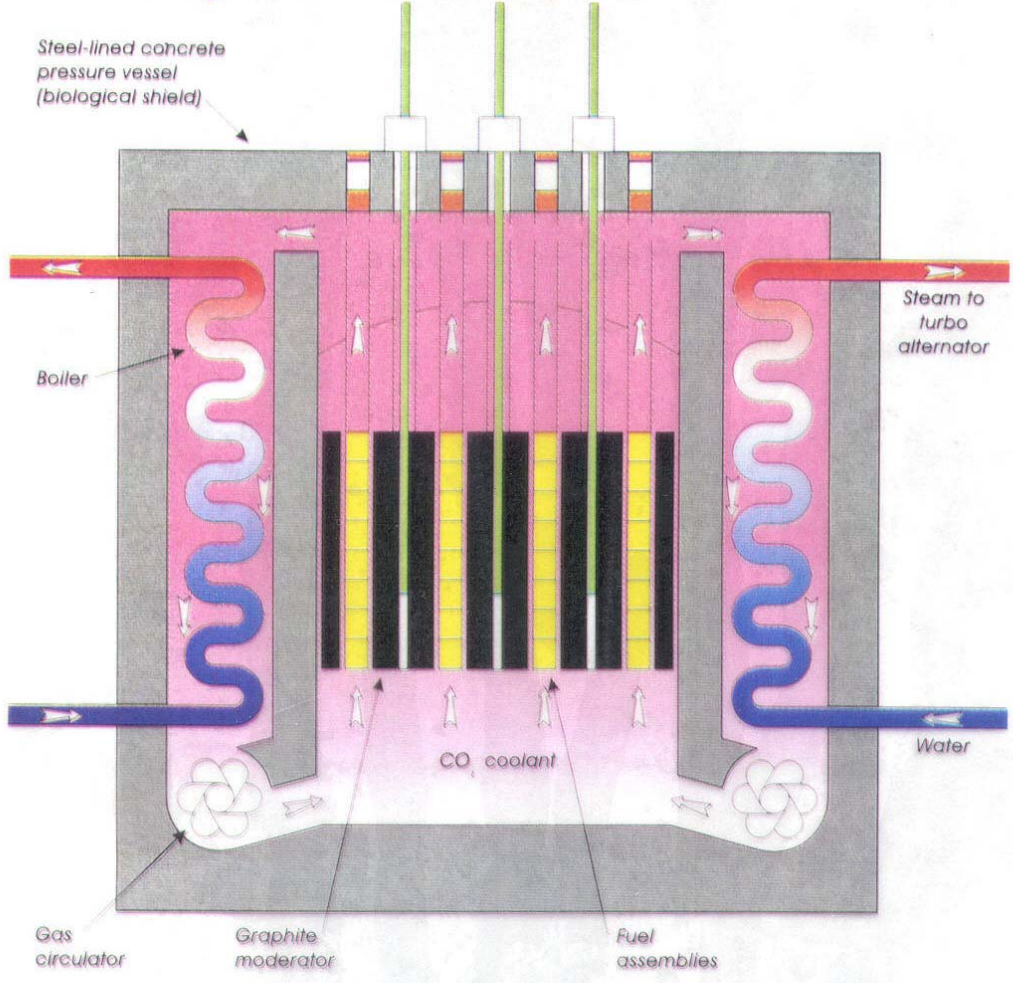


### Pressurised water reactor (PWR)





### Advanced gas cooled reactor (AGR)



### Pressurised heavy water reactor ( CANDU )

