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Internal Assesment Test – 3

Sub: ENERGY ENGINEERING				Code: 18ME81
Date: 13/05/2023	Duration: 90 mins	Max Marks: 50	Sem: 8	Branch (sections): ME (A,B)

Answer all FIVE questions.

		Marks	OBE	
			CO	RBT
1	Explain sodium - graphite nuclear reactor, with a neat sketch.	[10]	CO3	L2
2	Differentiate between Boiling water reactor and pressurized water reactor.	[10]	CO3	L2
3	Discuss about nuclear fuel used in reactors. What are all the main sources of nuclear waste in nuclear power plant?	[10]	CO3	L2
4	Draw a near diagram of breeder reactor and list out its advantages and disadvantages.	[10]	CO3	L2
5	Explain the principle of release of nuclear energy by fusion and fission reactions.	[10]	CO3	L2

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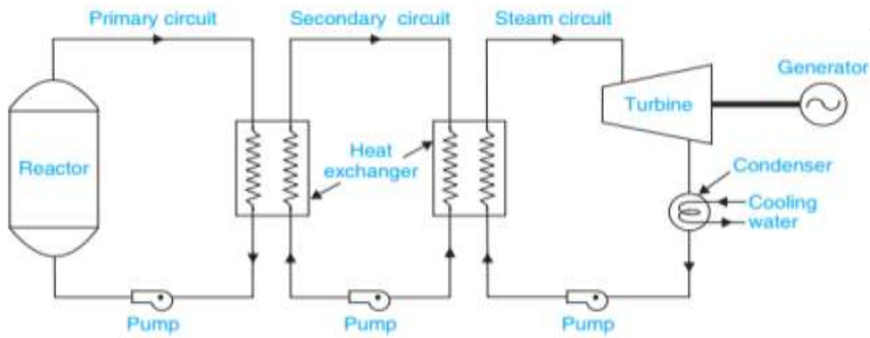
1.

Sodium graphite reactor/Liquid Metal Cooled Reactors

sodium works as a coolant and graphite works as moderator

Sodium boils at 880°C under atmospheric pressure and freezes at 95°C. Hence sodium is first melted by electric heating system and be pressurised to about 7 bar. The



The primary circuit has liquid sodium

The secondary circuit has an alloy of sodium and potassium in liquid form

The effectiveness of a nuclear shield against gamma rays approximately depends upon its mass. A heavy material like lead will be a more effective shield per unit weight, than a light element such as carbon. On the other hand, light elements, particularly hydrogen are much more effective per unit weight than heavy elements for fast neutron shielding. Concrete is a material that offers a compromise between these two extreme characteristics of shielding material for both gamma rays and fast neutrons. It is a material which has low cost and is easily available

The actual design of the shield, however, involves the following considerations :

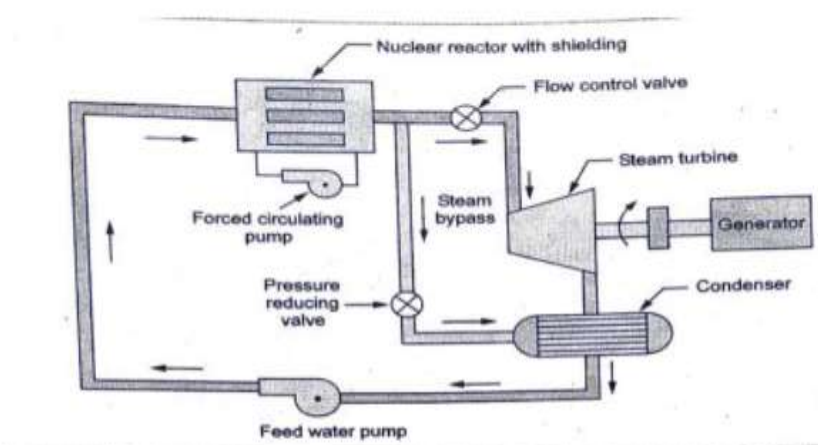
(i) The total amount of radiation produced in the reactor.

(ii) The amount of radiation that can be permitted to leak through the shield.

(iii) The shielding properties of material

2.

Boiling water reactor



Differences between PWR and BWR

Pressurized Water Reactor (PWR)	Boiling Water Reactor (BWR)
Pressurized Water Reactor (PWR) power plants consist of two loops—(i) primary loop or coolant loop that takes away heat from reactor, and (ii) secondary loop or working fluid loop that drives the turbine. A heat exchanger (HE) is employed to transfer heat from primary loop to the secondary loop.	Boiling Water Reactor (BWR) power plants consist of a single loop where the coolant that takes away heat from the reactor is directly fed to the turbine. Thus no heat exchanger is desired.
In the primary loop, normal water (H_2O) acts as coolant-cum-moderator. In the secondary loop, the normal water acts as working fluid. However, water from one loop is not allowed to mix with the water of other loop.	Since it has only one loop, so normal water (H_2O) serves all three purposes – cooling, moderation, and working fluid.
Normal water in the primary loop, that acts as moderator-cum-coolant, is not allowed to boil. That means the water remains in liquid phase throughout the cycle of primary loop. However, the water in the secondary loop is allowed to boil.	Here the normal water (H_2O) is allowed to change its phase. Thus the water (liquid phase) is first converted into steam (gaseous phase) within the reactor, and then the steam is again condensed to water before pumping back to reactor.
Here steam is generated in a heat exchanger outside the nuclear reactor.	Here steam is generated within the reactor itself.
Here the water in the primary loop is maintained at high pressure (15 – 17 MPa) to avoid boiling at reactor exit.	Here water pressure remains comparatively low (7 – 8 MPa) as it is allowed to boil.
A pressurizer is required to use mandatorily to maintain water pressure in such a way that it does not evaporate even at very high temperature.	No such pressurizer is employed as evaporation of the water is desired.
The temperature of the water at the reactor exit is kept around 310°C (corresponding to the working pressure to avoid boiling).	Steam temperature at reactor exit remains comparatively low (around 285°C).
PWR has comparatively low thermal efficiency owing to two different loops.	BWR offers higher thermal efficiency.
In PWR, the control rods are inserted from the top of the nuclear reactor.	In BWR, the control rods are inserted from the bottom of the nuclear reactor.
Since the fluid is maintained at high pressure, so the PWR core volume is less.	For the same power generation, core volume of the BWR is comparatively larger.
Since the working fluid loop is separated from the primary loop, so PWR is less risky in spreading of radioactive materials owing to leakage.	Since same fluid passes through the reactor and turbine in BWR plants, so any leakage in the turbine can spread radioactive elements into the atmosphere.

3.

10.10.2 NUCLEAR FUEL

Fuel of a nuclear reactor should be fissionable material which can be defined as an element or isotope whose nuclei can be caused to undergo nuclear fission by nuclear bombardment and to produce a fission chain reaction. It can be one or all of the following

U^{233}, U^{235} and Pu^{239}.

Natural uranium found in earth crust contains three isotopes namely U^{234}, U^{235} and U^{238} and their average percentage is as follows :

U^{238} — 99.3%

U^{235} — 0.7%

U^{234} — Trace

Out of these U^{235} is most unstable and is capable of sustaining chain reaction and has been given the name as primary fuel. U^{233} arid Pu^{239} are artificially produced from Th^{232} and U^{238} respectively and are called secondary fuel.

Pu^{239} and U^{233} so produced can be fissioned by thermal neutrons. Nuclear fuel should not be expensive to fabricate. It should be able to operate at high temperatures and should be resistant to radiation damage.

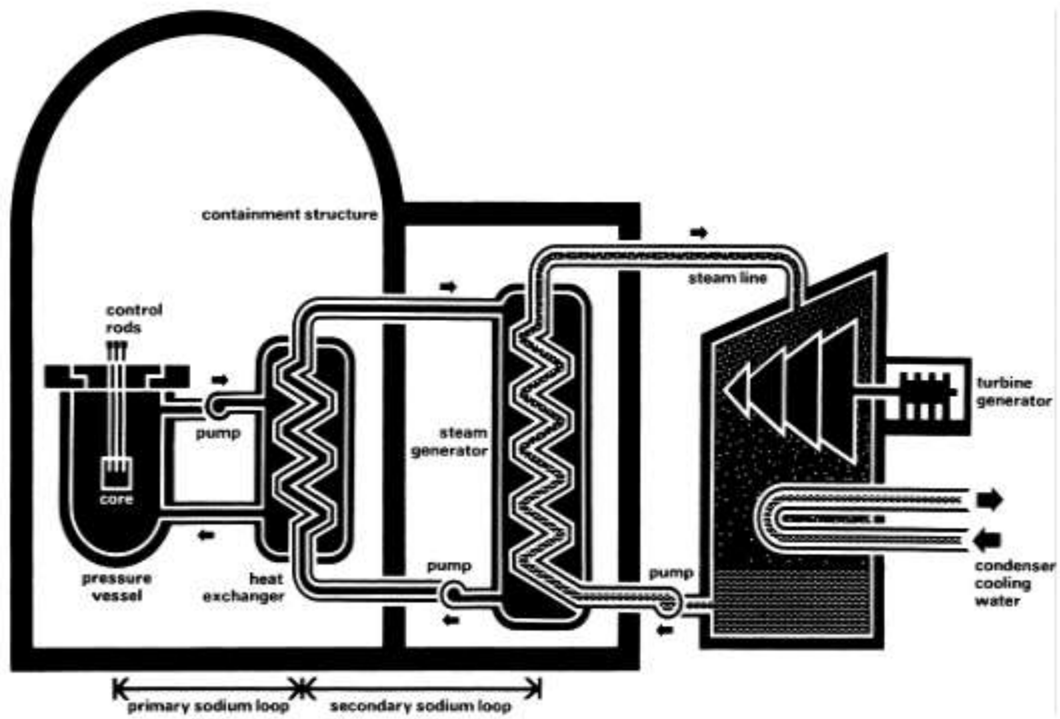
Uranium deposits are found in various countries such as Congo, Canada, U.S.A., U.S.S.R., Australia.

The fuel should be protected from corrosion and erosion of the coolant and for this it is encased in metal cladding generally stainless steel or aluminum. Adequate arrangements should be made for fuel supply, charging or discharging and storing of the fuel.

For economical operation of a nuclear power plant special attention should be paid to reprocess the spent: up (burnt) fuel elements and the unconsumed fuel. The spent up fuel elements are intensively radioactive and emits some neutron and gamma rays and should be handled carefully.

In order to prevent the contamination of the coolant by fission products, a protective coating or cladding must separate the fuel from the coolant stream. Fuel element cladding should possess the

4. Breeder Reactors



The breeder-reactor design concept is predicated on maximizing new fuel production in breeding more fuel than used to sustain the neutron chain reaction. For this purpose, fissile plutonium and fertile ^{238}U fuel with fast neutrons have been found to be the most efficient.

The liquid-metal fast-breeder reactor (LMFBR) keeps neutron energy high by using liquid sodium as a coolant, and thereby specifically avoiding the presence of moderating material. The liquid sodium, although not the heaviest coolant available, is not too light, has favorable heat-transfer properties, and is not an excessively strong absorber of neutrons compared to other choices.

Although experimental fast-breeder reactors have been operated in the United States since the late 1950s, the most recent intense focus on LMFBR systems had been in Western Europe, the Russia, Japan, and India. With shutdown of the major western European systems located in France and Germany, (which were funded by consortia that also include Italy, Belgium, Netherlands, and the United Kingdom), the future of this reactor type is in doubt.

The steam cycle is a three-loop system (Fig. 17) with the first two of sodium and the third of water. The intermediate loop is present to isolate the primary from possible contact with water in the steam generator. The primary sodium becomes radioactive from neutron absorption and also can pick up fission-product radionuclides from the fuel. If this sodium were to come in contact with water, it would lead to an exothermic reaction that also would spread contamination.

5.

Fission	Fusion
1. When heavy unstable nucleon is bombarded with neutrons, the nucleus *splits* into fragments of equal mass and energy is released.	1. Some light elements *fuse together* with the release of energy.
2. About *one thousandth* of the mass is *converted into energy*.	2. It is possible to have *four thousandths* of mass *converted into energy*.
3. Nuclear reaction *residual problem is great*.	3. Residual problem is *much less*.
4. Amount of radioactive material in a fission reactor is *high*.	4. A possible advantage is that the total amount of radioactive material in a working fusion reactor is likely to be *very much less* than that in a fission reactor.
5. Because of higher radioactive material, *health hazards is high in case of accidents*.	5. Because of lesser radioactive material, *health hazards is much less*.
6. It is *possible to construct self-sustained fission reactors* and have positive energy release.	6. It is *extremely difficult to construct controlled fusion reactors*.
7. *Manageable temperatures* are obtained.	7. Needs *unmanageable temperatures* like 30 million degrees for fusion process to occur.
8. Raw fissionable material is *not available in plenty*.	8. Reserves of deuterium, the fusion element, *is available in great quantity*.