Nuclear Theory - Course 227

NEUTRON DENSITY, NEUTRON POWER AND NEUTRON FLUX

In this lesson, we introduce a new quantity, called NEUTRON FLUX, which is closely connected with neutron production.

Neutron Density

The amount of power produced in a reactor depends on the number of fissions that occur per second, ie, on the rate of fissioning of U-235. Let us be quite clear on the meaning of the terms we are using here By "power" we mean the rate at which heat is released, ie, we mean THERMAL power in watts or joules/sec or Btu/minute or any other appropriate units. This thermal power, then, is directly proportional to the number of fissions occurring per second.

eg: To produce 1 watt of power, we must have

$$3.1 \times 10^{10} \text{ fissions/sec}$$

To produce 100 Megawatts, we must have

$$3.1 \times 10^{10} \times 100 \times 10^{6},$$

or $$3.1 \times 10^{18} \text{ fissions/sec}$$

We are referring here to the whole reactor producing this power and the corresponding rate of fissioning being the total throughout the whole core.

If the power production is to remain constant or steady, the same rate of fissioning must be maintained continuously. Therefore, the number of thermal neutrons causing fission in the first generation must be the same as in the second generation and in all following generations. This means that the total number of neutrons in the reactor must remain constant, ie, the neutron POPULATION, as it is called, must remain constant.

Now the power produced and, therefore, the rate of fissioning varies from one point to another in a reactor. To allow for this variation, we talk in terms of the NEUTRON DENSITY in the reactor.

The neutron density is the number of neutrons per unit volume (eg, per cubic centimeter).

Therefore, although the total neutron population in the reactor remains constant, the neutron density differs from one point to another having a maximum value, usually, at the centre of the reactor core. However, the average neutron density throughout the core, is constant when the power is constant. If the power changes, the numbers of fissions per second changes and the average neutron density changes.

Neutron Power

The thermal power in a reactor could be measured from the temperatures and flow rates in the heat transport system, ie, from the thermal energy transported out of the reactor core. However, when the rate of fissioning and the neutron densities are changed, there is some delay before the temperatures settle down. It is, therefore, desirable that the neutron densities be measured also. This is done with electronic equipment which measured the neutron density at one point in the reactor. The equipment is usually calibrated, by comparison with the thermal power, in percent of full power. This measurement of neutron density is known as NEUTRON POWER. It has the advantage, over thermal power, of being an instantaneous measure of reactor power.

Neutron Flux

The quantity that determines how many fissions take place per second and what the neutron density is at any point, is known as the NEUTRON FLUX. It is the most difficult of these three quantities to understand. It may be sufficient to say that, the higher the neutron flux, at any point in the reactor, the higher the rate of fissioning at that point, the higher the neutron density at that point and the greater the power produced at that point. Like neutron density, the neutron flux is greatest at the centre of the reactor and, at constant reactor power, the average neutron flux, over the reactor core, is constant.

A physical meaning or definition of neutron flux can be arrived at as follows. We have said that, at constant power, the neutron density at any point in the reactor remains constant. However, these neutrons are not like peas packed in a tin, so that none of them leak out and no more peas can get into the tin. The neutrons are moving around all the time. Some neutrons move away from a particular location but an equal number move in to replace them, so that the total number in a particular volume remain constant.

Fig. 1 illustrates a 1 cm cube in the reactor with neutrons continually entering this volume from the rest of the core and neutrons escaping from this cubical volume to the rest of the core. The net number in this cube will remain constant.

If we take one face of the cube, neutrons are continually crossing this 1 sq cm of area in both directions and at all angles. The total number of neutrons crossing this unit area per second is the neutron flux at the centre of that unit area. This neutron flux can be defined as follows: -

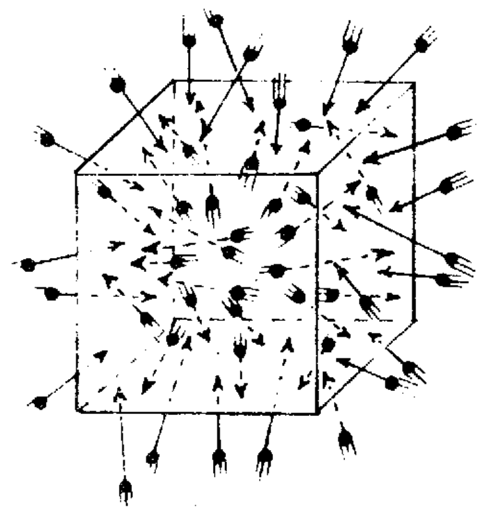

Fig. 1

> The neutron flux at a point in a reactor is defined as the number of neutrons per second, travelling in all directions, which cross a square centimeter area, placed at that point.

Therefore the flux will be measured in neutrons per square centimeter per second.

Neutron flux is usually denoted by the Greek letter ϕ.

ASSIGNMENT

1. What is meant by the term "Thermal Power" in a reactor?

2. (a) Define the term "Neutron Density" in a reactor.

   (b) If the th`-`mal power in a reactor is constant, what can be said of
   - (i) The average neutron density in the reactor?
   - (ii) The neutron densities at different points in the reactor?

(iii) The neutron density at the centre of the reactor?

3. What is meant by "Neutron Power" in a reactor and what advantage does measurement of neutron power have over measurement of thermal power?

4. (a) Define "Neutron Flux".

   (b) How does the neutron flux affect the rate of fissioning, the neutron density and the power in a reactor?