Nuclear Theory - Course 227

CHANGE OF REACTOR POWER WITH TIME

We have seen, in the previous lesson, how reactivity affects neutron multiplication and reactor power. We saw how reactor power increases from one neutron generation to the next. However, it is not the actual change in reactor power that is always of importance, but the rate at which power increases or decreases.

The rate of change of power is the factor that determines how difficult a reactor may be to regulate or whether it can, in fact, be regulated at all. This lesson will consider this aspect of reactor power.

Effect of Neutron Lifetime on Changes in Reactor Power

We have seen how reactor power changes, for positive and negative reactivities, in terms of neutron generations. In other words, we have seen how the neutron population or neutron density changes from one generation to the next when the multiplication factor, k, is greater than one or less than one. In all cases an exponential law is followed which may be written: -

$$P = P_o e^{N.\delta k} \quad \text{or} \quad n = n_o e^{N.\delta k}$$

where P_o and n_o are the initial power and neutron density respectively and P and n are the power and neutron density values, N neutron generations later. δk is the reactivity which is positive when k is greater than 1, zero when k = 1 and negative when k is less than one.

Thus we can find what the power would be after so many neutron generations. However, what we really want to know is what the power will be after a certain time. We want to know how fast or how slow the power changes for some definite value of δk. We want to know whether or not the increase in power is too fast to handle or whether or not decrease in power is rapid enough when the reactor is shut down. These are the facts that are of practical importance.

What other factor is required in order to determine how the power changes with time? We have to know the time between successive neutron generations. The average time between successive neutron generations determines how fast the neutrons multiply or how fast the power increases. It will also decide how fast the power decreases when δk is negative. This average time between successive neutron generations has been defined as the NEUTRON LIFETIME.

If $\mathcal{L}$ is used to denote the neutron lifetime, ie, the time between successive neutron generations, the time, t, for N neutron generations is given by: -

$$t = N.\mathcal{L}$$

$$\text{or} \quad N = \frac{t}{\mathcal{L}}$$

Therefore $P = P_o e^{\frac{\delta k}{\mathcal{L}}.t}$ and $n = n_o e^{\frac{\delta k}{\mathcal{L}}.t}$

These are, then the equations that give the reactor power or the neutron density t secs after the reactivity is changed from zero to δk. From the equations we can see that: -

(1) the greater the positive value of the reactivity, δk, the faster the increase in neutron density and power.

(2) the greater the negative value of the reactivity, δk, the faster the decrease in neutron density and power.

(3) the greater the value of the neutron lifetime, $\mathcal{L}$, the slower the change in neutron density and power.

Since the reactivity can be controlled at any suitable value in a reactor, the value of $\mathcal{L}$ will eventually decide how fast the power changes; the value of $\mathcal{L}$ is very important.

Reactor Period

From Fig. 1 in the previous lesson or from the above equations, we can say that the reactor power doubles in so many generations or in such and such a time.

eg, when δk = 0.5 mk, the power doubles in 1400 generations, or if one generation or neutron lifetime was 0.001 sec, then the power would double in 1.4 sec.

When δk = 3 mk, the power doubles in 250 generations or 0.25 sec.

Alternatively we could specify the time that the power takes to increase tenfold ie, for P to become 10 P_o. These are both indications of how fast the power increases.

In practice, however, the rate of increase or decrease of power is always indicated by specifying the time taken for the power to change by a factor of e (the exponential e = 2.718), ie, for P to become eP_o or P_o/e.

Thus when δk = 1 mk the power changes by a factor of e in 1000 neutron generations or 1 second, if $\mathscr{L}$ = 0.001 sec.

When δk = 3 mk the power changes by a factor of e in 333 generations or 0.33 sec., if $\mathscr{L}$ = 0.001 sec.

The <u>time</u> required for the power to change by a factor of e is called the REACTOR PERIOD and is denoted by the letter T sec.

Therefore, <u>if</u> the neutron lifetime is 0.001 sec and the reactivity is 1 mk, the reactor period is 1 second.

However, if the neutron lifetime is 0.1 sec. and δk = 1 mk, then T = 100 sec.

It can be seen, from these examples, that the reactor period is very dependent on the neutron lifetime as well as on the reactivity. In fact, the period is connected with these two quantities by the formula: -

$$T = \frac{\mathscr{L}}{\delta k}$$

The equations connecting the neutron density and power with time can now be modified to: -

$$P = P_o e^{t/T} \qquad \text{and} \qquad n = n_o e^{t/T}$$

It is precisely because of the exponential form of these equations that the reactor period is defined as the time for the power to change by a factor e rather than 2 or 10 or 100 or some other nice round number.

From the equations, when $t = T$ $P = eP_o$ and $n = en_o$

The shorter the reactor period, the faster the power changes will be.

ASSIGNMENT

1. Give two reasons why it is desirable to know how reactor power changes with time.

2. How does neutron lifetime affect the way in which reactor power changes with time?

3. Define the term "Reactor Period"?

4. (a) On what two quantities does the reactor period depend?

   (b) Write down the equation connecting the period with these two quantities.

   (c) Write down the equation connecting the power with the reactor period.

A. Williams