NEUTRON LIFE CYCLE

THIS SECTION IS NOT REQUIRED FOR MECHANICAL MAINTAINERS

OBJECTIVES

At the conclusion of this lesson the trainee will be able to:

1. Sketch the life cycle of a neutron including all possible fates of the neutron.
2. Discuss why our reactors use reflectors.

NEUTRON LIFE CYCLE

In a CANDU reactor a prompt neutron has a lifetime of approximately 0.001 seconds. During this time it will travel about 25 cm while slowing to thermal energy. Once thermalized it diffuses about 30 cm before it is absorbed in the fuel. The time from birth as a fission neutron to absorption by the fuel is called the neutron lifetime. If a neutron is not absorbed in the fuel then it must be absorbed elsewhere, or escape into the shielding. Figure 8.1 give a pictorial view of the possible fates of a neutron.

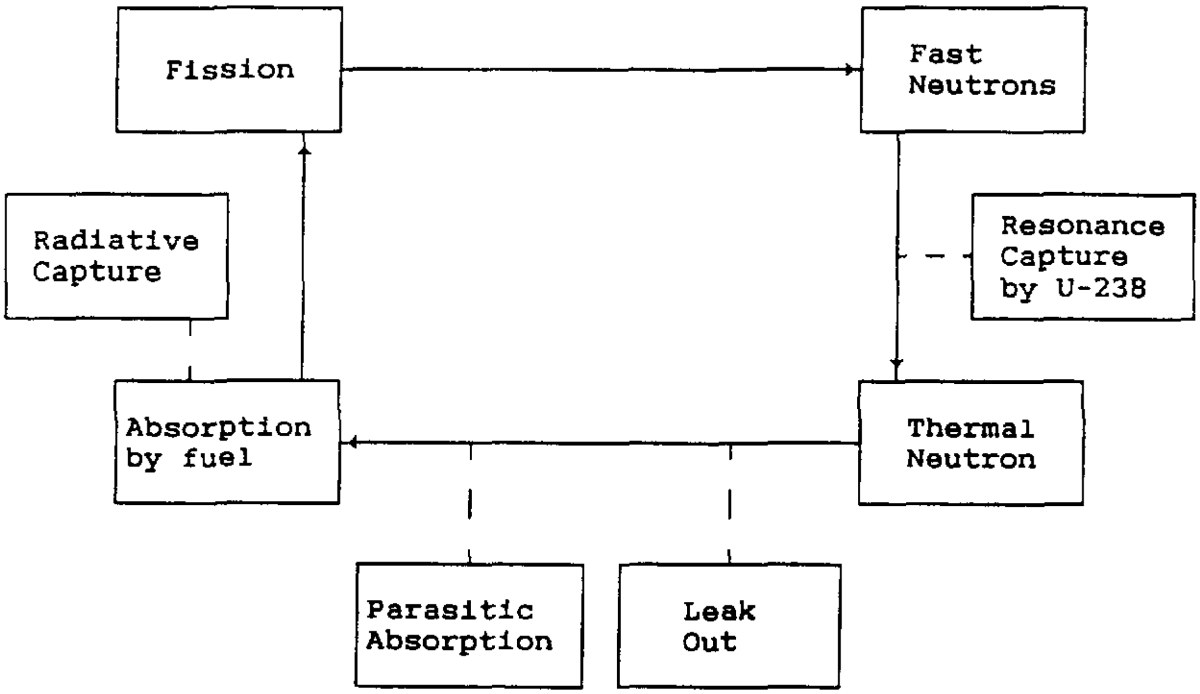

Figure 8.1: Neutron Life Cycle

We shall now examine each of the possible fates a neutron faces.

Resonance Capture

Recall from module 6 that in the energy range of about 10 eV to 1 keV U-238 has several extremely high absorption peaks with cross-sections as high as 6,000 barns. Virtually any neutron which returns to the fuel while it is slowed through these energy peaks will be absorbed.

In our reactor about 10% of the neutrons undergo resonance capture.

Leakage

If while travelling approximately 40 cm from birth to death a neutron reaches the boundary of the reactor it may "leak" out, never to return. Essentially three things influence how many neutrons actually leak out: size of the reactor, shape of the reactor, and what happens at the boundary. The designer can adjust these effects to minimize leakage into the shielding.

In our reactors leakage accounts for the loss of about 2.5% of the neutrons.

Size and Shape

Figure 8.2 shows three spherical reactors. Assuming that some neutrons travel 50 cm, a neutron born at any location in reactor 'A' has a possibility of escaping. As we increase the size of the reactor to 'B', the neutrons born inside the dotted circle normally won't leak before they are captured. By increasing the size again to 'C' a still smaller percentage of the neutrons can leak out.

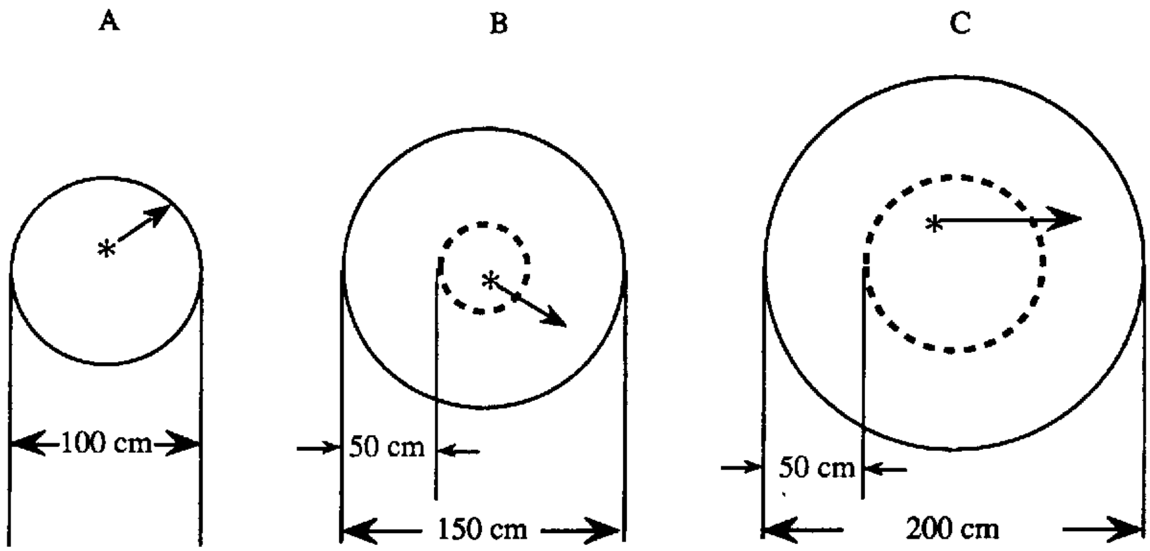

Figure 8.2: Effect of Size

Similar arguments can be made concerning the shape of a reactor. It can be shown that for a given volume of fuel and moderator a sphere will always have the smallest leakage. A sphere is not a practical shape from an engineering point of view. Instead we use approximately cylindrical reactors which have the diameter slightly bigger than the length. The actual shape is a compromise between engineering and nuclear considerations.

Reflectors

The final thing that affects leakage is what happens to a neutron when it reaches the boundary. If we surround the reactor with a material which will "bounce" some of the leaking neutrons back into the reactor, the loss due to leakage is reduced. We call this surrounding material a reflector.

An ideal reflector has a high probability of scattering neutrons and a low probability of absorbing them. Heavy water is an excellent reflector and is used in all our rectors. The reflector is merely an extension of the moderator as shown in Figure 8.3.

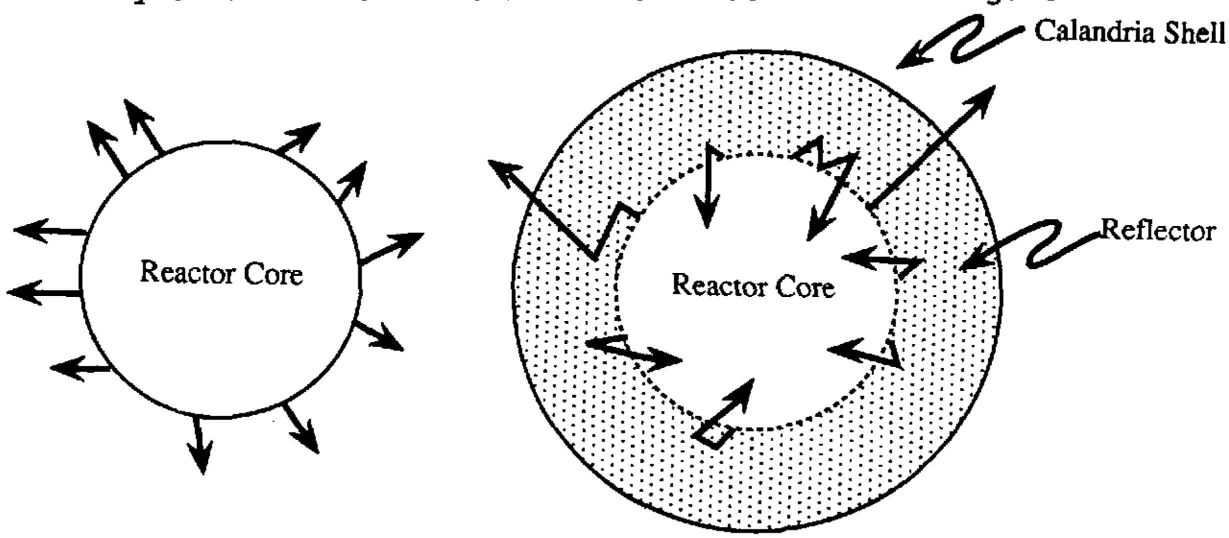

Figure 8.3: Reflector Location

The zone between the dotted line and the calandria shell serves as the reflector.

Parasitic Absorption

A neutron absorbed by something other than U-235 is unavailable to cause a fission. Neutrons can be absorbed by any of the following:

a) Fuel Sheath

b) Coolant, Moderator and Reflector

c) Pressure tubes and calandria tubes

d) Incore guide tubes

e) Various rods and control zone compartments

In total the materials on this list absorb about 5% of the neutrons, most of them in items (b) and (c).

Absorption by Fuel

The remaining neutrons are absorbed by the fuel which contains U-235, U-238, various isotopes of plutonium and a variety of fission products. Approximately 50% of the neutrons absorbed by the fuel simply undergo radiative capture. The remaining 50% cause fissioning of the U-235 and Pu-239.

The net result is that we get about 1.2 fast neutrons per thermal neutron absorbed by the fuel.

Overall Cycle

Roughly 20% of the neutrons are lost and do not return to the fuel. If about half of those remaining cause fissions (i.e. 40%) and each fission produces an average of 2.5 neutrons, this will restore the total to 100%. The cycle keeps going and the neutron number can be increased or decreased by adjusting one or more of the loss mechanisms.

ASSIGNMENT

1. Sketch the neutron life cycle.
2. Discuss each of the possible fates of a neutron.
3. Why do our reactors have reflectors?

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