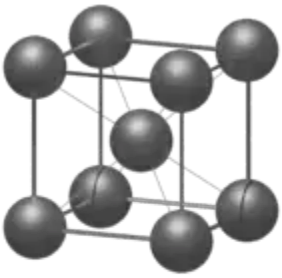

Moderator Temperature Coefficient – MTC

The moderator temperature coefficient – MTC is defined as the change in reactivity per degree change in moderator temperature.

$$\alpha_M = {}^{d\rho}/_{dTM}$$

It is expressed in units of pcm/°C or pcm/°F. The value of moderator temperature coefficient usually ranges from 0 pcm/°C to -80 pcm/°C. The **moderator temperature coefficient's** magnitude and sign (+ or -) is primarily a function of the **moderator-to-fuel ratio**. That means it primarily depends on a specific reactor design. It must be noted, according to the design requirements (e.g.,, ~~NUREG-0800, Chapter 4~~), reactor design must assure that:

"The MTC should be non-positive over the entire fuel cycle when the reactor is at a significant power level."

Therefore all light water reactors (LWR) must be designed **under moderated** because it ensures that the reactor may have a **negative moderator temperature coefficient**. If a reactor is over moderated, it can not reach a positive moderator temperature coefficient. A negative moderator temperature coefficient is desirable because of its **self-regulating effect**.

The total amount of reactivity, which is inserted to a reactor core by a specific change in the moderator temperature, is usually known as the **moderator reactivity defect** and is defined as:

$$d\rho = \alpha\ .\ dT$$

Example: moderator defect
The moderator temperature coefficient for a reactor is -30 pcm/°C.
Calculate the reactivity defect that results from a temperature increase of **20°C**.

Solution:

$$d\rho = \alpha\ .\ dT = -30 * 20 = -600\ \text{pcm}$$

The reactivity addition due to the moderator temperature increase is negative about -1 $ (for reactor core with βeff = 0.006).

Theory of Moderator Temperature Coefficient

It is very difficult to describe the physics of the moderator temperature coefficient because changes in **moderator temperature** lead to the change of almost **all the parameters** in a reactor core. For better understanding, we describe major physical mechanisms that occur in the **moderator temperature coefficient** in terms of the six-factor formula.

$\uparrow T_M \Rightarrow \downarrow k_{eff} = \eta.\varepsilon.\ \downarrow p\ .\uparrow f\ .\ \downarrow P_f\ .\ \downarrow P_t$ (BOC)

$\uparrow T_M \Rightarrow \downarrow k_{eff} = \eta.\varepsilon.\ \downarrow p\ .f.\ \downarrow P_f\ .\ \downarrow P_t$ (EOC)

Major impacts on the multiplication of the system arise from the change of the resonance escape probability and the change of total neutron leakage (see thermal non-leakage probability and fast non-leakage probability). But as can be seen at the beginning of the cycle (BOC), when the PWR core contains a large amount of boron dissolved in the primary coolant (chemical shim), an increase in temperature causes an increase in the thermal utilization factor.

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Change of the resonance escape probability. It is known, **the resonance escape**

probability is also dependent on the **moderator-to-fuel ratio**. All PWRs are designed as under moderated reactors. As the **moderator temperature** increases, the ratio of the moderating atoms (molecules of water) decreases due to the **thermal expansion of water**. Its density simply decreases. This, in turn, causes **hardening of neutron spectrum** in the reactor core resulting in **higher resonance absorption** (lower p). The decreasing density of the moderator causes that neutrons stay at a higher energy for a longer period, which increases the probability of non-fission capture of these neutrons. It must be added moderator density changes are not linear. At high temperatures, an increase in the moderator temperature causes a larger reduction in density than an identical increase at low moderator temperatures. This process (the **hardening of the neutron spectrum**) is one of two key processes that determine the **moderator temperature coefficient (MTC)**. The second process is connected with the leakage probability of the neutrons.

- **Change of the neutron leakage.** Since both (**P_f and P_t**) are affected by a change in **moderator temperature** in a heterogeneous water-moderated reactor and the directions of the feedbacks are the same, the resulting **total non-leakage probability** is also sensitive to the change in the moderator temperature. As a result, an **increase in the moderator temperature** causes that the probability of **leakage to increase**. In the case of **the fast neutron leakage,** the moderator temperature influences macroscopic cross-sections for elastic scattering reaction ($\Sigma_s=\sigma_s.N_{H2}O$) due to the **thermal expansion of water**, which increases the **moderation length**. This, in turn, causes an increase in the leakage of fast neutrons.
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