Reactor Experiment Training Manual

Reactivity Insertion Rate for Control Rod

Malaysian Nuclear Agency
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Objective:

To measure the reactivity insertion rate of a TRIGA PUSPATI Reactor (RTP) control rod and make sure the reactivity insertion rates are not more than 9 cents per minute.

Outcome:

In the end of the experiment, the student should:

- Understand the role of the reactivity insertion rate procedure for each RTP control rod.

Introduction:

The degree of criticality of a nuclear reactor is usually regulated by the use of control rods or chemical shim. Control rods are pieces or assemblies of neutron-absorbing material whose motions have an effect on the multiplication factor of the system. Thus, if a control rod is withdrawn from a critical reactor, the reactor tends to become supercritical; if a rod is inserted, the system falls subcritical.

Control rods are used in two ways: (a) to change the degree of reactor criticality for the purpose of raising or lowering the power level, and (b) to keep a reactor critical by compensating for the changes in the properties of the system that take place over its lifetime. Thus, to keep a safe operation of RTP, it is important for the operator to know the reactivity insertion rate for each control rod

When a rod is used in the first approach, the effect is to place a reactor on a stable period. In this case, the rod worth is defined as the magnitude of the reactivity required to give the observed period. Whilst, the second definition of the rod worth is the worth of a rod used to keep a reactor critical is measured in terms of the change in multiplication factor of the system for which the rod can compensate. Despite the fundamental difference in these two definitions of rod worth, these definitions of rod worth are essentially identical.

Theory:

Reactivity is one of the most important parameters for the study of the nuclear reactor dynamics. The reactivity is defined as follows:

$$\rho = \frac{k_{efl} - 1}{k_{efl}}$$

The reactivity is a dimensionless number. As the reactivity is a small number, it is preferable to use several units:

- Pour cent mille, pcm (1 pcm = 10^{-5})
- \$1 = $\frac{\rho}{\beta}$; β = effective delayed neutron fraction
- 1 cent = \$ 0.01
- $\frac{\Delta k}{k}$
- $\%\frac{\Delta k}{k}$ (=10^{-2})

Control Rod Effectiveness

The effectiveness of a control rod depends largely upon the value of the ratio of the neutron flux at

the location of the rod to the average neutron flux in the reactor. The control rod has maximum effect (inserts the most negative reactivity) if it is placed in the reactor where the flux is maximum. If a reactor has only one control rod, the rod should be placed in the center of the reactor core. The effect of such a rod on the flux is illustrated in Figure 1.

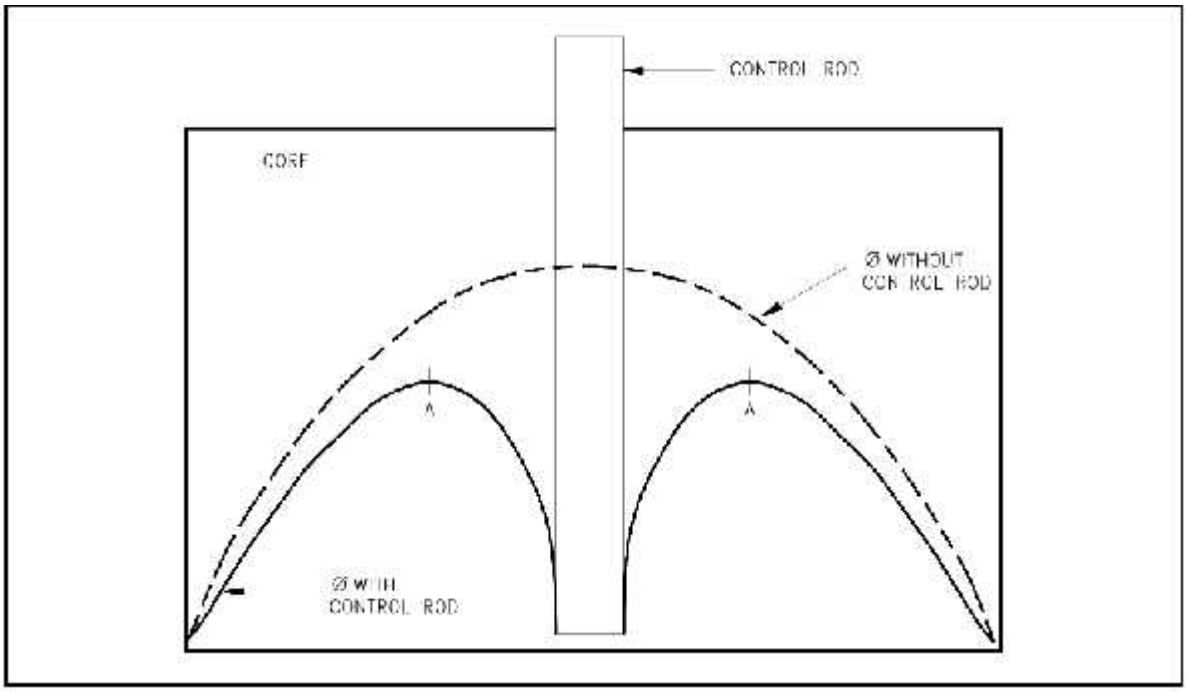


Figure 1 Effect of Control Rod on Radial Flux Distribution

If additional rods are added to this simple reactor, the most effective location is where the flux is maximum, that is, at point A. Numerous control rods are required for a reactor that has a large amount of excess reactivity (that amount of reactivity in excess of that needed to be critical). The exact amount of reactivity that each control rod inserts depends upon the reactor design. The change in reactivity caused by control rod motion is referred to as control rod worth.

Integral and Differential Control Rod Worth

The exact effect of control rods on reactivity can be determined experimentally. For example, a control rod can be withdrawn in small increments, such as 0.5 inch, and the change in reactivity can be determined following each increment of withdrawal. By plotting the resulting reactivity versus the rod position, a graph similar to Figure 2 is obtained. The graph depicts integral control rod worth over the full range of withdrawal. The integral control rod worth is the total reactivity worth of the rod at that particular degree of withdrawal and is usually defined to be the greatest when the rod is fully withdrawn.

The slope of the integral rod worth curve ($\Delta\rho/\Delta x$), and therefore the amount of reactivity inserted per unit of withdrawal, is greatest when the control rod is midway out of the core. This occurs because the area of greatest neutron flux is near the centre of the core; therefore, the amount of change in neutron absorption is greatest in this area. If the slope of the curve for integral rod worth in Figure 2 is taken, the result is a value for rate of change of control rod worth as a function of control rod position. A plot of the slope of the integral rod worth curve, also called the differential control rod worth, is shown in Figure 2. At the bottom of the core, where there are few neutrons, rod movement has little effect so the change in rod worth per inch varies little. As the rod approaches the centre of the core its effect becomes greater, and the change in rod worth per inch is greater. At the centre of the core the differential rod worth is greatest and varies little with rod motion. From the centre of the core to the top, the rod worth per inch is basically the inverse

of the rod worth per inch from the centre to the bottom.

Differential control rod worth is the reactivity change per unit movement of a rod and is normally expressed as ρ/inch, Δk/k per inch, or pcm/inch. The integral rod worth at a given withdrawal is merely the summation of all the differential rod worths up to that point of withdrawal. It is also the area under the differential rod worth curve at any given withdrawal position.

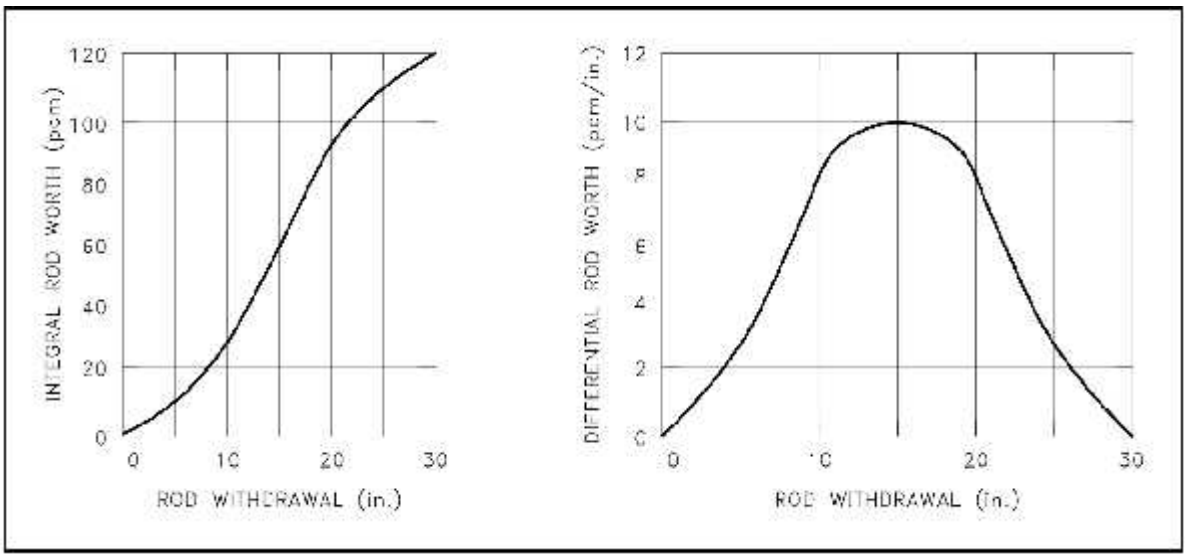


Figure 2 Integral and Differential Rod Worth Curve

Procedure:

1. Without using a magnetic switch key, reactor operator will make sure that the reactor in a TRIP condition.
2. Then, the reactor operator will turn on the magnetic switch key.
3. The reactor operator will press the TRIP RESET button.
4. The reactor operator will make sure the Operating Work Station (OWS) status indicate SHUTDOWN condition.
5. The reactor operator will click SHUTDOWN RESET at OWS.
6. The reactor operator will make sure the status of OWS indicates OPERATING condition
7. The reactor operator will select the control rod that will be raised by clicking the Control Rod Transient (TR) and select direction UP in OWS.
8. The reactor operator will enter value 10 into the DISTANCE in OWS and press ENTER on the keyboard.
9. The reactor operator will enter value 2 into the SPEED in OWS and press ENTER on the keyboard.
10. The reactor operator will click the RUN icon at OWS till the control rod drive reach in the top position or green colour. By using Stopwatch, record the time starting from RUN icon is clicked by the reactor operator until the status of the drive rod is in the top or green colour.
11. The reactor operator will click the SETBACK icon at OWS to insert back control rod.
12. Repeat the steps above for other three control rods.
13. Calculate the reactivity insertion rate ($/sec) for each control rod in Attachment 1 and the maximum reactivity insertion rates must be less than $0.09/sec or 4.87 mm/sec (based on RTP control design)
14. The reactor operator will trip the reactor by pressing the MANUAL SYSTEM TRIP switch.

Safety Consideration:

1. All operation of the reactor is under the direct control of the reactor operator only.
2. Do not touch any buttons or levers in the control room.
3. Always wearing a lab coat and covered shoes inside the reactor hall.

Results:

a) Calculate reactivity insertion rate for each control rod

Discussion:

I. Comment on the reactivity insertion rate for each control rod.

Questions:

a) Do you expect these withdrawal rates of control rods are same with its insertion rate? Why it is same or different?
b) Do you expect the same value of reactivity insertion rate for each control rod if this procedure being performs in next year? Please give justifications for your answer based on your knowledge in reactor physics/reactor engineering
c) Why this reactivity insertion rate should be design as low as possible in the reactor control design?

Attachment 1: Data Sheet for Reactivity Insertion Rate of Control Rod

Date:
Name:

Table 1: Reactivity Insertion Rate of Control Rod

Control Rod	Time (sec)		Rod Position (mm)	Withdrawal/ Insertion Rate (mm/sec)		Reactivity ($)	Reactivity Insertion Rate ($/sec)	
	SW	OWS		SW	OWS		SW	OWS
TR								
SF								
SH								
RG								