24.536 Reactor Experiments

Lab #2 Description/Procedure: Reactivity Measurements Techniques

Objective

The purpose of this experiment is to become familiar with various techniques for measuring reactivity changes and reactivity levels within a variety of reactor configurations. In particular, this lab exercise will address four different experimental techniques and show that a combination of these methods will allow the measurement of a range of reactivity changes, $\Delta\rho$, during both critical and subcritical operations, as well as the determination of the absolute reactivity level, ρ_o, of a subcritical configuration. In addition, with the appropriate predetermined blade worth curves for the UMass-Lowell Research Reactor (UMLRR), we can also evaluate the effectiveness of the various methods addressed during the lab exercise.

Introduction/Overview

Most reactor systems are usually configured as a subcritical, near critical, or critical system. In all these states, it is essential to know the reactivity level of the given configuration and the reactivity worth of the control devices used to adjust the reactivity to some new level. In this experiment, we will look at four of the most common reactivity measurement techniques used within real reactor systems. In particular, the **Asymptotic Period Technique** and **Rod Drop Method** will be used within the context of measuring the magnitude of a reactivity insertion within a critical system, and the **Source Jerk Method** and **Subcritical Multiplication Factor Approach** are used for application within subcritical systems. The background theory associated with all four methods is given in detail in Ref. 1, and the student should certainly be familiar with this material before continuing with this lab procedure.

Since the lab introduces and evaluates four different methods, there will be a sequence of four separate parts or phases to the full lab procedure. When the lab begins, the reactor will be in a steady-state, low-power, critical state with no external source. From this initial critical configuration, in **Phase I** we will use the **Asymptotic Period Technique** to measure the reactivity change associated with small positive and negative movements of the regulating blade (RegBlade) from its initial reference position.

Note: Upon completion of the Phase I tests, the external source will be inserted into the core in preparation for some subsequent test sequences. During the insertion, the RegBlade will be maintained in auto mode to sustain steady-state operation at near critical conditions with the source inserted -- and, from the amount of movement needed to compensate for insertion of the source, we should be able to estimate the worth of the source insertion. Recall, however, that in this state, the fission source totally dominates the external source within the system -- so having the source present at near critical for a short time will not seriously affect our subsequent Phase II tests. Note, however, that the real reason for inserting the source before the Phase II sequence, instead of after completion of the next test from critical, is so we can measure the approximate reactivity worth of moving the source into and out of the core -- since this quantity may prove useful as a "correction factor" in subsequent analyses...

As discussed in Ref. 1, the stable period method illustrated in the Phase I tests is limited to small changes in both positive and negative ρ. In **Phase II**, to address a large negative insertion within a critical configuration, we will disengage the electromagnet for one of the large control blades and drop the blade nearly instantaneously into the core, and then use the **Rod Drop Technique** developed in Ref. 1 to estimate the amount of reactivity that was inserted into the system. Note that, at this point, the reactor should be subcritical by the amount of reactivity inserted by the dropped blade, and that a new steady-state neutron level should be reached since the source is present within the core -- however, this new equilibrium level will be essentially zero relative to the flux level before the blade drop test.

Once the subcritical system has stabilized, the blade drive shaft and electromagnet will be re-engaged and, as part of the **Phase III** test, the blade will be withdrawn to within a few inches of its original position. This should represent a large positive reactivity insertion while still remaining subcritical and, by observing the ratio of count rates for these two subcritical states, we can use the **Subcritical Multiplication Factor Approach** to determine the magnitude of the reactivity associated with the blade withdrawal.

As the final **Phase IV** test, after the subcritical system has stabilized following the previous test, the source will be removed from the system as quickly as possible. This last sequence (i.e. removing the source) should cause the flux level to quickly drop towards zero (or its background level), and we will use the expressions developed in Ref. 1 for the **Source Jerk Method** to evaluate the subcriticality level of this particular configuration.

Close examination of the results of these four tests, along with predetermined blade worth curves for the blades of interest, should allow one to achieve the goals of this experiment -- that is, to establish a good understanding of how to measure and analyze various techniques for quantifying reactivity changes and reactivity levels within a variety of reactor configurations...

Experimental Procedure

The above overview can be formalized with the following experimental procedure:

Phase I: Small Reactivity Changes from Critical

1. The reactor should be at roughly 500 W with the RegBlade in Auto Mode at slightly below mid-height (about 10 or so inches withdrawn). The system should be stable in this state for several minutes to assure steady state operation.

2. Ask the reactor operator to go to **Manual Mode** and **ramp out** the RegBlade **about 3.0 inches** and to let the **power increase by about a factor of 10 (to roughly 5 kW)** and **to stabilize at this level by putting the RegBlade into Auto Mode**. Record your observations associated with this sequence as requested in the worksheet provided in the Appendix.

   Note: This sequence should initially put the reactor on a positive period and, once Auto Mode is turned on, the RegBlade should tend back close to its initial location.

3. After the reactor has stabilized at roughly 5 kW for several minutes, ask the reactor operator to put the RegBlade in **Manual Mode,** to **ramp in** the RegBlade **about 4.5 inches**, to let the **power decrease roughly a factor of 10 to about 500 W**, and finally, to **stabilize at this level by putting the RegBlade into Auto Mode**. Again record your observations as indicated in the worksheet and do any analyses that are requested.

   Note: This sequence should initially put the reactor on a negative period and, once Auto Mode is turned back on, the RegBlade should tend back close to its starting position for the sequence. At this point the reactor should be in a steady-state critical condition at roughly 500 W -- if so, proceed to Phase II.

Phase II: Blade Drop Method from Critical

1. Ask the operator to **insert the Startup Source into the core while in Auto Mode.** The RegBlade should quickly compensate for any reactivity effects associated with the source and make the reactor just critical with the source present. **Shortly after stabilization**, ask the operator to **put the RegBlade in Manual Mode** and then to **drop Blade N** -- that is, to de-energize the electromagnet for the specific blade of interest for this lab (note that a different blade may be used each time this sequence is performed).
2. Record your observations in a notebook or directly to your laptop, as appropriate, and do any analyses that are requested.

   Note: At this point we want the reactor to stabilize at its current subcritical level (with the blade of interest fully inserted, all other blades at their previous critical level, and the RegBlade in Manual Mode). Once the Startup Counter has stabilized (indicating that steady state has been reached), then proceed to Phase III.

Phase III: Subcritical Reactivity Change

1. From steady-state subcritical, after the blade drive mechanism has been re-attached to the physical control blade, ask the operator to **ramp the blade of interest out to about 15 inches withdrawn (this should be no closer than 2 inches from the blade's initial critical position, since we want the system to still be subcritical after the move).**
2. While waiting for the Startup Counter to stabilize, record your observations and perform the requested calculations/analyses.

   Note: At this point, the reactor should still be subcritical and the RegBlade should still be in Manual Mode. Be sure that the Startup Counter has stabilized (indicating that steady state has been reached) before proceeding to the final sequence.

Phase IV: Source Jerk Method

1. From steady-state subcritical with the RegBlade still in Manual Mode, ask the reactor operator to **pull the Startup Source completely out of the system** (do this as rapidly as practical).
2. The count rate should drop sharply and then head towards zero in an exponential manner. Record your observations and any additional information requested on the worksheet.
3. Once the system has been at equilibrium for several minutes, this lab sequence is complete. At this point, you should notify the reactor staff that you are finished and thank them for their assistance during the lab.

References

1. J. R. White, “Reactivity Measurement Techniques,” part of a series of Lecture Notes for the Nuclear Engineering Program at UMass-Lowell.

Worksheet/Checklist for the Reactivity Measurements Lab

Below is a list of items/tasks that should be recorded/performed as part of the current **Reactivity Measurements Lab**. This information and any general observations made during the lab should be recorded in a notebook or on your laptop during the in-lab portion of this experiment.

Date of Experiment: ________________ **Blade of Interest: ______**

Phase I: Small Reactivity Changes from Critical

Positive ρ:

Record the initial power level and RegBlade position.

Record the change in RegBlade position, Δz.

From the observed P(t) increase, estimate the reactor period based on the doubling time approximation -- is this close to your pre-lab prediction?

After returning to Auto Mode, record the new RegBlade position upon stabilization -- is this what you expected?

Record your general observations concerning this portion of the procedure.

Negative ρ:

Record the initial power level and RegBlade position.

Record the change in RegBlade position, Δz.

From the observed P(t) decrease, estimate the reactor period based on the "doubling time" approximation -- is this close to your pre-lab prediction?

After returning to Auto Mode, record the new RegBlade position upon stabilization -- is this what you expected? Do you see the same general behavior as for the +ρ change?

Record your general observations concerning this portion of the procedure.

Phase II: Blade Drop Method from Critical

Record the RegBlade positions before and after the source is inserted. Also, using the integral worth curve information for the RegBlade, estimate the worth associated with the source insertion. Also record the approximate time of source insertion -- since **this is not recorded electronically**.

Record the pre-drop position and the approximate time of the blade drop (again **this is not recorded directly**). Note that the data acquisition system records the location of the control drive mechanism, not the actual blade position -- so once the blade is dropped, the recorded data and actual blade location are not consistent. The reactor operator will eventually re-engage the drive and control blade, after which, the proper blade locations will be recorded again.

From the blade worth curve for the blade of interest, estimate the actual negative reactivity worth that was inserted -- this will be the approximate subcriticality level of this subcritical system. Note that, as part of your post-lab analyses, you will compute $\Delta\rho$ via the Rod Drop Method -- does this result compare well with the $\Delta\rho$ from the existing blade worth curve?

Record your general observations concerning this portion of the procedure.

Phase III: Subcritical Reactivity Change

Record the approximate count rate of the startup detector before and after the blade is withdrawn.

From these data and the ρ_o from the Phase II step, estimate the $\Delta\rho$ associated with the blade movement that was made. Does this compare reasonably well with the reactivity change obtained from the blade worth curve?

Record your general observations concerning this portion of the overall procedure.

Phase IV: Source Jerk Method

Record the average detector count rate prior to the source removal.

Record the approximate time of the source removal (note that **this is not recorded electronically**).

After source removal, wait several minutes for the count rate to stabilize and then record the background detector count rate -- this component will need to be subtracted from the integral computed as part of the Source Jerk Method.

Note that, as part of your post-lab analyses, you will compute ρ_o via the Source Jerk Method -- does the result here agree with the estimate made after Phases II and III?

Record your general observations concerning this portion of the full lab procedure.