24.536 Reactor Experiments

Lab #3 Description/Procedure: Measuring Integral Blade Worths Curves within the UMLRR

Objective

The purpose of this experiment is to become familiar with various techniques for measuring blade worths curves within the UMass-Lowell Research Reactor (UMLRR). In particular, this lab exercise will address three different experimental techniques that can be performed. However, actual data for generating a blade worth curve will be taken live for only the Inverse Kinetics method -- and the other methods will be illustrated using archived reactor data. In addition, some emphasis will be placed on validating the simple point kinetics model (with no feedbacks) that has been used to illustrate the various reactor operations scenarios addressed so far this semester, and also to formally benchmark the recently-implemented Inverse Kinetics capability at UMass-Lowell. This additional validation task will be accomplished by comparing measured vs. actual $\rho(t)$ data for a specific operational transient sequence involving several movements of the regulating blade (RegBlade). Combined, the exercises performed here should give a good understanding of basic reactor kinetics (with no feedbacks) and the various techniques used for measuring the integral worth curves for a real reactor.

Introduction/Overview

It is essential that the reactivity worth versus position be established for all of the control devices within the reactor. As part of this lab, we will look at three of the most common techniques for actually measuring the so-called integral rod worth or blade worth curves within real reactor systems. In particular, the **Stable Period Method**, **Inverse Count Rate Method**, and **Inverse Kinetics Method** will be addressed, where emphasis within the live interactive portion of the lab will be focused on the latter of the three methods. The background theory associated with all the methods is given in detail in Refs. 1-2, and the student should certainly become very familiar with this material before continuing with this lab description/procedure -- since the focus here will be on the actual lab procedures and tasks that will be performed in the pre-lab, in-lab, and post-lab portions of this full reactor laboratory exercise (and not on the theory)...

Since usually a minimum of 4-5 hours is needed to generate a complete data set for use with the **Stable Period Method**, an existing set of data for the blade of interest (BOI) generated by the reactor staff will be used as part of the post-lab work -- instead of taking the time within the lab to generate these data live. This is acceptable here, since the procedures needed to obtain the required data have already been demonstrated in a previous lab.[3-4] Thus, for this method, only post-lab activities will be required to process and analyze the previously available data.

Similarly, for the **Inverse Count Rate Method**, we have already generated data for a large portion of the full traverse for the blade of interest (BOI) within a previous lab.[5] Thus, instead of repeating that sequence, we will simply use the subcritical count rate data generated earlier in the semester to test out the Inverse Count Rate technique as applied to the UMLRR. Since the BOI was only withdrawn from fully inserted to about 75-80% of the fully withdrawn position as part of the Approach to Critical lab,[5] we will not be able to generate a full blade worth curve profile from the available data. However, comparing about 75-80% of the worth profile for the BOI with those generated by the other methods should be sufficient to evaluate the overall method and to draw some conclusions concerning its general effectiveness as a tool for generating blade worth curves for the UMLRR. Thus, as for the **Stable Period Method**, only a post-lab component will be required when addressing the **Inverse Count Rate Method** as part of this overall lab exercise.

With two methods moved to the post-lab portion of the experiment, the focus of the pre-lab and in-lab segments will be to validate the basic **Inverse Kinetics formulation** and to use this method to generate a full blade worth curve for the blade of interest (BOI) for this lab. In particular, the live lab will have two separate phases. In **Phase I** we will put the RegBlade (with a known integral worth curve) through a series of positive and negative movements to generate the real P(t) profile that is associated with a given ρ(t) behavior, and then these data can be used for subsequent analyses and validation studies. For **Phase II**, one of the large control blades will be designated as the blade of interest (BOI), and this will be moved from a fully withdrawn starting position to fully inserted, while the other blades are used to slightly overcompensate for negative reactivity added by the BOI. In this way, we should be able to achieve a full blade traverse (full-out to full-in state) while maintaining a strong neutron signal relative to the gamma background (as discussed in Refs. 1 and 2). These data will then be used within the **umlrr_data** GUI to generate a full blade worth curve for the BOI.

Experimental Procedure

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

Phase I: Sequence of Movements with the Regulating Blade

1. The reactor should be at about 7-8 kW with the RegBlade in Auto Mode at about 12 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 to perform the pre-planned sequence of movements of the RegBlade to achieve a desired P(t) profile (approximately). This sequence will involve repeated movements of the RegBlade, both outward and inward, to add positive and negative reactivity as needed to generate a good test case for validating the Inverse Kinetics method. Since there will only be a few minutes between each blade maneuver, you should stay in continuous contact with the operator, and try to keep as close as possible to the planned sequence and timing of the blade movements (some flexibility is okay here since, during the post-analysis phase, the simulations can be updated with the actual times and positions that were used). After the sequence is complete, wait about 5 minutes for data collection purposes, and then request that the operators put the reactor in the desired initial state for Phase II (as noted below).

Preparation for Phase II

At this point, the system should be brought to steady state critical at about the 7-8 kW level with the BOI fully out of the core. The RegBlade can be in Auto Mode to achieve these conditions, as needed.

As noted in Refs. 1-2, because of limitations with the existing neutron detectors, we can’t let the system go too subcritical for extended periods, since the measured detector signal is then no longer strictly proportional to the neutron level -- and this gives a false reading with the inverse kinetics methodology (since it implicitly assumes that the neutron detectors only measure the neutron level). Thus, to maintain near critical conditions, the system during the Phase II test should be within about ±0.4 %Δk/k from critical, with a power level that is no more than a factor of 2-3 higher than P_o and no less than $P_o/10$. To accommodate this requirement, we will need to compensate for the test blade insertion by removing the other blades to counter the negative reactivity associated with the BOI insertion and to keep the power level within some reasonable range. Thus, a series of negative reactivity insertions (BOI is put in a short distance) followed immediately by positive reactivity swings (where the other blades are withdrawn to slightly over-compensate for the original negative transient) will be completed. This will result in a sequence of power decreases followed by power increases, where the power range here should be roughly 1 to 20 kW (this is very rough since we just need to be in the 'ballpark'). The key here is to do the BOI insertions and compensating blade withdrawals as quickly as possible so the full BOI traverse (i.e. full out to full in) can be completed in a reasonable amount of time (about 30 – 45 minutes).

Phase II: Measurement of Blade Worths Curve during Transient Operation

1. Configure the control blades for roughly 7-8 kW operation with the BOI fully withdrawn, with the other blades in a suitable location to give a stable critical state.
2. Put the RegBlade into manual mode and leave its location fixed until the sequence is complete.
3. Perform a series of blade movements as follows: ramp the BOI in a small amount, wait a few seconds, then remove the other blades as needed to over-compensate the negative insertion and to bring the power back up into the top half of the given range (1 – 20 kW). Then, as quickly as possible, repeat this sequence as many times as necessary to get the BOI fully inserted. When the BOI is above 16 inches or below 8 inches withdrawn, 2-inch increments for movement of the BOI should be fine. However, in the highest worth region from about 8 – 16 inches withdrawn, the insertion increment should be decreased to about 1 inch.
4. After the last increment when the BOI is fully inserted, record the power decay vs. time for about 5 minutes before movement of the other blades. At this point, this lab sequence is complete, and you should notify the reactor staff that you are finished and thank them for their assistance during the lab.

Note: Since the sequence of events here will be continuous, the reactor staff will perform the full sequence as we monitor operations from a remote site. Thus, be sure the reactor operators understand the desired procedure, and then let them do their job without interruption, since they will need to focus on the job at hand. After the sequence is complete, you may communicate with the reactor staff, as needed, to address any questions you may have.

References

1. J. R. White, "Integral Worth Curves: Theory and Measurement Techniques," part of a series of Lecture Notes for the Nuclear Engineering Program at UMass-Lowell.
2. J. R. White, "Inverse Point Kinetics," part of a series of Lecture Notes for the Nuclear Engineering Program at UMass-Lowell.

3. J. R. White, “Reactivity Measurement Techniques,” part of a series of Lecture Notes for the Nuclear Engineering Program at UMass-Lowell.
4. J. R. White, “Lab Description/Procedure: Reactivity Measurement Techniques,” one of a series of labs for the Reactor Experiments course at UMass-Lowell.
5. J. R. White, “Lab Description/Procedure: Understanding Subcritical Multiplication via an Approach to Critical Experiment,” one of a series of labs for the Reactor Experiments course at UMass-Lowell.