

## Automatic Time Step Control for Nodal Kinetics

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*An automated kinetics time step independent of the thermal hydraulics time step has been implemented to allow improved performance.*

### Introduction

It is desirable to allow the kinetics to advance independently of the thermal hydraulics to improve RELAP5-3D performance and fidelity. Prior to Version 4.0.3b, manual control logic for a kinetics time step was added to provide the user with the ability to control the kinetics advancement. This feature, while useful, required the user to choose the appropriate kinetics time step size based on the model being executed. Therefore, in an effort to improve the efficiency of the kinetics solution, an automatic kinetics time step algorithm was added that predicts the kinetics time step size based on changes in specified parameters. This new logic can be activated by setting W1 of Card 2200 to "1".

### Background

The basis for this work came from a paper by Pope and Mousseau<sup>[1]</sup>. In this paper, the authors introduced the concept of a dynamic time scale based on the linear rate of change of a series of specified parameters. Here, a parameter-based time step size is computed and limited by a user-defined fractional change allowed. Then the minimum of all the parameter-based time step sizes is determined and then further restricted such that the time step size does not grow by more than some user-defined amount. This is necessary to prevent unstable solutions.

### Implementation

For the work here, the parameters of interest used to predict the kinetics time step size are the local cross sections and neutron fluxes. Besides the restrictions outlined above, other restrictions are placed on the kinetics time step. The predicted time step must be within the minimum and maximum specified by the user on the 2201-2299 cards (an extra word was added to these cards to allow the user to input these quantities). In addition, it is restricted such that the ratio of the predicted kinetics time step size to thermal-hydraulics time step size is a rational fraction. This allows the code to automatically synchronize following any subcycling or supercycling.

Previously in the code, the logic to compute the control rod and thermal-hydraulic feedback, and subsequently update the cross sections, was spread out over multiple subroutines. This created complications from a code maintenance standpoint, but more importantly, prevented the ability to compute a predicted kinetics time step size at the beginning of the kinetics advancement. Therefore, all of the logic to compute feedback and evaluate cross sections was collected and is now called from a single driving subroutine, xsdrv.F. This new cross section driver subroutine is called from the transient driver, tran.F, prior to the kinetics advancement. The cross section evaluation process is now much

easier to understand, and the updated cross sections can be computed prior to advancing the kinetics solution, allowing the predicted kinetics time step size to be determined.

It is important to note that flux extrapolation is not currently active for the automatic kinetics time step control logic. The code encountered accuracy and stability issues when using the exponential extrapolation. A linear extrapolation module was added for testing, and is now available in the code.

However, issues exist even with the linear extrapolation. The reason for poor results appears to be due to the fact that the delayed neutron precursor concentration is not being properly updated during the extrapolation. There are complications with calculating the precursor concentrations when the code is switching between the kinetics advancement and a flux extrapolation step. Further study is needed to make this logic work properly. Therefore the flux extrapolation has been deactivated at this time.

## Results

This new logic was tested with a mix of input models based on the NEACRP-C1 peripheral rod ejection benchmark problem. These input models were developed to compare results obtained with manual and automatic kinetics time step control logic. The results showed that the code prediction for the kinetics time step size is very good, and is in line with expectations of what the time step size should be for the NEACRP-C1 problem. A significant improvement in CPU time was observed, with negligible degradation in solution accuracy. The only issue is that when the kinetics is supercycling the thermal-hydraulics, the power plot shows some "stair stepping" in between kinetics advancements. This is expected since flux extrapolation is not currently active. Future work in this area should resolve this issue.

This new functionality will be available to users in future versions of RELAP5-3D. If anyone is interested in obtaining more information on this latest improvement, they can contact Doug Barber of ISL ([dbarber@islinc.com](mailto:dbarber@islinc.com)).

## References

1. Pope, Michael A. and Mousseau, Vincent A., "Accuracy and Efficiency of a Coupled Neutronics and Thermal Hydraulics Model," Nuclear Engineering and Technology, Vol. 47 No. 7, September 2009.
2. Barber, D., "RELAP5-3D Nodal Kinetics Upgrade, Task 3: Automatic Time Step Control," ISL Report No. ISL-ESD-TR-13-08, December 2013.