Preliminary Analysis of DCRM Method for Fission Chamber Excore Detector

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1. Introduction (1/2)

❖ Rod Worth Measurement

- ➢ Essential item in the low power physics test (LPPT) program of the commercial pressurized water reactors (ANSI/ANS-19.6.1)
- ➢ Check consistency between the predicted and the measured rod worths to ensure safety margin for the reactor shutdown
- ➢ Check power distributions to prevent a possible fuel misloading condition

❖ Rod Worth Measurement Methods

(Traditional) Boron Dilution & Rod Swap Method

- Measures cumulative reactivity by boron dilution or reference bank withdrawal during test bank insertion
- Reactor maintains near critical state.
- Produces liquid waste due to the boron dilution
- Takes 8 ~ 12 hours for cautious positive reactivity addition

Dynamic Control Rod Reactivity Measurement (DCRM) Method

- Developed by KEPRI and licensed in 2006
- Ex-core detector signal during the test bank insertion is converted into rod worth by inverse PK calculation.
- Reactor becomes subcritical state as test bank is inserted.
- Significantly reduces liquid waste
- Takes less than 3 hours

1. Introduction (2/2)

❖ Challenges of the DCRM Method

- Originally developed to utilize the current signal of the uncompensated ion chamber (UIC)
- Due to the relatively low neutron sensitivity of integrated wide-range fission chambers (FCs):

1) Linearity of voltage signal at low power level was not guaranteed.

(noise signal + alpha decay signal + gamma rays…)

→ Do not use "voltage" signal. Pulse signal (cps) is the best viable option.

2) Pulse pile-up distorts the reactivity curve at high power level of 2~3 10^5 cps

❖ Modified DCRM Procedure (DCRM-EK) for Wide Range FC

- Measurement procedure is modified to maximize test range of pulse mode:

25 cps < Test Range < Pulse Pile-up Level

2. Framework of DCRM Method (1/2)

❖ Overall Framework of the DCRM Method (see Ref. [1] for more details)

➢ Pre-measurement Stage

- Neutron transport calculation (core-detector geometry) to obtain detector response function (DRF)
- Lattice Physics Calculation (Fuel Assembly) to obtain two-group constants and delayed neutron data
- Static and Transient Nodal Diffusion Calculation (Core) to generate DCRM design constants:
  - Detector Response Conversion Factor (DRCF)
  - Point Kinetics Parameters (PK Parameters)
  - Dynamic to Static Conversion Factor (DSCF)

➢ Measurement Stage

- Ex-core detector signal is converted into core-average neutron density (CAND) by DRCF.
- CAND is utilized to determine the dynamic rod worth by inverse PK calculation.
- Update the background signal if the dynamic reactivity curve does not pass the check list.
- Dynamic rod worth is converted into the static rod worth by the DSCF.

[1] E.K. Lee, et al., "New Dynamic Method to Measure Rod Worths in Zero Power Physics Tests at PWR Startup," Annals of Nuclear Energy, 32, 1457–1475 (2005).

2. Framework of DCRM Method (2/2)

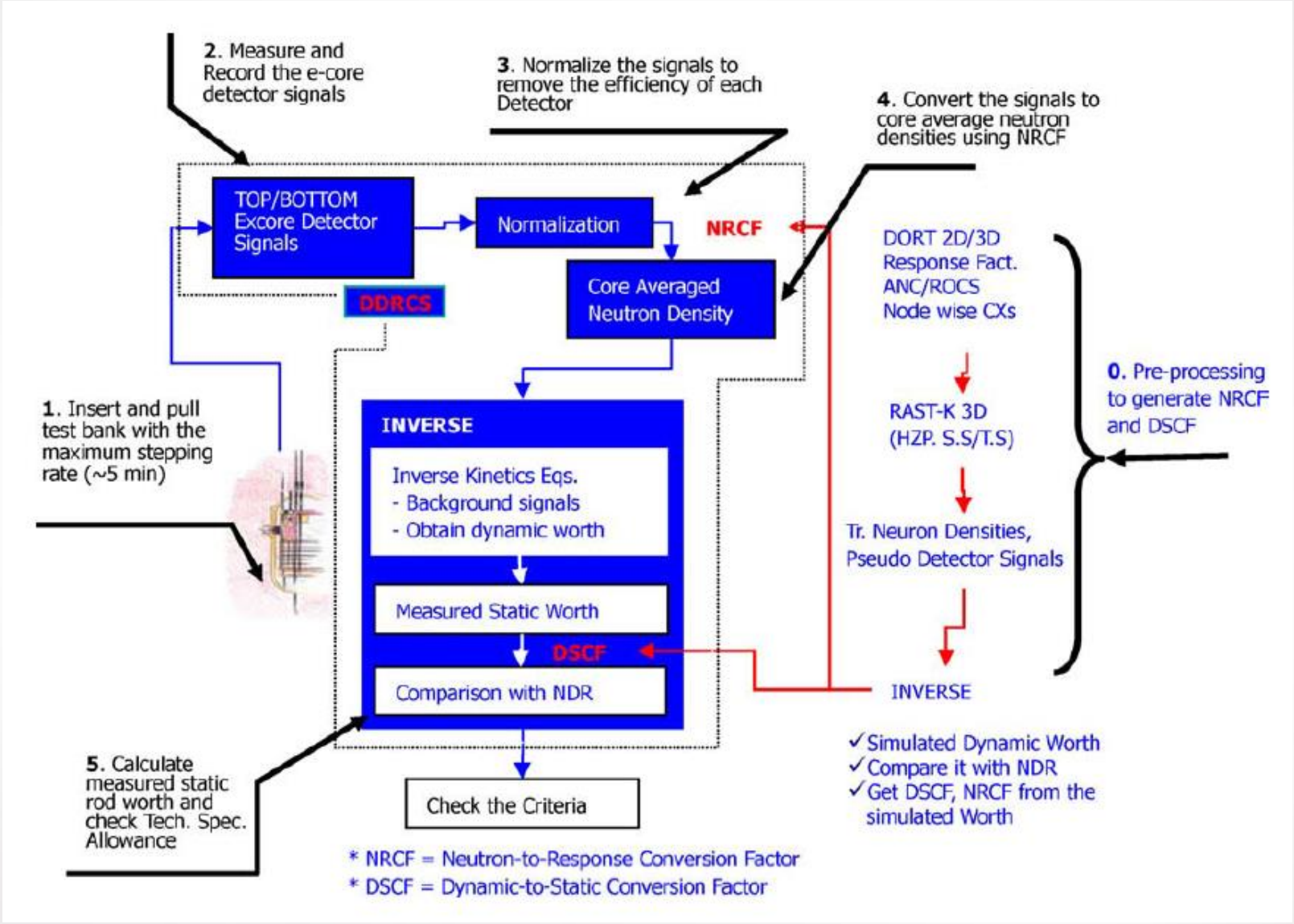

Figure 1. Overall framework of DCRM Method (Ref. [1])
(Red Color : pre-measurement procedure, Blue Color : measured data processing procedure)

3. Modified DCRM Procedure (DCRM-EK)

❖ **Measurement procedure is modified to maximize test range of pulse mode.**

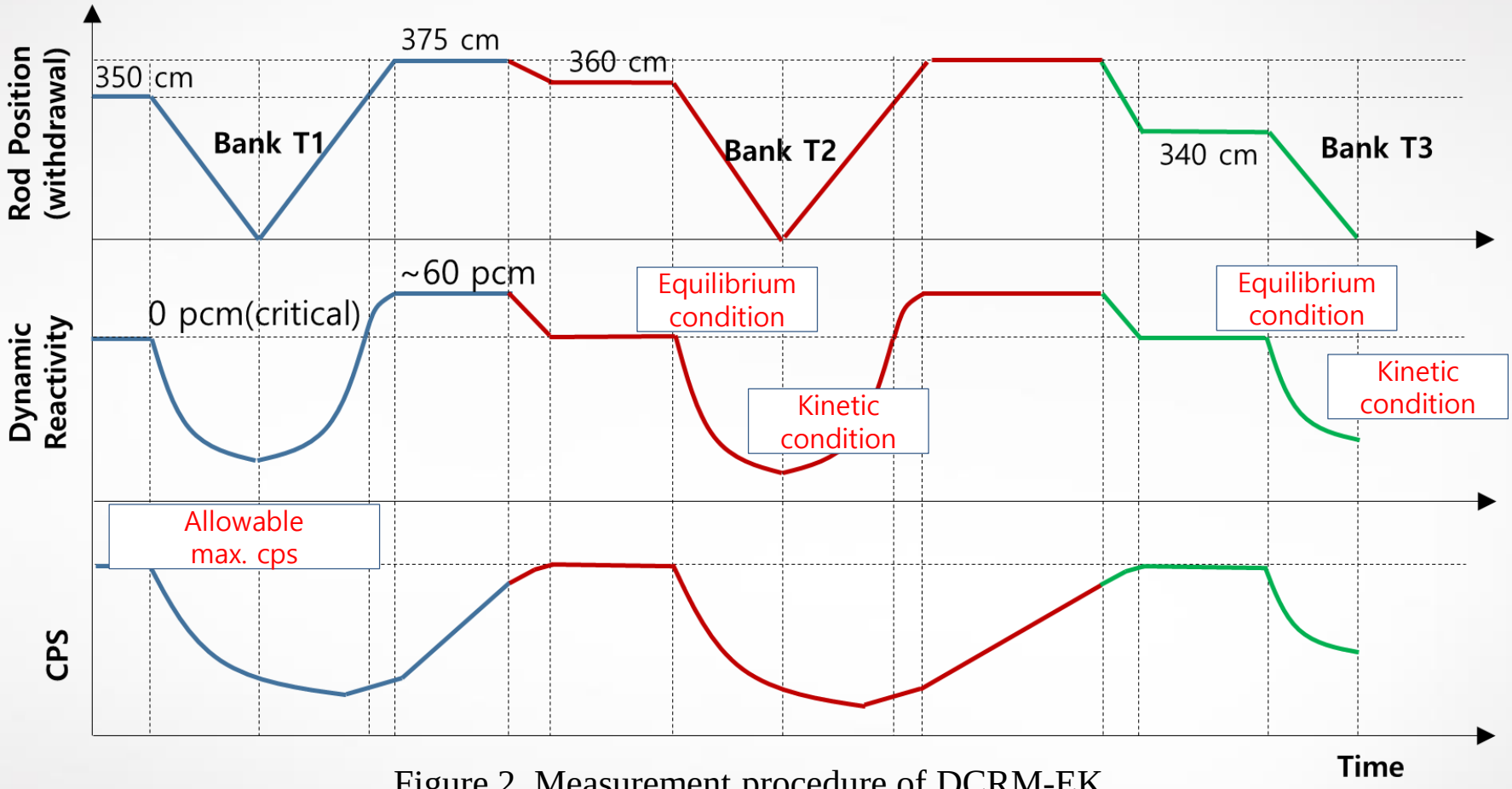

Figure 2. Measurement procedure of DCRM-EK.

❖ **Core condition during the DCRM-EK procedure changes from equilibrium (or critical condition) to kinetics (or transient) status ('EK' means 'Equilibrium to Kinetics').**

4. Preliminary Results

❖ Preliminary Results of DCRM-EK Method

- Good agreement between the measured static rod worth and the designed rod worth from the Nuclear Design Report (NDR).

- Difference between the measured static rod worth and the NDR rod worth is -1.8%, which sufficiently satisfies the test acceptance criteria.

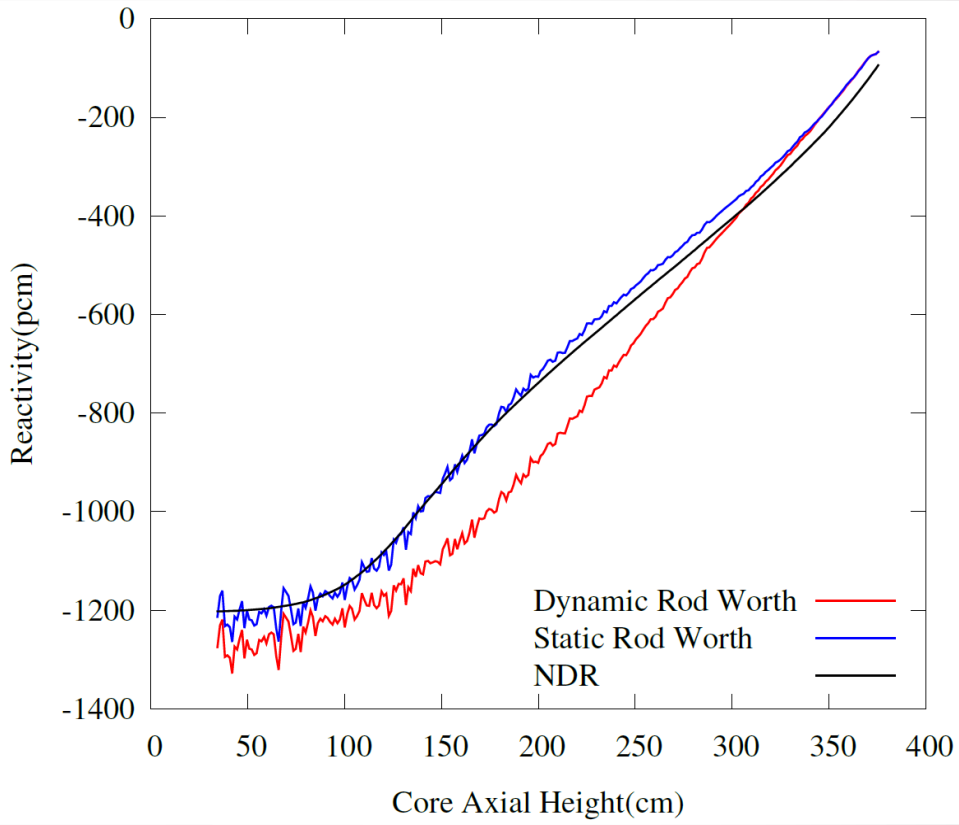

Figure 3. Measured integral rod worth (blue line) by DCRM-EK Method.

5. Summary and Further Works

❖ Summary

- The DCRM-EK method has been proposed for pulse mode of the wide-range FC.
- Measurement procedure is modified to maximize the test range:
  - 25 cps < Test Range < Pulse Pile-up Level
  - Core condition during the DCRM-EK procedure changes from equilibrium (or critical condition) to kinetics (or transient) status.
- The very preliminary analysis shows a promising result.

❖ Further Works

- Once sufficient measured data (about 30 rod worth cases) has been obtained, the DCRM-EK method can be applied to PWRs using the integral FC in South Korea.
- The DCRM-EK method will also be applicable even if the signal noise is large so that it is difficult to estimate appropriate rod worth by the original DCRM method.

Q & A

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