# ELIMINATION OF DYNAMIC CODE FROM THE PROCESS OF SPATIAL EFFECT CORRECTION IN SCRAM DROP MEASUREMENTS

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## ABSTRACT

In the AER materials a great attention is given to the necessity of accounting for spatial effects of neutron flux redistribution in the VVER scram drop measurements. It has been emphasized that the said spatial effects manifest themselves the stronger the higher is the absolute value of negative reactivity inserted into the rector. It was proposed to determine the time dependence of the ratio of neutron density in the ion chamber's location to the neutron flux averaged over the reactor using the dynamic BIPR-8 KN or NOSTRA-type code.

At the same time it is known that in the insertion of a high negative reactivity (scram drop) the above ratio of neutron fluxes will remain unchanged during the whole measurement period. This fact makes it possible to use steady-state BIPR-type codes for this ratio.

The present paper is one in the series of authors'works on the possibility of correct experimental determination of classical reactivity of the reactor – the differences from the effective multiplication factor unit.

It is supposed that the measurements are carried out at a low power level with scram drop of absorbing control rods (CR) into the core which is in the critical or near-critical state. Using one or several ion chambers (IC) outside the core the change in the time of neutron density in the chambers' location is fixed.

There are two possible methods. The first one, with no account for the spatial effects: substitute the result of measurements of neutron density in the ion chamber location directly into the inverted point kinetics equation. This method is not correct because as a result we do not obtain the scram efficiency but rather a certain value, which is sometimes called the "dynamical" reactivity that depends on the measurement area and may differ from the scram efficiency by 100% and more [1-4].

The second method (with the spatial effects considered) of using the measurement results is when the ion chamber indications multiplied by the correction factor *f(t)* sometimes called "sensitivity factor", is sent into the reactivity meter for solving the inverted point kinetics equation [1-3]. Factor *f(t)* is supposed [3-4] to be determined by calculations as a ratio of the neutron flux averaged over the reactor with importance (adjoined function) to the neutron flux in the ion chamber location:

$$f_k(t) = \frac{\langle n(t,r), \varphi^+(r) \rangle}{n(t,r_\kappa)} \qquad (1).$$

Here $n(t,r)$ - the calculated neutron flux at point r at time $t$;

$n(t,r_k)$ - the calculated neutron flux in the ion chamber location;

$\varphi^+(r)$ - the neutron value, calculated for the reactor's state for which the reactivity is measured; usually the approximation $\varphi^+(r) \approx n_{st}(r)$ is used.

In the reactivity meter the finite difference analog of the inverted point kinetics equation is used:

$$\frac{\rho}{\beta} = 1 - \frac{N(0)}{N(t)} \sum_{i=1}^{6} \frac{\beta_i}{\beta} exp(-\lambda_i t) - \frac{1}{N(t)} \sum_{i=1}^{6} \lambda_i \frac{\beta_i}{\beta} \int_0^t N(t') exp(-\lambda_i (t - t'))\ dt' \qquad (2)$$

Fig. 1 presents the typical plots observed during scram drop measurements at the VVER-440 (without one CR stuck with its subsequent drop); Fig. 3 – during scram drop measurements at the VVER-1000. Fig 2. and 4 present the plot of correction factor *f(t)* obtained for that experiments.

It can be concluded from the analysis of the above plots and formula (2) that after the CR scram the correction factor *f(t),* remains practically unchanged in the course of measurements except the time intervals of CR movement.

The experimenters have long noted [1] that the duration of scram drop efficiency measurements does not practically affect the measurement result. The information on the scram efficiency (without corrections for spatial effects) can be obtained from the analysis of the "first ramp" of neutron power

$$\frac{\rho}{\beta} \approx 1 - \frac{N_0}{N_1} \qquad (3)$$

where $N_1$ the IC current after the completion of CR movement

A similar conclusion can be also made in the case when the spatial effects are considered, i.e.

$$\frac{\rho}{\beta} \approx 1 - \frac{N_0 f_0}{N_1 f_1} \qquad (4)$$

Where $f_0 = \frac{\langle n_0(r), \varphi^+(r) \rangle}{n_0(r_k)} \approx \frac{\langle n_0(r), n_{st}(r) \rangle}{n_0(r_k)}$

$f_1 = \frac{\langle n_1(r), \varphi^+(r) \rangle}{n_1(r_k)} \approx \frac{\langle n_1(r), n_{st}(r) \rangle}{n_1(r_k)}$

(in the $\varphi^+(r) \approx n_{st}(r)$ approximation).

$n_0(r)$ - the distribution of neutron density in the critical reactor before CR scam drop;

$n_1(r)$ - the distribution of neutron density in the subcritical reactor after CR scram drop if the delayed neutron source coincides with neutron distribution before CR scram drop i.e. their distribution corresponds to $n_0(r)$ ;
$n_{st}(r)$ - the neutron density distribution in the quasicritical reactor after CR scram drop:
$r_k$ - the coordinate of location of the reactivity meter ion chamber.

When using the standard reactivity meter, solving equation (2) and procedures of introducing corrections (1) it is possible, as in the "first ramp model" to use the stepwise correction function *f(t)*.

$$f(t)=\begin{cases}1, t \le t_0 \\ \dfrac{\langle n_1(r), n_{st}(r)\rangle}{n_1(r_k)} \times \dfrac{n_0(r_k)}{\langle n_0(r), n_{st}(r)\rangle}, t > t_0\end{cases}, \qquad (5)$$

here $t_0$ – the scram drop time, the rest of notation are as in (4).

The use of this simplified method appears to be justified, which is illustrated by the data of the table.

The experiments on CR scram drop on different VVER reactors were modeled. In the first line of the table the spatial effects are taken into account by means of accurate function *f(t)* (1), in the second line – using the approximated stepwise function (5). As seen from the comparison of the table data the results of application of different forms of correction functions *f(t)* are in reasonable agreement.

Note that the above method is only valid in the case when a high negative reactivity is inserted, when, due to low neutron density in the reactor after the CR scram drop, the distribution of delayed neutron emitters is mainly determined by their starting concentrations.

The authors would like to attract attention to the simplified method for calculation of corrections for considering the spatial effects in the scram drop efficiency measurements since its application might be expedient due to relative simplicity and reasonable accuracy. The simplified correction coefficients can be calculated without using spatial dynamical codes which sometimes are complicated for application. For the method proposed it is enough to use standard stationary BIPR-type codes which should be only slightly modernized for the calculation with a source.

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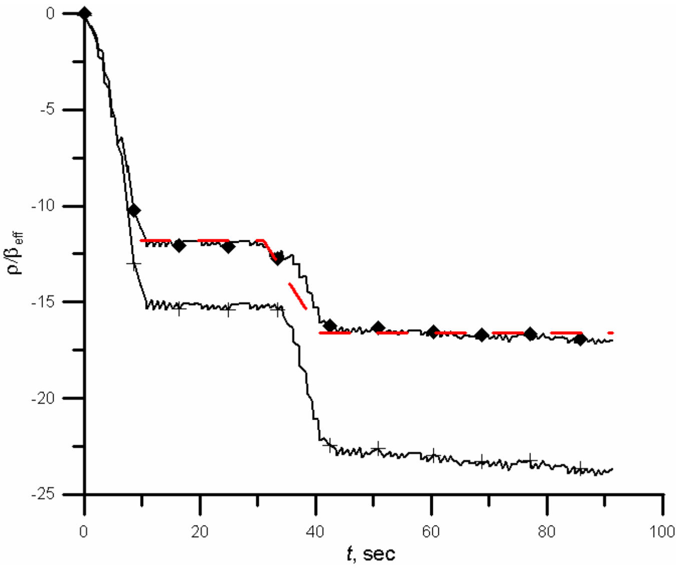


Figure1. Measurements of VVER-440 scram efficiency using the scram drop method

+ – the reactivity meter indications without consideration of spatial effects;

♦ – the reactivity meter indications with spatial effects considered

- - – the reactivity from the quasicritical calculation.

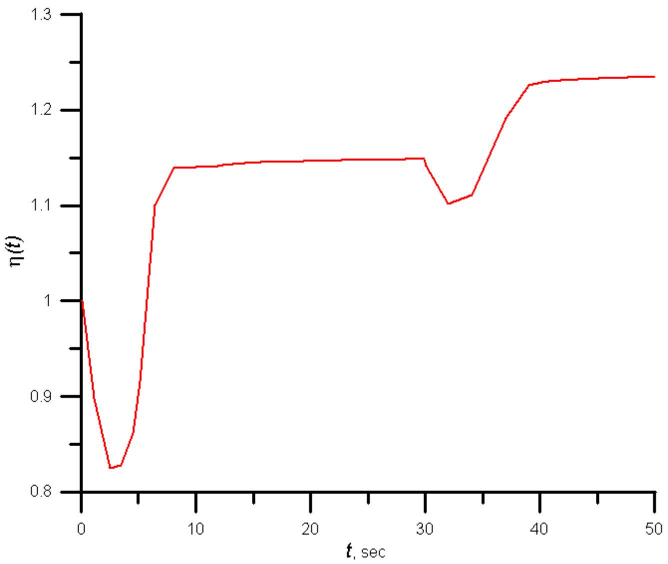


Figure 2. Plot of correction factor *f(t)*, scram drop VVER-440.

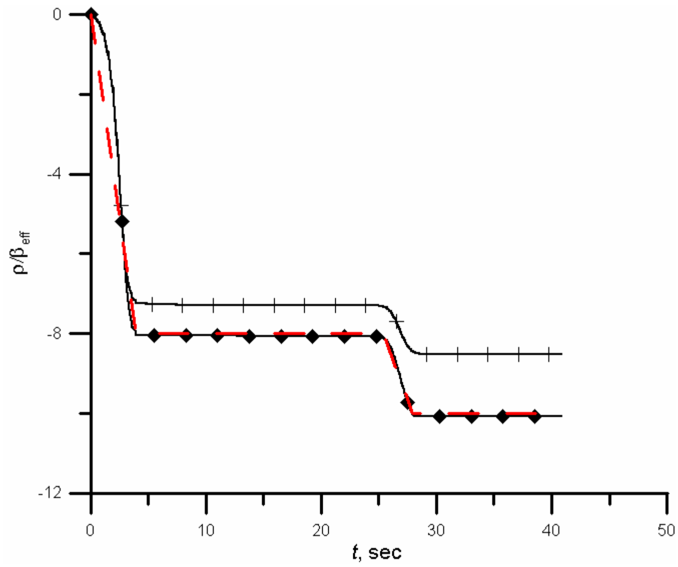


Figure 3. Measurement of VVER-1000 scram efficiency using the scram drop method

+ – the reactivity meter indications without consideration of spatial effects;

♦ – the reactivity meter indications with spatial effects considered

- - – the reactivity from the quasicritical calculation

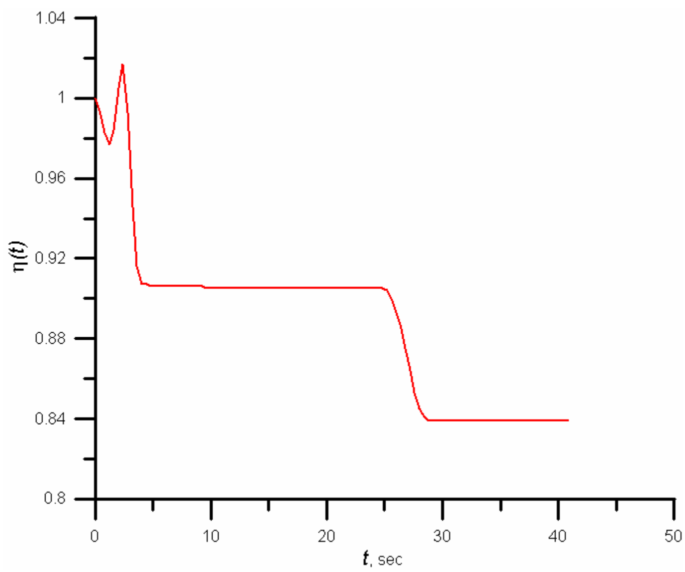


Figure 4. Plot of correction factor *f(t)*, scram drop VVER-1000.

Table. VVER scram efficiency, in $\beta_{eff}$

| Efficiently | | VVER-440 | | VVER -1000 | |
|---|---|---|---|---|---|
| | | Without one CR | Full scram | Without one CR | Full scram |
| 1 | Reactivity meter indications without corrections | 15.6 | 23.3 | 7.3 | 8.5 |
| 2 | Reactivity with a correction (1) (accurate value *f(t)* | 11.9 | 16.7 | 8.1 | 10.1 |
| 3 | Reactivity with stepwise correction (5) (approximated value at *f(t)* | 12.2 | 17.2 | 7.9 | 10.0 |
| 4 | Accurate value of reactivity inserted | 11.8 | 16.6 | 8.2 | 10.2 |