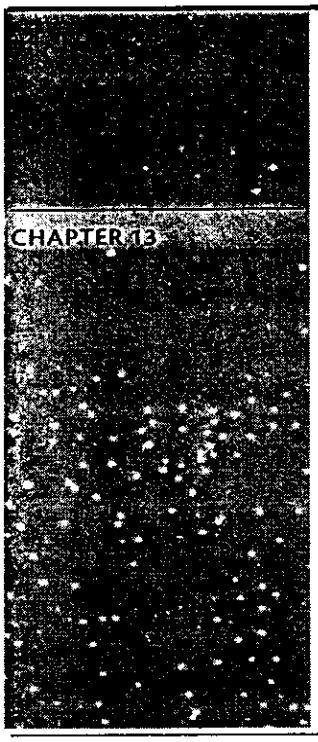

CHAPTER 13

Quasistatic Method

We saw in the preceding chapter the inherent difficulties of the adiabatic method. The quasistatic method is a generalization of the adiabatic method, but has the great advantage that it provides a true solution to the space-time kinetics equations. It is also a very competitive method compared to direct methods and is in widespread use for the solution of CANDU problems.

Flux Factorization

The idea is to express the flux as a combination of a shape function and of an amplitude function,

$$[\phi(\vec{r}, t)] = [S(\vec{r},t)]T(t)$$

Just as in the point kinetics method, this expression is not an approximation, since the shape function depends both of space and time. The same definitions and normalizations as in the point kinetics method are used for $[S(\vec{r},t)]$ and $T(t)$, namely

$$T(t) = \langle [W][v]^{-1}[\phi(\vec{r},t)] \rangle$$

and

$$\langle [W][v]^{-1}[S(\vec{r},t)] \rangle = 1$$

What makes the quasistatic method different from the point kinetics method is the exact treatment of the effects due to the dynamic changes in the shape function during transients.

Time Intervals

In the quasitatic method, point kinetics is used to calculate $T(t)$, and the shape function $[S(\vec{r},t)]$ is calculated by solving the full space-time kinetics equations. It is hoped that the shape function varies much more slowly than the flux, since the fast varying amplitude has been removed from it. The time dependence of the shape function should then be slow. Large time intervals would be possible between flux shape evaluations.

From the point of view of spatial discretisation, a hierarchy of time intervals appears. The point kinetics equations are solved on very short time intervals, the "micro-intervals", while a full spatial calcula-

tion for the shape function is done over much larger time intervals, the so-called "macro-intervals". This hierarchy is illustrated on Figure 8, page 147.

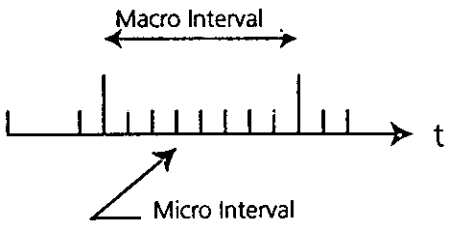

FIGURE 8. Micro and Macro Intervals for the IQS Method

As we will see, consistency between the shape function and point kinetics requires that micro intervals and macro intervals fall on the same values.

Mathematical Formulation

Since we have a time dependent shape function, the terms that come into play in the definitions of the parameters that dictate the behavior of $T(t)$, that is to say the point kinetics parameters, will be determined by using a time dependent shape function together with parameters (such as cross-sections) that also vary as a function of time. We have obtained in chapter 10, *Point Kinetics*, page 107 the rigorous defini-

tions of the point kinetics parameters, with a time dependent shape function. It is not necessary to repeat them here, since the same definitions hold true.

We only have to determine the differential equation for the shape function $[S(\vec{r}, t)]$. To do this, we come back to the matrix formulation of the space-time kinetics equations. We substitute in it *the exact expression* $[\phi(\vec{r}, t)] = [S(\vec{r}, t)]T(t)$, which gives

$$[v]^{-1}T\frac{\partial}{\partial t}[S] + [v]^{-1}[S]\frac{\partial}{\partial t}[T] = \nabla \cdot [D]\vec{\nabla}[S]T - [\Sigma][S]T + (1-\beta)[\chi^p][\nu\Sigma]^T[S]T + \sum_{i=1}^{D}[\chi_i^d]\lambda_i C_i$$

that we divide by $T(t)$ to get

$$[v]^{-1}\frac{\partial}{\partial t}[S] + [v]^{-1}[S]\frac{1}{T}\frac{\partial}{\partial t}[T] = \nabla \cdot [D]\vec{\nabla}[S] - [\Sigma][S] + (1-\beta)[\chi^p][\nu\Sigma]^T[S] + \frac{1}{T}\sum_{i=1}^{D}[\chi_i^d]\lambda_i C_i$$

while the delayed precursor equations become

$$\frac{\partial}{\partial t}C_i = \beta[\nu\Sigma_f]^T[S]T - \lambda_i C_i$$

Since we already have $T(t)$ from the micro intervals and therefore also in the macro time intervals, the terms involving $T(t)$ in these last two equations can be evaluated.

But the shape function solution $[S(\vec{r},t)]$ depends on $T(t)$, thus on the solution of the point kinetics equations, whose parameters are in turn dependent on the shape function. In order to maintain system consistency, some iterations are necessary to get the point kinetics parameters as a function of the shape function, and a shape function depending on the point kinetics solution. In practice, very few iterations are necessary, maybe 1 or 2, to attain an acceptable degree of consistency.

Application Domain

The quasitatic method is very satisfactory for the analysis of CANDU transients. This comes form the fact that perturbations propagate far away from their point of origin, and that they have a tendency to produce global effects, such as zone power mismatch.

The IQS method is not in such widespread use for light water reactor applications, probably because of the very localized nature of perturbations found in these reactors. The shape function must then be calculated at more shorter time intervals: the macro time steps are quite small. This makes the method less competitive with regard to well optimized direct methods.