

CALCULATION OF OBSERVABLE STREAMING EFFECTS IN GCFR LATTICES

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- (1) The standard calculational methods of reactor physics handle the problem of void regions by conceptually smearing the surrounding material over a volume containing the void. This treatment is inadequate for voids whose characteristic dimensions exceed the mean neutron mean free path in the assembly. In LMFBR's such voids will be along control rods guides or may arise in loss of coolant accident situations. In the GCFR, the low coolant cross section and typical open geometry means that the normal lattice also contains a large array of inter-pin void channels which can account for up to 60 % of the core volume. The transport theory methods with which one can tackle the problem of large discrete voids are inapplicable to such a configuration. The assessment of neutron streaming along these channels is, however, important because of its possible impact on reactivity, reaction rates, and leakage spectrum incident on the reactor diagrid.
  
- (2) In principle the voided lattice could be explicitly represented in Monte Carlo type calculations but the computing requirements are in practice prohibitive. Accordingly the most common approach to the calculation is to derive from transport theory cell calculations effective diffusion coefficients which will produce the correct results when used in standard diffusion theory calculations. Much effort has been devoted to deriving such expressions (refs 1-5). Less commonly found are estimates of the observable effects of these adjusted diffusion coefficients on reactor properties. Of the practical experiments

and calculations, most concern streaming in the plate lattices typical of zero energy assemblies, and the results are normally confined to the change in  $k_{eff}$  (refs 6-10). Typically this change is around 0.4 - 0.8 %. Zolotar (ref 9) also looked at the impact on central worths and central reaction rate ratios, but found only minor changes.

- (3) The more extreme effects in a GCFR have been calculated by Pellaud (ref 11) whose figures relate to the General Atomic Company 300 MW demonstration plant with a void fraction of 52 %. Analysis using Benoists methods produced axial diffusion coefficients 2-11 % greater than the homogeneous values and these yielded a 0.8 % change in  $k_{eff}$ . Subsequent to this application of Benoists work however, Eisemann and Kohler and Ligou have separately derived methods for calculating the diffusion coefficient anisotropy by explicitly taking account of the actual hexagonal lattice rod arrangement. Kohler and Ligou indicate that their calculated anisotropy is greater than Eisemann's, and that both methods yield values greater than the Benoist result.
- (4) With a view to establishing by measurement the effect of streaming, and to discriminating between the various theoretical proposals, further calculations are in progress at EIR. These calculations use the Kohler-Ligou approach to derive diffusion coefficients for the rodded fast zone and blanket of the zero energy PROTEUS reactor, and proceed to assess the impact of these new parameters on reaction rate distributions and reactivity.

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- (5) The calculation of anisotropic diffusion coefficients is done by the code DIFFAX (ref 12). Because the code is expensive in computing time and calculates only one energy group at a time, simplifications have been made using the observed facts that the changes in diffusion coefficients are only a weak function both of the energy and of the axial buckling. The results for the relatively close packed PROTEUS lattice (void fraction 39 %) are given in table 1, which shows a change in axial diffusion coefficient of about 5 % in the most populated of the 4 energy groups calculated. To judge the effects in a larger pitch lattice however some calculations were also performed with a further 0.1 cm added to all the axial diffusion coefficients, corresponding to a void fraction nearer to 60 %.
- (6) Initially calculations were carried through using the UK code CRAM (ref 13) which has the required capability for handling anisotropic diffusion coefficients. It is slower than the current generation of codes, however, and only a simplified reactor model could be considered. Reaction rate distributions and  $k_{eff}$  values were calculated for the simple 2 zone GCFR model of figure 1 with the diffusion coefficient anisotropy calculated for the PROTEUS lattice and also with the higher anisotropy previously mentioned as more typical of the power reactor case. These calculations are currently being checked and extended using the GAUGE code (ref 14) which has been modified at EIR to handle anisotropic diffusion, and the associated perturbation edit STOER (ref 15) which has been likewise modified. These calculations are aimed more at investigation of the measurement possibilities in the PROTEUS mixed critical system and do not alter the broad conclusions of the preliminary results described below.

- (7) The changes in  $k_{eff}$  found in the reactor calculations are in line with published values and are great enough to be of importance in the power reactor case. The PROTEUS anisotropy runs gave a  $\delta k$  of -0.6 % and the higher anisotropy runs a  $\delta k$  of -1.2 %. Much smaller effects will, of course, arise in a mixed critical system in which the fast lattice streaming can be varied only in a central zone.
- (8) An important result is that the reaction rate ratios and distributions appear to be only slightly affected by the anisotropy. Table 2 gives typical figures. In columns 1 and 2 of the table are compared the central ratios from isotropic 4-group calculations and calculations with the anisotropy given in table I. It can be seen that there is no significant change. This can be seen to be true even for higher anisotropies by comparing the isotropic case with the column 3 case in which a further 0.1 cm was added to all the  $\delta D_z$  values of table 1. The 10 group cases that were run to give a more adequate treatment of spectrum effects also reveal the central ratios to be independent of the anisotropy even with the relatively high increment of 0.15 cm which was added to all the 10 group diffusion coefficients. The ratios of the principal reaction rates at the off-central positions shown in figure 1 to the central value are also given in table 2. It can be seen that for the normal lattice case the maximum change occurs in the U238 fission ratio in the outer blanket and is only about 2V2 % which is barely measurable. Even with the increased  $D_z$  case in column 3 the maximum reaction rate ratio change is only around 5 %, and the changes in the other ratios much less.

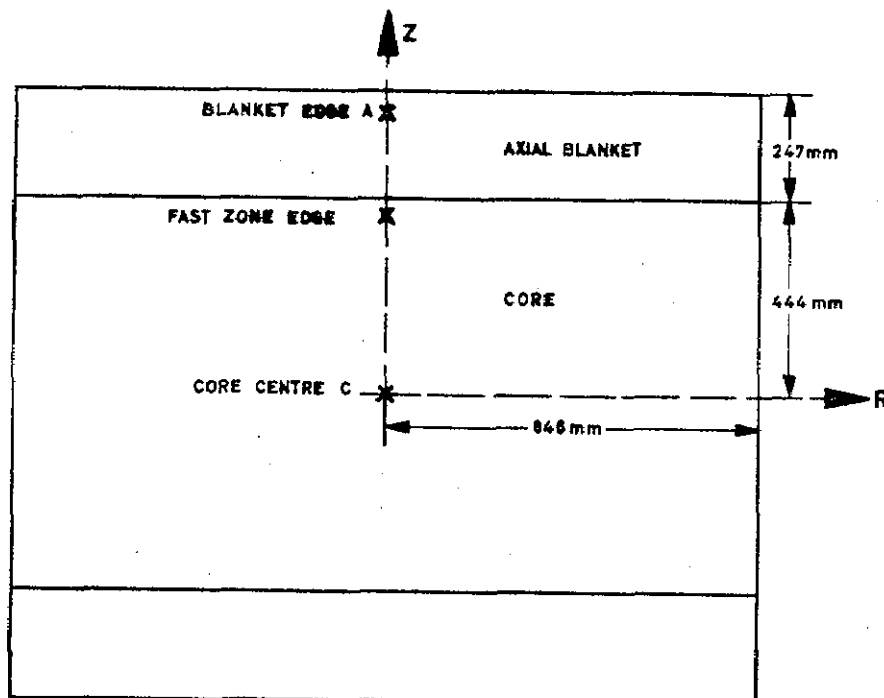
(9) Approximations made in the derivation of diffusion coefficients and in the application of these near reactor boundaries restrict the accuracy of the above figures. They do not, however, affect the broad conclusion of this preliminary study that the effects of axial streaming appear too small for reliable investigation via reaction rate distribution measurements. The reactivity losses, on the other hand, should be measurable as a function of fuel pin arrangement in a rodded lattice. Current work is aimed at assessing the sensitivity of measurable parameters to the predictions of competing theories.

TABLE 1

Diffusion Coefficient Anisotropies

<u>group</u>	<u>boundaries</u>	<u>D(cm)</u>	<u><math>\delta D_z^*</math></u>	<u><math>\delta D_R</math></u>
1	15 MeV	3.121	.065	.023
2	.821 keV	1.732	.072	.029
3	3.35 keV	1.291	.075	.030
4	.683 eV	0.5458	.081	.033
	thermal			

\* notes: For the higher anisotropy 4 group cases, all the  $D_z$  values were increased by a further 0.1 cm. For the 10 group cases all  $\delta D_z$  were taken as 0.15 cm, all  $\delta D_R$  as zero.



REACTOR MODEL

FIG.1.

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	Isotropic Diffusion	PROTEUS Anisotropy $\delta k = -0.6\%$	Increased Anisotropy $\delta k = -1.2\%$
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Central Reaction Rate Ratios			
F5/F9	1.035	1.034	1.034
F8/F9	0.0301	0.0303	0.0301
C8/F9	0.131	0.131	0.131
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Core Edge to Core Centre Reaction Rate Ratios			
F9	0.516	0.518	0.522
F5	0.530	0.533	0.536
F8	0.433	0.435	0.437
C8	0.526	0.529	0.533
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Blanket Edge to Core Centre Reaction Rate Ratios			
F9	0.186	0.189	0.193
F5	0.207	0.211	0.216
F8	0.0619	0.0634	0.0657
C8	0.200	0.204	0.209
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EFFECT OF ANISOTROPIC DIFFUSION ON REACTION RATES

TABLE 2

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