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TITLE: Use of the Streaming Matrix Hybrid Method for Discrete-Ordinates Fusion Reactor Calculations

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USE OF THE STREAMING MATRIX HYBRID METHOD FOR DISCRETE-ORDINATES FUSION REACTOR CALCULATIONS

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The use of the discrete-ordinates method for solving two-dimensional, neutral-particle transport in fusion reactor blankets and shields is often limited by inherent inaccuracies due to the "ray-effect." This effect presents a particular problem in the case of neutron streaming in the large internal void regions of a fusion reactor. A deterministic streaming technique called the Streaming Matrix Hybrid Method (SMHM)[1,2] has been incorporated in the two-dimensional discrete-ordinates code TRIDENT-CTR.[2,3,4] Calculations have been performed for an actual inertial-confinement fusion (ICF) reactor design using TRIDENT-CTR both with and without the SMHM. Comparisons of the calculated fluxes indicate that substantial mitigation of the "ray effect" can be achieved with the SMHM.

Calculations were performed for the Los Alamos "FIRST STEP" hybrid ICF reactor designed for tritium production.[5,6,7] Conventional ^{238}U fuel rod assemblies surround the spherical steel target chamber to form an annular cylindrical blanket. An axial fuel region is included to complete the blanket. The TRIDENT-CTR triangular mesh used to model the geometry is shown in Fig. 1.

Calculations both with and without the SMHM were performed in the S_8P_3 approximation with 30 neutron and 12 gamma-ray groups. The source was D-T neutrons with a degraded spectrum[6] distributed in the cylindrical mesh region at the origin. Two streaming matrix regions were specified--a cylindrical region extending from above the source region to Z = 140 cm, and an annular cylindrical region of radius 136 cm surrounding the source and other void region. The streaming-matrix void regions were defined in this manner to exclude the source region. Creation of the streaming matrices in TRIDENT-CTR is performed prior to the transport calculations.

The major effects of streaming are observed in the dominant fusion neutron source groups 2 and 3 (source fractions of 0.683 and 0.167, respectively). Shown in Fig. 2 is a contour plot of the flux in group 2 for the calculation without the SMHM. The five streaming directions with the S_8 quadrature are plainly visible. The flux contours in the radial fuel region clearly indicate a strong non-existent axial variation due to streaming. A similar contour plot is presented in Fig. 3 for the flux in group 2 calculated using the SMHM. The selection of the two steaming matrix regions appears to be less than optimal because some axial flux variation in the fuel region is still apparent. However, little variation is exhibited up to the height of the streaming matrix regions. In the fuel region the calculated flux appears to be well behaved, and integral results such as tritium breeding agree well with 1-D calculations globally. Selection of streaming matrix regions that more completely represent the actual target chamber void should result in a more uniform variation in the flux over the entire fuel region.

The use of the SMHM in discrete-ordinates calculations for complex reactor designs appears to offer substantial reductions in the inaccuracies due to streaming effects without the penalties of high quadrature orders. Selection of the streaming matrix regions to represent all actual voids should give optimal results; however, benefits achieved by increasing the number of streaming matrix regions must be weighed against increases in matrix computation times.

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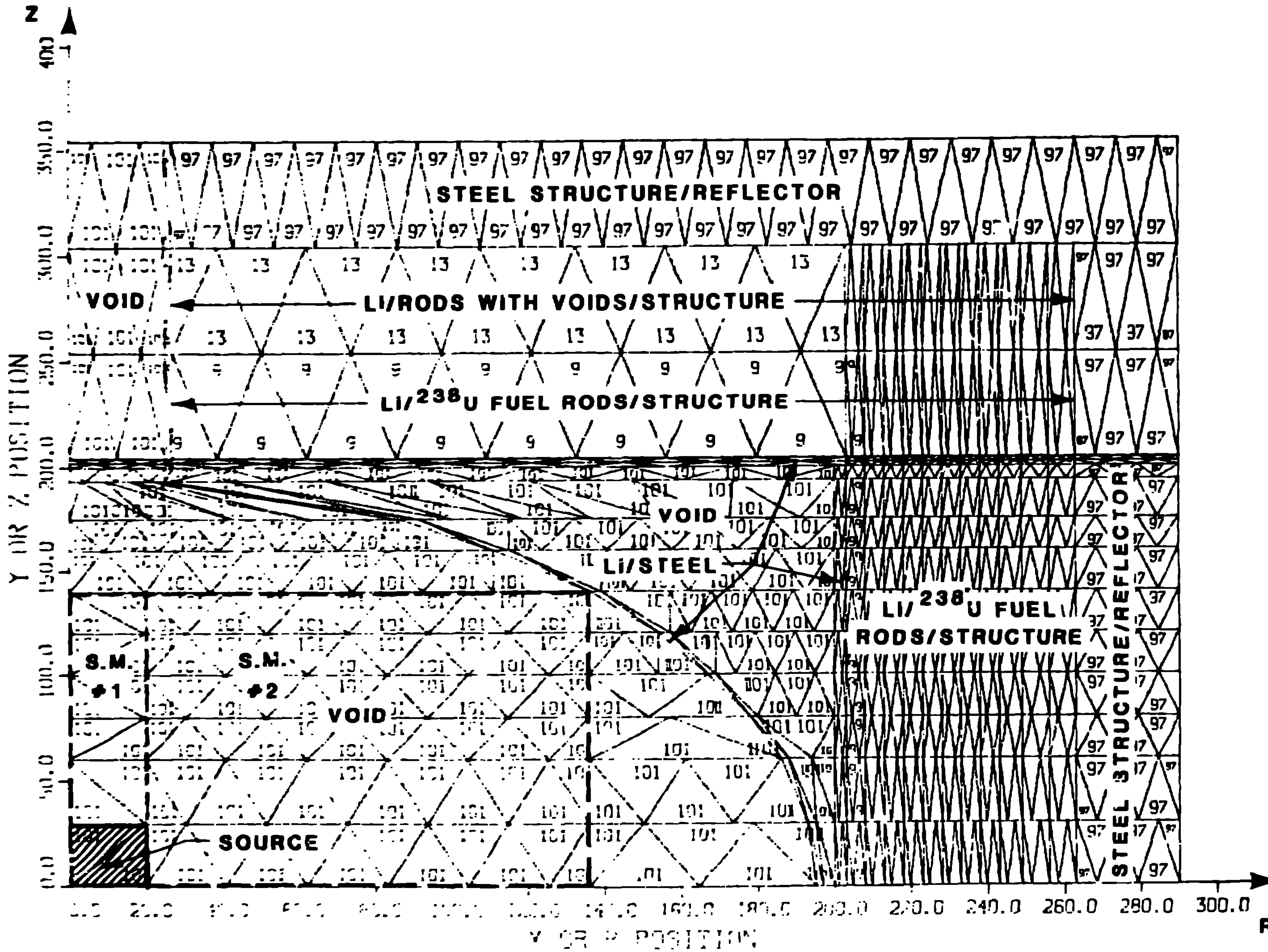
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STEEL STRUCTURE/REFLECTOR
S.M. #1
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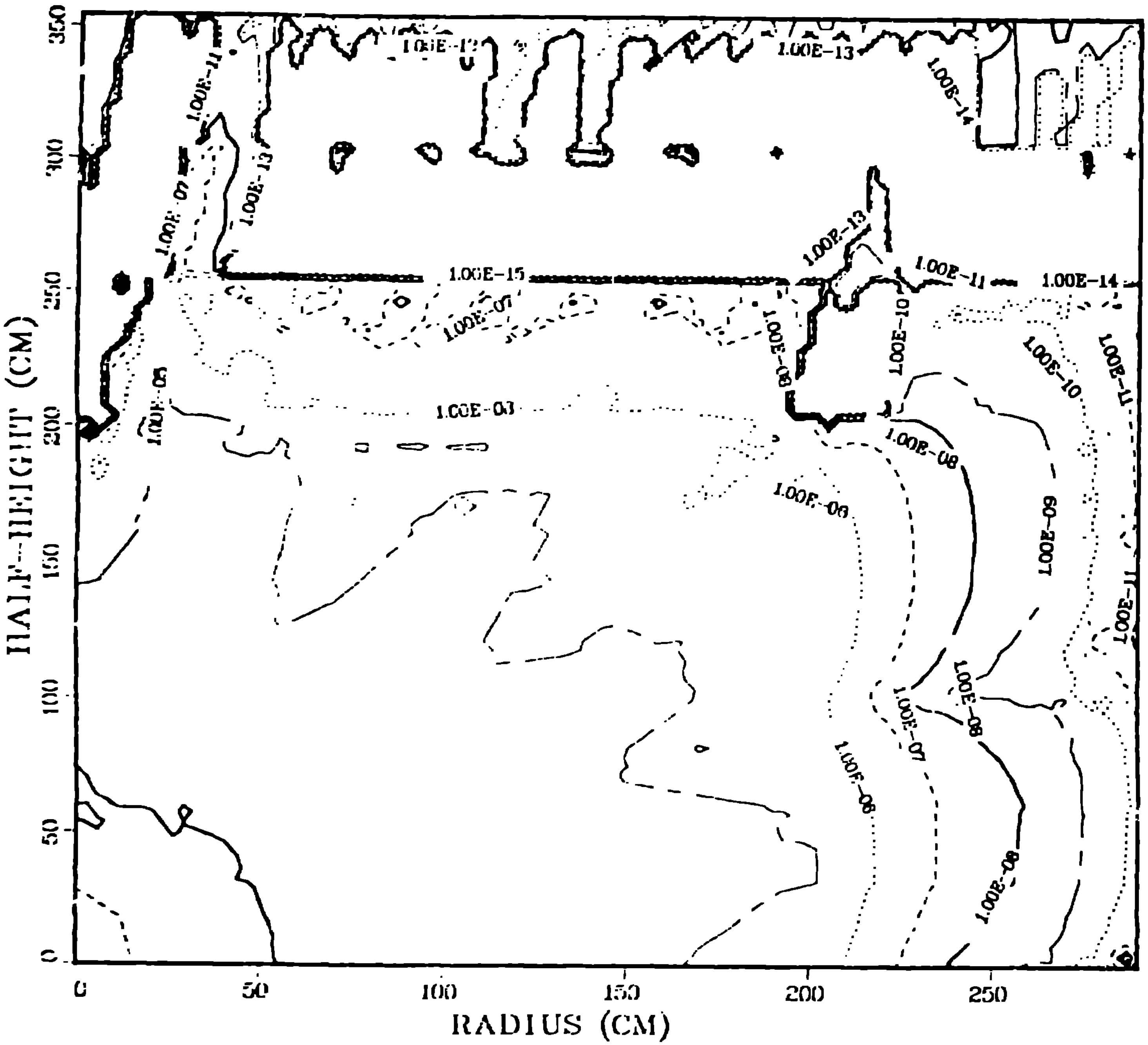

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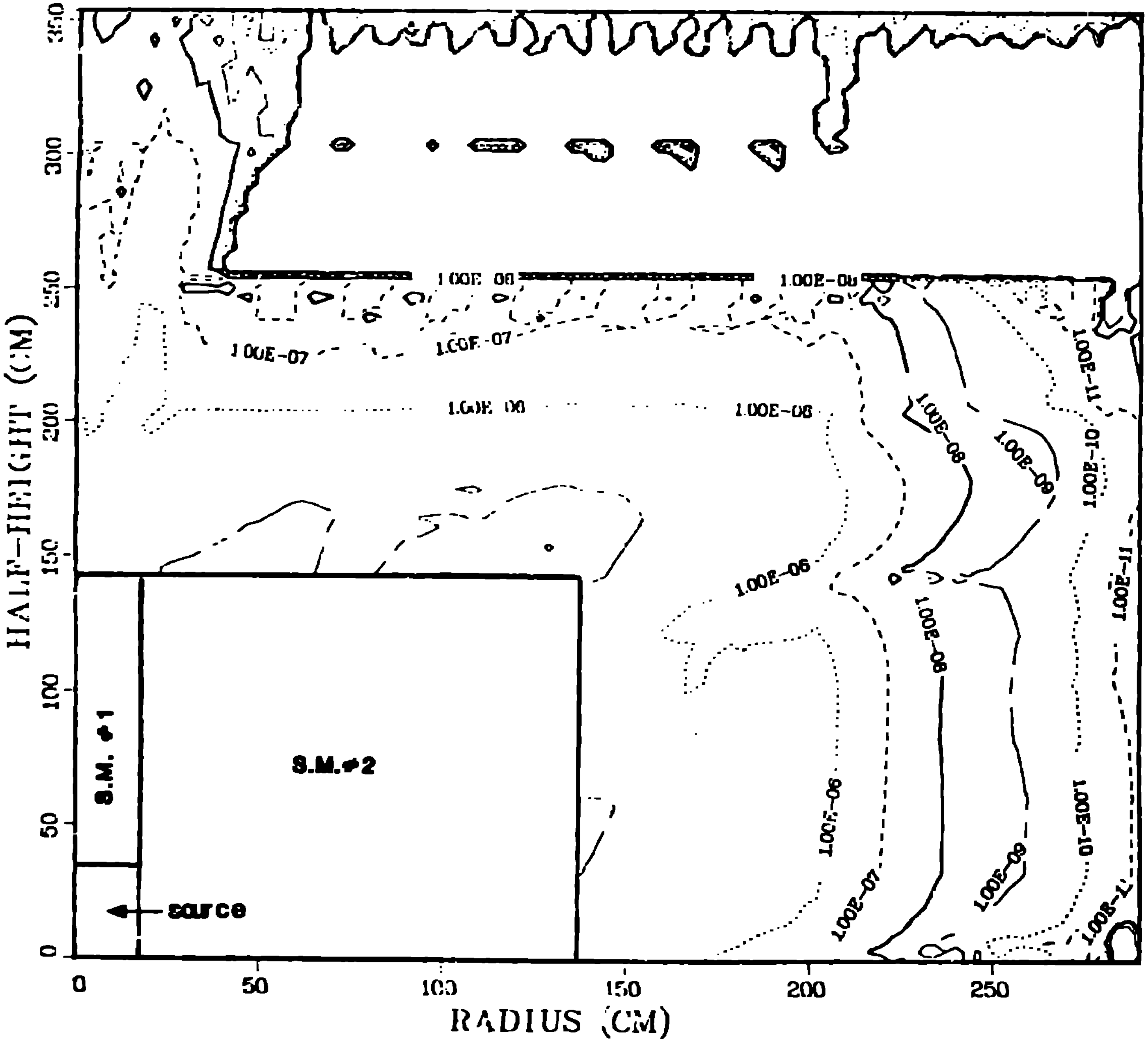

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Figure Captions

Fig. 1. Triangular Mesh Used to Model the ICF Reactor Geometry in TRIDENT-CTR (mesh numbers indicate material composition; e.g., 101 is void).

Fig. 2. Contours of the Source Normalized Neutron Flux in Group 2 Calculated by TRIDENT-CTR Without Modifications.

Fig. 3. Contours of the Source Normalized Neutron Flux in Group 2 Calculated by TRIDENT-CTR with the Streaming Matrix Hybrid Method.