(weight factor), Russian Roulette, the method of fractional generated neutrons, double sampling, semi-systematic sampling, and the method of expected leakage probability. The neutron histories are assigned a discrete energy value after each collision process. The nuclear data input is done, however, by group averaged cross sections.

The program can generate the neutron fluxes either resulting from an external source or in the form of fundamental mode distributions by a special source iteration procedure. In this latter case, the calculations of eigenvalues are based on the life-cycle concept.

5. Restrictions on Complexity of the Problem: Number of energy groups ≤ 50, number of isotopes ≤ 20, number of isotope mixtures ≤ 20.

6. Related and Auxiliary Programs: The program can be linked to the ENDF/B data file via the CODAC code. CODAC generates for any desired group structure the nuclear parameters and group averaged cross sections needed by TIMOC. The program PLOTGEOM can be used to display the specified geometry and to detect errors in the geometry input.

7. Running Time: The running time depends very much on the problem treated and to some extent on the options specified. A complete eigenvalue and flux analysis in an unreflected highly enriched system requires for a probable error of ±0.5% in $k_{eff}$ 6 min of computing time on an IBM 7090. A reflected system, consisting of 85 geometrical regions, and 18 isotope mixtures using 26 energy groups needs for obtaining the same probable error 45 min.

8. Unusual Features: A special option allows the calculation of geometrical perturbation effects. In such calculations the differential effect does not depend on the total variance of the considered quantity. The sampling of these differential effects is based on the method of similar flight paths.

9. Status: The program is in production use.

10. Machine Requirements: The program was written for the IBM 7090/95. It requires a 32K memory, 2 channels and 3 tapes, in addition to the monitor tapes. On the IBM 360/65 it can run in the "Emulation Mode."

11. Operating System and Environment: The program runs under the FORTRAN II Version 2 monitor system.

12. Miscellaneous Programming Information: The program is a link job. The assembled programs (3 links) and the data libraries are stored on a Program System Tape and read into the computer at execution time. Data communication between the different link programs and a dump of the computer memory for a later continuation of the calculation is done via a second tape. In the case of real time-dependent calculations, the characteristic parameters of all events (collisions and boundary crossings) are stored on a third tape, which is afterwards scanned.

13. Material Available: Distribution of the TIMOC Program Package (7 updated files containing all Fortran and FAP decks and 4 files with sample cases) via the ENEA Computer Programme Library, 21020-Ispra (Varese), Italy.

Code Manuel: H. Kschwendt and H. Rief, "TIMOC; A General Purpose Monte Carlo Code for Stationary and Time Dependent Neutron Transport," Euratom Report, in press 1970.

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## 3DDT

### A Three-Dimensional Multigroup Diffusion-Burnup Program

1. Name of Program: 3DDT Code.[1]

2. Computer for Which Program is Designed: CDC 6600.

3. Nature of Physical Problem Solved: 3DDT is a three-dimensional (X-Y-Z or R-$\theta$-Z) multigroup diffusion theory code for use in fast reactor analysis. The code can be used to compute $k_{eff}$ or to perform criticality searches on reactor composition, time absorption, and reactor dimensions by either the regular or the adjoint flux equations. Material burnup and fission product buildup can be computed for specified time intervals,

and criticality searches can be performed during burnup to compensate for fuel depletion and fission product growth.

4. Method of Solution: Standard source-iteration techniques are used to compute eigenvalues and flux profiles. Using an initial fission source distribution, new flux profiles in each group are sequentially computed, beginning in the highest energy group in regular problems and in the lowest energy group in adjoint problems. The group fluxes are computed by horizontal (R-$\theta$ or X-Y) planes, beginning with the plane at the lower-most axial position. Convergence is accelerated by group rebalancing, successive over-relaxation, and line inversion. Material burnup is computed using zone- and group-averaged cross sections which are recomputed after each time step. The burnup equation for each material in each zone provides for one decay source, two capture sources, seven fission sources, and losses by decay and absorption.

5. Restrictions on the Complexity of the Problem: Since variable dimensioning is used, no simple restrictions can be placed on individual components of the problem such as number of energy groups or number of mesh points. However, a 16-group problem containing $30 \times 30 \times 30$ mesh points and 80 zones can be accommodated on a 65k computer. Up-scattering is not treated in 3DDT.

6. Typical Running Time: Execution times are on the order of 0.01 to 0.02 sec per mesh point per energy group on the CDC-6600. Thus, a 2-group problem containing $20 \times 20 \times 20$ mesh points would require 2.7 to 5.3 min of Central Processor time. The low estimate applies to a $k_{\text{eff}}$ calculation, and the high estimate applies to an implicit eigenvalue search calculation. Each successive burnup interval requires about one-half of the above times. These estimates are based on experience with up to 3 energy groups and up to 2800 mesh points. It is expected that the running time will increase more than linearly with the number of energy groups, especially if the downscattering matrix is relatively full.

7. Unusual Features of the Program: Variable dimensioning is used to make maximum use of fast core storage. Both Extended Core Storage (ECS) and disk storage are utilized in 3DDT. Four-dimensional arrays [e.g., $\phi$ (x,y,z,g)] are stored in the disk using tape file simulation; three-dimensional arrays [e.g., $\phi$ (x,y,z) for a particular energy group] are stored in the ECS using random access; and two-dimensional arrays [e.g., $\phi$ (x,y) for a particular energy group and axial position] are stored in the fast central memory. Thus, central memory storage requirements are insensitive to the number of energy groups and the number of axial mesh points. Because of the manner in which arrays are stored, very large two-dimensional (in R-Z or X-Z geometry) problems can be run with 3DDT on a 65k computer.

8. Related and Auxiliary Programs: 3DDT is an extension to three space dimensions of the two-dimensional 2DB code.[2] The generalized input subroutines used for reading data in the DTF-IV code[3] are also used in 3DDT.

9. Status: All options have been tested, and the code is currently in use at the Los Alamos Scientific Laboratory.

10. Machine Requirements: CDC-6600 computer with $65\,000_{10}$ fast central memory, $500\,000_{10}$ ECS, $6\,000\,000_{10}$ disk (four tape files are simulated on the disk), two magnetic tape units, and the usual input-output devices.

11. Programming Language Used: FORTRAN IV.

12. Operating System: CDC SCOPE 3.2.

13. Material Available: A source deck, source listing, input instructions, sample problem, and sample problem results are presently available from the author. The document (Ref. 1) which describes the code and its operation should be available by September 1970. Also, a complete code package will be available from the Argonne Code Center by that time.

14. *Acknowledgment:* This work was performed under the auspices of the U. S. Atomic Energy Commission.

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