or the angular distribution function $d\sigma(\mu)/d\mu$ is calculated for each energy group. The inelastic scattering is described by a transfer matrix which can also include $(n,2n)$ reactions.

4. Method of Solution: Averaging is done by using a weighting spectrum to be input. Group averaged cross sections are calculated by summing up the smooth contributions and the contributions of the resolved and unresolved resonances, using the methods of the ETOG-ETOM code[2,3] and of MC[2] at zero temperature.[4] Anisotropic elastic secondary angular distribution is calculated optionally as $\bar{\mu}_{Lab}$, Legendre expansion, or point by point along the μ-axis. The inelastic secondary energy distribution is computed as transfer matrix.

5. Restriction on Complexity of Problem: The code will handle any number of ENDF/B materials during one run. The number of energy groups is limited to 50. The output formats of CODAC correspond to the input formats of TIMOC.[5,6]

6. Unusual Features: Anisotropic elastic scattering secondary angle distribution can optionally be calculated in three different ways: as Legendre expansion in the c.m. system, point by point along the μ-axis in the c.m. system, as averaged cosine in the lab system. In calculating, nearly isotropic scattering is assumed in and below the resonant region.

7. Typical Running Times: The running time is very sensitive to the input options and items and to the materials chosen. For instance, an unweighted calculation will decrease the computation time by about a factor of $\frac{1}{2}$ to $\frac{3}{4}$. Running time increases with increasing number of data given for the material. For instance, a material with many resonances or many different types of reactions and a lot of energy points for each reaction will need much more time than one without resonances or with only few possible reactions and few energy points. So computation times for one material lie between 1 min and about 10 min on the IBM 360/65.

8. Status: In use. Available from ENEA Computer Programme Library, Casella Postale N. 15, 21020-ISPRA (Va), Italy.

9. Machine Requirements: The code is built in an overlay structure where it requires 155 600 bytes (38 900 words) on the 360/65. Without overlay 221 400 bytes (55 350 words) are necessary. CODAC requires two I/O devices for reading and printing, one I/O device for the ENDF/B library tape and one on which the TIMOC library is written or punched. One additional I/O device is necessary if the program is loaded from tape.

10. Related and Auxiliary Programs: CODAC uses the ENDF/B retrieval subroutines from H. C. Honeck,[7] and parts of the MC[2] code[4] and the ETOG-ETOM code[2,3] of Westinghouse.

11. *References:*

[1]H. KRAINER, "CODAC—A FORTRAN IV Program to Process a TIMOC Library from the ENDF/B File," Euratom Report, in press.

[2]R. A. DANNELS and D. E. KUSNER, "ETOM-1—A FORTRAN IV Program to Process Data from the ENDF/B File to the MUFT Format," WCAP 3688-1/ENDF 113, Westinghouse Electric Corporation (1968).

[3]R. A. DANNELS and D. E. KUSNER, Private Communication (to be published as WCAP 3845-1/ENDF 114, Westinghouse Electric Corporation).

[4]D. M. O'SHEA, B. J. TOPPEL, and A. L. RAGO, "MC[2]—A Code to Calculate Multigroup Cross Sections," ANL-7318, Argonne National Laboratory (1967).

[5]H. RIEF and H. KSCHWENDT, *Nucl. Sci. Eng.*, **30**, 395 (1967).

[6]H. KSCHWENDT and H. RIEF, "TIMOC; A General Purpose Monte Carlo Code for Stationary and Time Dependent Neutron Transport," Euratom Report, in press (1970).

[7]H. C. HONECK, "Retrieval Subroutines for the ENDF/B System," Private Communication (March 1967).

*H. Krainer**

EURATOM CCR,
I-21020 Ispra (Varese), Italy

Received April 20, 1970

*Present Address: AEG-Telefunken, Konstanz, Germany.

TIMOC

1. Name of Code: TIMOC

2. Computer for Which Program is Designed: IBM 7090/95. Programming Language: FORTRAN II and FAP.

3. Nature of Physical Problem Solved: TIMOC solves by the Monte Carlo technique the energy- and time-dependent (or stationary) homogeneous or inhomogeneous neutron transport equation in three-dimensional geometries. The program can treat absorption and all commonly used scattering kernels, such as: fission, isotropic and anisotropic scattering, level excitation, the evaporation model, and the energy transfer matrix model, which includes $(n,2n)$ reactions. The exchangeable geometry routines at present consist of:

   a. periodical multilayered slab, spherical and cylindrical lattices.

   b. an elaborate three-dimensional cylindrical geometry, which allows all kinds of subdivisions

   c. the very flexible 05R geometry routine which is able to describe any body or body combinations with surfaces of second order.

   The program calculates the stationary or time-energy- and region-dependent fluxes as well as the transmission ratios between geometrical regions and the following integral quantities or eigenvalues: the leakage rate, the slowing down density, the production to source ratio, the multiplication factor based on flux and collision estimator, the mean production time, the mean destruction time, time distribution of production and destruction, the fission rates, the energy dependent absorption rates, and the energy deposition due to elastic scattering for the different geometrical regions.

4. Method of Solution: TIMOC is a Monte Carlo program and uses several, partially optional variance reducing techniques, such as: the method of expected values

(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.

14. *References*:

[1]H. RIEF, "An IBM 704 Monte Carlo Code to Calculate Fast Fission Effects in Homogeneous and Heterogeneous Systems," BNL-647 (T-206), Brookhaven National Laboratory (1961).

[2]H. RIEF and H. KSCHWENDT, "A Monte Carlo Approach to the Calculation of Characteristic Reactor Parameters in Threedimensional Assemblies," ANL-7050, *Proc. Conf. on the Application of Computing Methods to Reactor Problems*, p. 581, Argonne National Laboratory (1965).

[3]H. RIEF and H. KSCHWENDT, *Nucl. Sci. Eng.* **30**, 395 (1967).

[4]T. ASAOKA, H. KSCHWENDT, W. MATTHES, and H. RIEF, *Trans. Am. Nucl. Soc.*, **7**, 514 (1964).

[5]H. RIEF, H. KSCHWENDT, and R. JAARSMA, "Reactivity Calculations for a Periodically Pulsed Fast Reactor by the TIMOC Code," presented at the International Conference on Research Reactor Utilization and Reactor Mathematics, CNM-R-2, Mexico City, May 1967.

[6]K.-H. MÜLLER and H. KSCHWENDT, *Atomkernenergie*, **10**, *Heft 11/12* (1965).

[7]H. KSCHWENDT and H. RIEF, *J. Nucl. Energy*, **22**, 127 (1968).

[8]H. KSCHWENDT, *J. Nucl. Energy*, **23**, 67 (1969).

[9]R. J. JAARSMA and H. KSCHWENDT, "Geometry Routines for Use in the TIMOC Code," to be published as a Euratom Report (1970).

[10]H. KRAINER, "CODAC—A FORTRAN IV Program to Generate a TIMOC Library from the ENDF/B File," to be published as a Euratom Report (1970).

*H. Kschwendt**
H. Rief

EURATOM CCR,
I-21020 Ispra (Varese), Italy

Received April 20, 1970
Revised May 19, 1970

*Present Address: European Communities, CID, Luxemburg, Rue Aldringer 29.

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-θ-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,