Computer Code Abstracts

ISUNE 1

Thermal, Radiation, and Mechanical Analysis for Oxide Fuel Elements of Liquid-Metal Fast Breeder Reactors in Unsteady State

1. Name or Designation of Program: ISUNE 1
2. Computer for which Program is Designed: IBM-360
3. Nature of Physical Problem Solved: ISUNE 1 is a three-dimensional iteration code for performing thermal, radiation, and mechanical analysis for cylindrical oxide fuel pins (or rods) or fuel elements of liquid-metal fast breeder reactors in unsteady state. The code consists of three main parts (from the center of the fuel zone outward):

   a. Computing temperature distributions in the central void, columnar-grain, equiaxed-grain and unaffected grain regions of the fuel zone and in the cladding of the fuel elements.

   b. Computing irradiation swelling, fission-gas release and burnup of the fuel by using a modified Barnes' and Nichols' model.[1-3] The calculated results compared to the experimental data are in closer agreement (in comparison to either Barnes' or Nichols' model).

   c. Computing stress and strain distributions in the fuel zone and in the cladding after the irradiation swelling, fission gas release and fuel-cladding gap thickness are determined. In the fuel zone a Prandtl-Reuss material is assumed and the von Mises yield criterion is used.[4] The method of solution may be described as follows: By assuming the appropriate input data the temperature distributions, irradiation swelling, fission-gas release, and stress and strain distributions in the fuel element at unsteady state are computed through the successive approximations of an iteration method. The convergence of the iteration method is rapid when the input data assumed are reasonable and acceptable.
4. Restrictions on the Complexity of the Problem: Since the code contains the three main parts given above, restriction on complexity is carefully carried out.
5. Typical Running Time: A typical computation of the code requires about 5 min on an IBM-360.
6. Unusual Features of the Program: ISUNE 1 is probably the first computer code to perform thermal, radiation, and mechanical analysis for oxide fuel elements for liquid-metal fast breeder reactors in unsteady state where the central void, columnar-grain, equiaxed grain, and unaffected grain regions in the fuel zone are concerned.
7. Related and Auxiliary Programs: No related or auxiliary programs are required.
8. Status: In use.
9. Machine Requirements: No machine is required but a complete set IBM-360.
10. Programming Language(s) Used: FORTRAN-IV.
11. Operating System or Monitor under which Program is Executed: IBM-360, Model 65, Release No. 18. (No other operating system or monitor under which the program is executed.)
12. Other Programming or Operating Information or Restrictions: None of them is required or present.
13. Material Available: Flow charts, operating instructions and sample problems are available from the authors.
14. *References:*

[1]R. S. BARNES and R. S. NELSON, *Brit. Ceram. Soc. Proc.*, **7**, 343 (1967).

[2]F. A. NICHOLS, *J. Nucl. Mater.*, **22**, 214 (1967).

[3]F. A. NICHOLS, "Behavior of Gaseous Fission Products in Oxide Fuel Elements," WAPD-TM-570, Bettis Atomic Power Laboratory (1966).

[4]B. M. MA and GLENN MURPHY, *Nucl. Sci. Eng.*, **20**, 536 (1964).

Benjamin M. Ma
C. K. Cheng

Nuclear Engineering Department
and
Engineering Research Institute
Iowa State University
Ames, Iowa 50010

CODAC

1. Name of Code: CODAC[1]
2. Computer: CODAC has been written in FORTRAN IV for use on the IBM 360/65.
3. Nature of Problem Solved: CODAC is a nuclear data processing code. It converts ENDF/B data into group averaged cross sections in the form needed by Monte Carlo codes. CODAC generates the mean values of σ_{cap}, σ_{el}, σ_{in}, σ_{fiss}, and ν for any group structure by using specified weighting spectra. In the case of anisotropic elastic scattering either the average cosine (μ_L)

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