Computer Code Abstract

ATHENA

1. Name of Program: ATHENA, Radiation Transport and Heating Calculations in Complex Reactor Geometries.[1]

2. Computers for Which Program is Designed and Programming Languages Used: IBM-7094 (FORTRAN IV) and CDC-1604-A (FORTRAN 63).

3. Nature of Program and Physical Problems Solved: ATHENA is a system of programs for the Monte Carlo calculation of neutron and gamma-ray transport and gamma heating in complex three-dimensional geometries. Component programs compile and combine nuclide-dependent cross sections; generate source-particle tapes representing the energy and spatial distributions of fission neutrons, monoenergetic particles, or prompt and delayed fission gammas (with reactor-history-dependent spectrum); generate secondary-gamma source tapes; and track particles to obtain flux spectra and gamma-ray heating at point detectors and in finite volumes. Energy and spatial biasing may be employed. Optional output of the main program includes particle transmission and interaction tapes.

4. Unusual Features:

   a) There are two basic geometry routines, permitting complete (360°) or partial (30°) representation of a reactor or other physical system. The 360° mode, based on the UNC-SAM program,[2] permits nested objects (spheres, cylinders, parallelepipeds, wedges) within a framework of rectangular boxes; new extensions in the ATHENA system permit the specification of cylinders partially contained in each of several boxes, radially sectored cylinders with scoring in sectors (up to 12 sectors per cylinder), externally cobasal cylinders,[a] and frustums of cones.[a]

   The 30° representation is economical of computer storage in describing systems having 12-fold hexagonal symmetry. Nested cylinders and other shapes may be located on and between planes through the z axis and forming a 30° dihedral angle; in the Monte Carlo tracking, particles are reflected quasioptically on impact with either of these planes.

   b) The source-generator program permits spatial selection of particles from arbitrary, separable radial and z-axial distributions; for the 30° mode, arbitrary relative source strengths may be specified for different fuel rods, as well as detailed source distributions within a fuel rod. Available source spectra include monoenergetic, arbitrarily-truncated fission spectrum, and a variable fission-gamma spectrum, computed by the program to correspond to the input reactor operating history (power *vs* time). For this option, the program uses built-in tables[3] of polyenergetic fission-product activity *vs* time following fission. These tables can on option be replaced by input data.

   c) Macroscopic gamma-heating response functions for use in the Monte Carlo routine are generated and transmitted by the program, which does the cross-section compilation.

   d) Exhaustive checks to debug the geometry input, prior to running the main problem, are provided in the source-generator routine and in an optional Monte Carlo tracking routine that tests tracking between each pair of innermost regions in a configuration and gives diagnostics of geometry errors.

   e) Primary and secondary gamma fluxes and heating are computed with finite variance for regions and all point detectors, including those immersed in source regions.

5. Principal Restrictions on Complexity: Geometry: 200 regions, 127 special (nonparallelepiped) regions. Compositions: 32 distinct compositions; 15 nuclides/composition for neutron, 20 for gamma problems. Delayed-gamma tables: 80 instants, 15 energies. Reactor operating history: 50 instants. Variable dimensioning is used for most of the output array; Ref. 1 gives details.

6. Running Time: Variable, depending on problem complexity. A large-scale problem run by Klann and Paulson[4,5] attained a statistical accuracy of ~10% in several relatively small scoring volumes distributed in a 144-region 30°-type geometry; it ran 42 min on the IBM-7094 computer for 80 000 primary-gamma histories, 51 min for 8000 fission neutrons, and 41 min for the secondary gammas generated in the 8000 neutron histories.

7. Status: IBM-7094 version operational, in regular use at NASA, Lewis Research Center; program and code package, with sample problem, available from Radiation Shielding Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830. CDC-1604A version at United Nuclear Corporation; not presently in use.

8. Machine Requirements: 32 K core, reader, printer, and up to four magnetic tapes or equivalent.

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[a]These two capabilities were devised and implemented by Walter A. Paulson, of the NASA Lewis Research Center, Cleveland, Ohio.

10. *References*:

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[2]B. EISENMAN and F. R. NAKACHE, "UNC-SAM: A FORTRAN Monte Carlo System for the Evaluation of Neutron or Gamma-Ray Transport in Three-Dimensional Geometry," UNC-5093, United Nuclear Corporation (1964).

[3]J. CELNIK and D. SPIELBERG, "Gamma Spectral Data for Shielding and Heating Calculations," UNC-5140, United Nuclear Corporation (1965).

[4]PAUL G. KLANN and WALTER A. PAULSON, "Comparison of Absolute Calculated and Measured Gamma and Neutron Doses in Tungsten-Water-Moderated Critical Assembly," NASA TN D-4223, National Aeronautics and Space Administration, Lewis Research Center (1967).

[5]GEORGE HOUGHTON, CLYDE JUPITER, GERALD TRIMBLE, DAVID SPIELBERG, PAUL G. KLANN, and WALTER A. PAULSON, *Nucl. Appl.*, **6**, 81 (1969).

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