# Computer Code Abstracts

## ESP

### A General Reactor Analysis Monte Carlo Code

1. Name of Program: ESP.[1]
2. Computers for Which Program Is Designed: IBM 360/75 and 360/91.
3. Nature of Physical Problem Solved: The ESP code is a general purpose Monte Carlo reactor analysis code. It covers the energy range $10^{-3}$ eV to 15 MeV and is designed for both eigenvalue and fixed source reactor and reactor cell calculations. Cross section and related nuclear data are accepted only in the version I, II, and III ENDF/B format. In addition to smooth data, the cross-section preparation includes a detailed treatment of resolved and unresolved resonances and the free gas and $S(\alpha,\beta)$ thermal models. The collision and source routines utilize the ENDF/B nonelastic secondary distributions, the anisotropic scattering data, and the fission spectra. The energy range may be divided into as many as 25 000 intervals, and over each interval the appropriately averaged cross sections are used as constant point-energy values. A general three-dimensional geometry description is available, as well as several specialized geometries. Use of fixed-source options allows calculations on nonmultiplying systems. A steady-state analysis of neutron histories is performed in core providing such quantities as neutron fluxes, reaction rates, and cross sections, all averaged over arbitrary energy ranges and spatial regions.
4. Method of Solution: ESP utilizes standard Monte Carlo techniques in the neutron tracking and collision processes. Analysis of histories is performed by either collision density or track length estimation. The nuclides are assumed to be at rest except in the thermal energy range. Non-absorption weighting, splitting, and Russian Roulette are used as variance reduction methods. To obtain estimates of the statistical error of ESP calculations, the neutron histories are processed in batches. The fission neutrons produced in a batch may be used as the starting neutrons for the next batch. Anisotropic scattering is handled by the Coveyou technique.[2] The resonance cross sections are compiled using the Doppler broadening single-level Breit-Wigner model. A detailed statistical treatment is applied to this model in the unresolved resonance energy region.
5. Restrictions on the Complexity of the Problem: The energy range is restricted to neutron energies for which data are available in the ENDF/B files. Each physical boundary of the system must be describable by a general second order algebraic equation. There may be as many as 25 nuclides in as many as 16 different mixtures in the system.
6. Typical Running Time: Running times are highly problem dependent. Less than 5 min were used on the IBM 360/91 for data preparation, tracking, and analysis of 20 000 histories for GODIVA. A heterogeneous mockup of ZPR-III Assembly 48 took 3 h; 2 h for a detailed resonance cross section data preparation, and 1 h for the Monte Carlo calculation of 15 000 histories giving a 0.5% standard deviation of the calculated eigenvalue. The IBM 360/75 time would be about 3.3 times slower.
7. Unusual Features of the Program: ESP may be run in one problem setup and computer pass. No peripheral subroutine preparation or tape processing is necessary, although some information concerning a calculation may be retained on tape for use in future calculations. Reactor systems may be calculated in complete geometric detail with a version of ESP which utilizes a nonanalog transport model and an array version of the generalized geometry.[3]
8. Related and Auxiliary Programs: ESP is one of several codes recently developed at Oak Ridge National Laboratory which has the 05R code[2] as its predecessor.
9. Status: ESP is in production use on the IBM 360/75 and 360/91 computers at Oak Ridge National Laboratory.
10. Machine Requirements: It is doubtful that meaningful problems can be run with ESP with less than 350K bytes of computer core available.
11. Programming Language Used: ESP is written in FORTRAN IV except for the random-number routines, which are in assembly language.
12. Operating System or Monitor Under Which Program Is Executed: IBM 360 System/Operating System, Level 20.1 FORTRAN H.
13. Other Programming or Operating Information or Restrictions: ESP has over 100 subroutines and ~16 000 source cards. A six segment overlay structure is used to conserve computer storage.
14. Material Available: The code and documentation may be obtained through the Argonne Code Center at Argonne National Laboratory and the Radiation Shielding Information Center at Oak Ridge National Laboratory.

15. Acknowledgment: This research was supported by the U.S. Atomic Energy Commission under contract with Union Carbide Corporation.

16. *References:*

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[2]D. C. IRVING, R. M. FREESTONE, Jr., and F. B. K. KAM, "05R, A General-Purpose Monte Carlo Neutron Transport Code," ORNL-3622, Oak Ridge National Laboratory (1965).

[3]S. N. CRAMER, "Monte Carlo Analysis of the Exact Geometric Mockup of ZPR-III Assembly 48," ORNL-TM-3596, Oak Ridge National Laboratory (1971).

*S. N. Cramer*
*R. S. Carlsmith*
*G. W. Morrison*
*G. W. Perry**
*J. L. Lucius*

Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, Tennessee 37830

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*Present address: Tennessee Valley Authority, Chattanooga, Tennessee.

## HETC

### A High Energy Transport Code

1. Name of Code: HETC[1]

2. Computers for Which Code Is Designed: IBM 360/75 and 360/91.

3. Nature of Physical Problem Solved: HETC is a Monte Carlo transport code for computing the properties of high-energy nucleon-meson cascades in matter. HETC is basically an extension of the code NMTC[2] (valid for energies $\lesssim$3 GeV) to allow particle transport up to several hundred GeV.

   The source-particle description is specified in a user-written subroutine and may be arbitrarily distributed in energy, direction, and space. Proton, neutron, $\pi^+$, $\pi^-$, $\mu^+$, and $\mu^-$ sources are allowed.

   Although the maximum allowable source-particle energies are not well defined, HETC has been run successfully for energies up to 1 TeV. However, because of the lack of experimental data at very high energies, comparison of HETC results with experimental data have been made only for energies $\lesssim$ 30 GeV (e.g., Ref. 3).

   The code stores on magnetic tape a complete description of each "event" (nuclear interaction, geometry boundary crossing, pion decay, etc.) that occurs during the transport process. This information is then read and processed by user-written analysis programs to obtain results for a particular problem.

4. Method of Solution: HETC consists of two basic transport codes: HET and a modified version of 05R.[4] HET transports particles in the energy range from the source-particle energy down to a specified energy cutoff, which is commonly taken to be 15 MeV for protons and neutrons, 2 MeV for charged pions, and 0.2 MeV for muons. Neutrons produced in HET below the cutoff energy are transported via the 05R code.

   The description of nonelastic-collison products in HET is obtained using an intranuclear-cascade-extrapolation-evaporation model. At each nonelastic collision a calculation is performed using subprogram versions of Bertini and Guthrie's[5] latest intranuclear-cascade program and Guthrie's[6] evaporation program to determine the energy and direction of emitted cascade nucleons and pions and evaporated nucleons, deuterons, tritons, $^3$He's, and alpha particles, and the mass, charge, and recoil energy of the residual nucleus. For nonelastic collisions $\lesssim$3 GeV, these intranuclear-cascade-evaporation results are used directly; for nonelastic collisions $\lesssim$3 GeV, the results from an intranuclear-cascade-evaporation calculation at ~3 GeV are scaled to the proper energy using the extrapolation method of Gabriel, Alsmiller, Jr., and Guthrie.[7] Nonelastic collisons with hydrogen nuclei are treated using experimental data and the calculational method of Gabriel, Santoro, and Barish.[8] Nonelastic collisions in 05R are treated using the evaporation model[4] in conjunction with experimental cross sections. Experimental data are used for elastic-collision cross sections.

   Charged-pion and muon decay in flight and at rest are taken into account using known lifetimes. Negative-pion capture at rest is treated via the intranuclear-cascade-evaporation model.[9]

   A detailed description of the methods used by HETC to treat various physical processes is given in Ref. 3.

5. Restrictions on the Complexity of the Problem: Present dimensions restrict the number of different media to 15 or less and the number of types of nuclei per medium to 11 or less. Virtually arbitrary geometries may be specified.

6. Typical Machine Time: Running time is extremely problem dependent. A sample problem included with the code documentation requires ~10 min on the IBM 360/91 and ~3 times longer on the IBM 360/75.

7. Unusual Features of the Code: Differential cross sections for nucleon-nucleus and pion-nucleus nonelastic collisions are not required as input since they are, in effect, computed in the course of the transport calculation using the intranuclear-cascade-extrapolation-evaporation model.

   Since HET provides a complete description of the low energy ($\lesssim$15 MeV) neutron production, HET may be readily coupled with codes other than 05R (e.g., ANISN,[10] DOT,[11] MORSE[12]) to obtain the low energy neutron transport.

8. Related and Auxiliary Programs: XSECT, an 05R cross-section preparation code, and user-written analysis programs.

9. Status: In use. Several comparisons (e.g., Refs. 3, 13, and 14) between results obtained using HETC and