tabular array of $\sigma_e^m(E,\mu)$ or a set of one-dimensional tabular arrays of Legendre polynomial coefficients. Output is available as a printed listing and as punched card input to Monte Carlo Programs FMC-N and FMC-G.

4D. Restrictions: Number of energy groups ≤ 100
Number of entries of angle variable ≤ 100
Order of Legendre polynomial ≤ 15

5D. Magnetic Tapes Required: 3

6D. Typical Running Time: Data prepared for 3 materials, 19 energy groups, and 10 angle intervals on IBM 7090 in 4.5 minutes.

3E. Nature of Code: Program 20-5 applies the evaporation model of nuclear reactions to determine cumulative probability tables for energy spectra of inelastically scattered neutrons. Output includes a printed listing and punched cards suitable for input to Monte Carlo Program FMC-N.

4E. Restrictions: Number of energy groups ≤ 100
Number of intervals in cumulative probability table ≤ 100

5E. Magnetic Tapes Required: 3

6E. Typical Running Time: Data prepared for 4 materials and 10 energy groups on IBM 7090 in 0.6 minute.

3F. Nature of Code: Program 20-6 computes excitation and transition probabilities for excited states of the residual nucleus from a neutron inelastic-scattering reaction given the relative gamma-ray intensities of the transitions that occur in the process and the energy level structure of the nucleus. Output is of printed form only.

4F. Restrictions: Number of levels ≤ 100

5F. Magnetic Tapes Required: 2

7. Status. All codes are in production use and are available as computer code packages CCC-14 (FMC-G, etc.) and CCC-15 (FMC-N, etc.) from Radiation Shielding Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

8. *References*:

[1]J. J. Loechler and J. E. MacDonald, "Flexible Monte Carlo Programs FMC-N and FMC-G," APEX-706, (July 1961).

[2]J. J. Loechler, "Flexible Monte Carlo Source Generator," XDC 61-4-52, (April 1961).

[3]J. P. Yalch and J. E. MacDonald, "Program 20-2, A Program for Approximating Cross Section Dependence on Energy," GEMP-113, (June 1962).

[4]J. P. Yalch and J. E. MacDonald, "Program 20-4, A Program for Averaging Differential Scattering Cross Sections," GEMP-115, (June 1962).

[5]J. P. Yalch and J. E. MacDonald, "Program 20-5, A Program for Preparation of Spectrum Tables from Evaporation Model," GEMP-116, (June, 1962).

[6]J. P. Yalch and J. E. MacDonald, "Program 20-6, A Program for Computing Nuclear Excitation and Transition Probabilities from Measured Gamma Ray Intensities," GEMP-117, (June 1962).

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1. Code Name and Programming System:
   A. Monte Carlo Program 18-0 (NMPO No. 349) - FAP
   B. Source Generator Program 20-0 (NMPO No. 398) - FAP
   C. Nuclear Data Program 20-2 (NMPO No. 481) - FORTRAN II
   D. Nuclear Data Program 20-3 (NMPO No. 482) - FORTRAN II
   E. Nuclear Data Program 20-4 (NMPO No. 483) - FORTRAN II
   F. Nuclear Data Program 20-5 (NMPO No. 484) - FORTRAN II
   G. Nuclear Data Program 20-6 (NMPO No. 485) - FORTRAN II
   H. Shield-Region Data Converter Program 20-7 (NMPO No. 486) - FAP
   I. Particle Tape-Analyzer Program 20-8 (NMPO No. 487) - FORTRAN II/FAP
2. Computer: IBM 7090 and 7094—32-K core memory

3A. Nature of Code: Program 18-0 applies Monte Carlo methods to simulate neutron and gamma-ray histories in reactor-shield assemblies. The program is specialized to provide: energy deposition in each shield region due to certain neutron and gamma ray reactions; energy-angle leakage distribution for neutrons and gamma rays for a point source equivalent to the assembly, or, optionally, a tape record of the parameters of es-

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caping particles. Parameters of generated secondary particles may form part of the output.

A shield-region geometry routine is used for source and shield regions that can be approximated by contiguous homogeneous regions that are formed by rotation of a class of simply connected quadrilaterals about the reactor-shield assembly axis. A reactor geometry subroutine is provided for approximate analysis of reactors with off-axis cylindrical fuel cells.

Importance sampling techniques of splitting and Russian roulette on energy and region for neutrons and on region for gamma rays are optionally allowed.

4A. Restrictions: Number of regions $\leq$ 300
Number of neutron energy groups $\leq$ 25
Number of gamma-ray energy groups $\leq$ 100

5A. Magnetic Tapes Required: 7

6A. Typical Running Time: Approximately 3.6 minutes on IBM 7090 for 5000 histories, with splitting on region, of 3-4 MeV gamma rays in 48 regions of fast-spectrum refractory-metal reactor.

3B. Nature of Code: Program 20-0 generates and writes on tape the source-particle parameters to be used as input for Monte Carlo Program 18-0.

Source particles are generated in source tubes defined by right circular cylinders with mutually parallel axes of symmetry. A point source and treatment of an entire reactor as a single source tube can also be handled.

Source-particle spatial coordinates are chosen from appropriate source-density distributions by one of two methods: a random method based on uniformly distributed random numbers, and a systematic method that determines the number of source particles to be started from specified volume elements. The systematic method is the only method that can be used for the special case of a single source tube. The energy of each source particle is chosen by a random method from an energy spectral distribution that is space independent.

5B. Magnetic Tapes Required: 3

6B. Typical Running Time: Source tape for 55 000 gamma rays, 11 energy groups, and 3 radial distributions prepared on IBM 7090 in 3.4 minutes.

3C. Nature of Code: Program 20-2 approximates cross-section dependence on energy by discontinuous straight line segments across specified energy groups. Output is available on punched cards suitable for input to Monte Carlo Program 18-0. A printed listing is also prepared.

4C. Restrictions: Number of energy groups $\leq$100
Number of materials $\leq$ 20

5C. Magnetic Tapes Required: 3

6C. Typical Running Time: Neutron cross sections prepared for 11 materials and 19 energy groups on IBM 7090 in 12 minutes.

3D. Nature of Code: Program 20-3 computes the total macroscopic cross section and collision probabilities for a material composition given the densities, atomic weights, volume fractions and the microscopic cross sections of all constituent materials. In addition to the usual printed output, output is available on punched cards suitable for input to Monte Carlo Program 18-0.

4D. Restrictions: Number of materials $\leq$ 20
Number of collision types $\leq$ 6
Number of energy groups $\leq$100

5D. Magnetic Tapes Required: 3

6D. Typical Running Time: Neutron cross sections prepared for 7 compositions and 19 energy groups on IBM 7090 in 0.66 minutes.

3E. Nature of Code: Program 20-4 averages input differential-scattering cross sections over specified energy groups to obtain angular distribution data in the form of cumulative probability tables suitable for use in Monte Carlo Program 18-0. Differential-scattering cross-section input data can be either in the form of a two-dimensional tabular array of $\sigma_e^m(E,\mu)$ or a set of one-dimensional tabular arrays of Legendre polynomial coefficients. Output is available as a printed listing and as punched card input to Monte Carlo Program 18-0.

4E. Restrictions: Number of energy groups $\leq$ 100
Number of entries of angle variable $\leq$ 100
Order of Legendre polynomial $\leq$ 15

5E. Magnetic Tapes Required: 3

6E. Typical Running Time: Data prepared for 3 materials, 19 energy groups, and 10 angle intervals on IBM 7090 in 4.5 minutes.

3F. Nature of Code: Program 20-5 applies the evaporation model of nuclear reactions to determine cumulative probability tables for energy spectra of inelastically scattered neutrons. Output includes a printed listing and punched cards suitable for input to Monte Carlo Program 18-0.

4F. Restrictions: Number of energy groups $\leq$ 100
Number of intervals in cumulative probability table $\leq$ 100

5F. Magnetic Tapes Required: 3

6F. Typical Running Time: Data prepared for 4 materials and 10 energy groups on IBM 7090 in 0.6 minute.

3G. Nature of Code: Program 20-6 computes excitation and transition probabilities for excited states of the residual nucleus from a neutron inelastic-scattering reaction given the relative gamma-ray intensities of the transitions that occur in the process and the energy level structure of the nucleus. Output is of printed form only.

4G. Restrictions: Number of levels ≤ 100

5G. Magnetic Tapes Required: 2

3H. Nature of Code: Program 20-7 prepares data necessary to describe a shield configuration in the form of binary cards for direct insertion in a Monte Carlo Program 18-0 binary deck. Program 18-0 requires extensive and somewhat redundant information about a shield configuration in order to operate efficiently. Approximately 45% fewer input data are required in Program 20-7 for description of the same configuration, and the data are considerably less complex. Output contains printed listings of the volumes of the shield regions and comparisons of the coordinates included in the input with the adjusted coordinates used in setting up the data. The program also searches for errors in the input.

4H. Restrictions: Number of regions ≤ 300
Number of intersection points ≤ 602
Number of current count boundaries ≤ 100
Number of exterior boundaries ≤ 50
Number of boundaries colinear with axis ≤ 25

5H. Magnetic Tapes Required: 3

3I. Nature of Code: Program 20-8 interprets and analyzes Monte Carlo Program 18-0 source- and escape-particle tapes. A Program 20-0 source-particle output tape is interrogated to determine the number of neutrons or gamma rays generated in specified source volume elements and source spectrum-energy intervals. The expected and actual number of neutrons or gamma rays in each volume element and energy interval are compared. A Program 18-0 output escape tape is interrogated to determine the number of neutrons or gamma rays leaving the reactor-shield assembly through specified surface area elements with energy and direction in specified energy-angle increments. Energy-angle distributions for the leaking radiation are then computed from these data.

4I. Restrictions: Number of energy groups ≤ 50
Number of perimeter line segments ≤ 50
Number of intervals in polar-angle mesh ≤ 50
Number of intervals in azimuthal-angle mesh ≤ 50

5I. Magnetic Tapes Required: 3

6I. Typical Running Time: Interrogated tape of 20 000 source-particle parameters on IBM 7090 in 2 minutes.

7. Status: All codes are in production use and are available as computer code package CCC-16 from Radiation Shielding Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

8. *References:*

[1]J. E. MacDonald, J. T. Martin and J. P. Yalch, "Specialized Reactor-Shield Monte Carlo Program 18-0," GEMP-102, (October 1962).

[2]J. E. MacDonald and J. T. Martin, "Shielding Computer Program 20-0," APEX-610, (August 1961).

[3]J. P. Yalch and J. E. MacDonald, "Program 20-2, A Program for Approximating Cross Section Dependence on Energy," GEMP-113, (June 1962).

[4]J. P. Yalch and J. E. MacDonald, "Program 20-3, A Program for Computation of Total Macroscopic Cross Section and Collision Probabilities for Specified Material Composition," GEMP-114, (June 1962).

[5]J. P. Yalch and J. E. MacDonald, "Program 20-4, A Program for Averaging Differential Scattering Cross Sections," GEMP-115, (June 1962).

[6]J. P. Yalch and J. E. MacDonald, "Program 20-5, A Program for Preparation of Spectrum Tables from Evaporation Model," GEMP-116, (June 1962).

[7]J. P. Yalch and J. E. MacDonald, "Program 20-6, A Program for Computing Nuclear Excitation and Transition Probabilities from Measured Gamma Ray Intensities," GEMP-117, (June 1962).

[8]J. M. Martin, "Shield Region Data Converter Program 20-7," APEX-605, (August 1961).

[9]J. P. Yalch and J. E. MacDonald, "Program 20-8, A Program for Interpreting Program 18-0 Source and Escape Particle Tapes," GEMP-123, (July 1962).

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