5. Restrictions on the Complexity of the Problem: 5 Annular Regions. Neutron injection in proportion to slowing down power and assuming $1/E$ spectrum above maximum energy considered in the problem. Resonance integrals are calculated from reaction rates using constant slowing down power in each energy group. Resonances of structural and coolant materials are ignored.

6. Typical Running Time: The running time depends on the number of histories run, the atomic weight of the principal moderator nuclide, the number of resonance nuclides in the lattice and the number of resonances above and below the neutron energy used in the cross-section calculation. For a slightly enriched uranium-rod light-water-moderated lattice and using two resonance pairs spanning the neutron energy ~10 min CDC-6600 time are required for 10 000 histories.

7. Unusual Features of Program: Unresolved resonance routine uses a different resonance ladder in each history. s and p wave resonances can be included.

8. Related and Auxiliary Programs: Extends the REPETITIOUS code, brings it in line with ENDF/B procedures, uses Fortran IV.

9. Machine Requirements: 36K storage. One library tape.

10. Operating System or Monitor Under Which Program is Executed: CDC-6600 SCOPE 3.

11. Any Other Programming or Operating Information or Restrictions: Adaptation to IBM 360/65 available.

12. Material Available: Magnetic Tape (BCD Card Images) Source Deck, Library Deck, Reference Reports BNL-13851.

13. Category: Resonance Absorption of Neutrons.

14. Acknowledgment: This work was performed under the auspices of the U.S. Atomic Energy Commission.

15. *References:*

W. ROTHENSTEIN, Monte Carlo Code for the Calculation of Resonance Reaction Rates and Effective Resonance Integrals Based on ENDF/B Data (REPCDC) -BNL-13851, Brookhaven National Laboratory (July 1969).

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LAPH

1. Name of Code: LAPH, Multigroup Photon Production Matrix and Source Vector Code for ENDF/B.
Auxiliary Routines: CHECKER, Format Syntax Checking Code for ENDF/B. PHOX, "Physics" Checking Code for Photon Production Data in ENDF/B. ETOL, A Code to Prepare an Input Tape for LAPH from One or More ENDF/B Data Tapes.

2. Coding Language and Computer: FORTRAN IV; CDC 6600.

3. Nature of Problem Solved: LAPH retrieves photon production cross sections or multiplicities and corresponding neutron interaction cross sections from the ENDF/B data file, applies suitable weighting functions over N specified neutron broad groups and G specified photon groups, and constructs a $G \times N$ photon production matrix. As an option, it operates on this matrix with flux vectors from a neutronics code, as well as with scalar multipliers such as atom number densities and effective photon group energies, to directly provide spatially dependent photon source vectors (number or energy) for transport calculations. Multiple zones can be accommodated, with separate cross-section weighting functions for each zone. Input is in the DTF-IV format and source vector output is also in this format, allowing direct coupling to DTF-IV. Complete freedom is allowed to pick those materials and reaction types for which photon production matrices are desired.

4. Method of Solution: LAPH first constructs photon production cross sections, pointwise in neutron and photon energy, from the ENDF/B data. These cross sections are then integrated over photon energy groups with either constant or direct energy weighting. After integrating over neutron energy in all neutron fine groups, weighting in neutron broad groups is by input fine-group weighting functions, usually the scalar fluxes from a fine-group neutronics calculation. At LASL, the MC^2 code has been modified to provide the weighting functions in the LAPH input format. Macroscopic photon production matrices and photon energy production matrices are then computed by scalar multiplication. Photon source vectors are computed by operating on these matrices with spatially dependent neutron flux vectors.

5. Restrictions or Limitations: The microscopic pointwise data must be in ENDF/B format. The code is presently restricted to 99 fine or broad groups, 49 photon groups, and 50 mixture specifications.

6. Typical Running Time: The central processor time for a sample problem with 3 regions, 6 materials, 10 mesh points, 26 neutron groups, and 11 photon groups, including calculation of both photon production matrices and source vectors, was 6 min.

7. Computer Hardware Requirements: (a) CDC 6600: 65 k_{10} words of memory; (b) One magnetic tape—the ENDF/B data tape is designated as tape 2. All other tapes are virtual tapes on disk.

8. Computer Software Requirements: The code runs under the SCOPE 3.2 System for the CDC 6600.

9. Contents of Code Package: The package contains the following items:

   a. the reference document

   b. a reel of magnetic tape with the following files:

      (1) a card-image copy of the BCD source deck

      (2) the sample problem input in BCD card image

      (3) the sample problem output in BCD card image

   c. a reel of magnetic tape with the ENDF/B data for the sample problem. This tape is the output tape from an ETOL run.

10. How to Obtain Package: Inquiries or requests for the code package may be mailed to

    CODES COORDINATOR
    Radiation Shielding Information Center
    Oak Ridge National Laboratory
    Post Office Box X
    Oak Ridge, Tennessee 37830

    or telephoned to

    Area Code 615, 483-8611, Extension 3-6944, or to FTS 615-483-6944

    Persons requesting the package should send two reels of magnetic tape to the above address.

11. *Reference:*
    DONALD J. DUDZIAK, ALAN H. MARSHALL, and ROBERT E. SEAMON, "LAPH, A Multigroup Photon Production Matrix and Source Vector Code for ENDF/B," LA-4337, Los Alamos Scientific Laboratory (1969).

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REFLOS

1. Name of Program: REFLOS.
2. Computer for Which Program is Designed and Programming Language Used: IBM 360/65 in FORTRAN IV.
3. Nature of Problem Solved: REFLOS is a code for the evaluation of fuel-loading schemes in heavy water-moderated reactors. It consists of a sequence of subroutines which treat the individual problems involved in such a study:

   a. ORACLE 1 executes the burnup calculations for the reactor cell.

   b. The reactor code evaluates reactivity and power distribution of the reactors. This code has been split in PREVOL and TREVOL. PREVOL executes the fuel-independent part of the calculations of the reactor code, while TREVOL treats the dependence on the nuclear-fuel properties.

   c. STATUS contains TREVOL and, moreover, defines the neutronic state of the reactor core and governs the operations referring to the fuel management. Among other things, the burnup attainable in the fuel management investigated is obtained.

   d. COST evaluates mass flows of heavy atoms through the reactor and fuel-cycle costs for the running-in, the equilibrium, and the shut down of a power reactor.

   If the subroutine for treating the reactor cell were replaced by a suitable routine, other reactors with weakly absorbing moderators could be analyzed.

4. Method of Solution: Nuclear constants and isotopic compositions of the different fuels in the reactor are calculated by the cell burnup code and tabulated as functions of the burnup rate (MWd/t). Starting from a known state of the reactor, the three-dimensional heterogeneous reactor code (applying an extension of the technique of Feinberg and Galanin) calculates reactivity and neutron flux distribution using one thermal- and one or two fast-neutron groups. After a given irradiation time, the new state of the reactor is determined, and new nuclear constants are assigned to the various defined locations in the reactor. Reloading of fuel may occur if the prescribed life of the reactor is reached or if the effective multiplication factor or the power form factor, defined as the ratio of mean to maximum specific power within the core, falls below a specified level. The scheme of reloading to be carried out is specified by a load vector, giving the number of channels to be discharged during a single reloading event and the kind of movement of fuel from one to another channel.
5. Restriction on Complexity:

   a. ORACLE 1:

   - The only moderator considered is heavy water.

   - Xenon is assumed to be in equilibrium during the burnup process.

   b. Reactor code:

   - Maximum number of groups of channels having rotation symmetry: 60.

   - Maximum number of groups of channels having specular symmetry: 120.

   - Maximum number of harmonics for the approximation of the axial flux distribution: 19.

   - Highest order of Bessel functions for the approximation of the radial flux distribution: 12.

   - Maximum number of axial pieces of a channel with possibly different neutronic properties: 20.

   - Maximum number of neutron groups: two fast, one thermal.

   - Reflector and moderator must have the same macroscopic neutron cross-sections.

   c. STATUS:

   - Maximum number of different types of channels in the reactor: 10.

   - Maximum number of burnup steps characterizing one type of channel: 50.

   - Spatial Xe- and temperature-distributions within the reactor core are not considered.

   - In the management decision processes (which determine the time when a reloading event must happen), only the operation time of the reactor, the reactivity and/or the power form factor are foreseen.

   - No automatic fuel management (a search for a suitable way of reloading of the fuel by the code itself in order to approach the requirements as, e.g., for a power distribution as flat as possible) are programmed. The kind of reloading must be prescribed by means of the load vector.