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.

- Fuel may be moved only in the radial direction with no axial changes; refueling must be for the full height of one group of channels.

d. COST:

- The running-out period, during which the refueling shall prepare for shut-down of the reactor, is taken by the code to be a normal cycle of the equilibrium period at the most (assuming that the so-called equilibrium period of the reactor consists of a certain number of cycles where each cycle reproduces the same state of the reactor as the previous cycle).

6. Typical Running Time on IBM 360/65:

a. ORACLE 1: ~2 min for one type of fuel channel.

b. PREVOL: ~3 min for 60 channels.

c. STATUS: time per calculation for one state of the reactor is equal to $0.45 \frac{(\text{channels})^2}{60^2}$ min.

d. COST: ~3 min.

7. Unusual Features of the Program:

a. The channels of the reactor are treated as line sources and line sinks for neutrons. Thus, their finite size is not taken into account. As a consequence, the channels must not be too large nor too closely packed within the moderator.

b. The code does not take into account the condition that the fast flux vanishes at the extrapolated boundary of the radial reflector. The error thereby introduced is negligible if the radial reflector does not become smaller than $4\sqrt{\tau}$, where τ is the slowing down area of the moderator.

c. The slowing down properties of the materials within the channel are not treated separately but must be included in a suitable way by modifying the slowing down properties of the moderator.

8. Status: The program has been in productive use since February 1969, and may be obtained from the ENEA computer program library ISPRA (Varese), Italy. It is classified there under number E 262.

Extensions of the code to treat spatial temperature- and Xe-distribution, axial shuffling, and automatic fuel management are under way.

9. Machine Requirements: 5 I/0 devices.

10. Operating System: IBM OS 360.

11. Material Available: FORTRAN deck, binary deck, library, test problem and test problem results.

12. *Acknowledgments:* Work performed under contract with the firm GAAA (France) and in collaboration with the TCR of the CCR-EURATOM, Ispra.

13. *Reference:*

[1]W. BOETTCHER, E. SCHMIDT, "REFLOS, a Code for the Refined Evaluation of Fuel-Loading Schemes," EUR 4250 e, CCR-EURATOM, Ispra (1969).

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