3. Nature of problem solved: The KATE-1 program determines the spectrum of thermal neutrons according to the Wigner-Wilkins theory and averages cross sections and related quantities over this spectrum.
4. Restrictions on the complexity of the problem: This program is intended to operate within the BKS System.
5. Typical running time: 3 sec
6. Present status: In use
7. *References:* H. J. Amster and J. B. Callaghan, KATE-1—A program for calculating Wigner-Wilkins and Maxwellian averaged thermal constants on the Philco-2000. WAPD-TM-232 (October 1960).
   R. B. Smith and C. H. Hunter, The BKS system for the Philco-2000. computer. WAPD-TM-233 (April 1961).
8. Material available from Philco:
   Binary program deck
   Symbolic program tape
   Referenced documents

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PDQ-4

1. Name of program PDQ-4
2. Computer for which program is designed: Philco-2000 Programming system: TAC
3. Nature of problem solved: PDQ-4 solves the few-group, time-independent, neutron-diffusion equations over a rectangular region of the x-y or r-z plane. Either a zero flux or a zero gradient condition may be applied along each external boundary and a 180° rotational symmetry condition may be applied along the top boundary. In addition, a logarithmic derivative condition may be applied at internal boundaries for control rod description.
4. Method of solution: A nonuniform mesh is imposed on the region of solution, with mesh intervals chosen so that all region interfaces coincide with mesh lines. The differential equations are replaced by five-point difference equations at the mesh points, and the resulting matrix equation for each group is solved by a successive two-line overrelaxation iteration technique. The convergence of the source iterations is accelerated by a procedure based on Chebyshev polynomials.
5. Restrictions on the complexity of the problem: Limited to four groups, 255 compositions, 200 mesh points in each coordinate direction, and a total of 20,000 mesh points. This program is intended to operate within the BKS System.
6. Typical running time: Running time is a function of many variables. Convergence occurs when $\lambda_{max} - \lambda_{min} < 2\lambda\epsilon^2$ where λ_{max} and λ_{min} are the maximum and minimum pointwise values of the eigenvalue and ϵ is an input quantity. Typically, $\epsilon = 0.05$. On a model 211 computer with 2 or more assembler units, using $\epsilon = 0.05$, the time in minutes is approximately (groups) × (points)/400. Some four-group 20,000-point problems have been observed to run as long as five hours.
7. Present status: In use
8. *References:* W. R. Cadwell, PDQ-4—A program for the solution of the neutron-diffusion equations in two dimensions on the Philco-2000. WAPD-TM-230 (June 1961).
   W. R. Cadwell and H. P. Henderson, Input preparation for diffusion-depletion programs on the Philco-2000 computer. WAPD-TM-238 (January 1961).
   R. B. Smith and C. H. Hunter, The BKS System for the Philco-2000 computer. WAPD-TM-233 (April 1961).
9. Material available from Philco:
   Binary program deck
   Symbolic program tape
   Referenced documents

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TURBO

1. Name of program: TURBO
2. Computer for which program is designed: Philco-2000 Programming system: TAC
3. Nature of problem solved: This two-dimensional few-group nuclear depletion calculation is composed of four sections plus input and output as follows. Macroscopic cross sections required in the few-group diffusion equations are computed from nonuniform isotopic number densities of the materials present and few-group fitted microscopic cross sections. The resulting two-dimensional diffusion equations are solved in xy or rz geometry for the neutron flux and eigenvalue. A power shape is generated and used to normalize the flux to a specified power output. The first-order ordinary differential equations describing the buildup and depletion of isotopic number densities are solved over an interval of time in which the flux shapes can be considered constant. The entire process is repeated to continue further in time.
4. Method of solution: The PDQ-4 spatial calculation is used to approximate the eigenvalue and fluxes by solving standard 5-point difference equations used to represent the diffusion equations in a rectangular region of the plane. Zero flux or normal derivative conditions can be applied along the outer boundaries or a 180-deg periodic boundary condition can be applied along one edge. Provision is included for special calculations in which the usual symmetry is temporarily lost, such as stuck rod problems. In solving the depletion equations quadratic approximations are used for the fuel isotope equations while higher order procedures are used for the burnable poisons and fission products. During a time-step, partial account can be taken of the effect of fuel depletion on the power by renormalizing the thermal flux at specified times to maintain constant power assuming the fast fluxes to remain constant.
5. Basic physics approximations in the problem formulation: Thirteen time-dependent isotopes are allowed including U^{235}, U^{236}, U^{238}, Pu^{239}, Pu^{240}, Pu^{241}, Pm^{149}, Sm^{149}, I^{135}, Xe^{135}, B^{10}, and two gross fission products. If U^{238} is absent, four isotopes of hafnium can be studied, namely, Hf^{177} through Hf^{180}.

Two cross section fitting procedures may be used. In one, fitted cross sections are provided for each isotope which are independent of position but may be changed at any time in life. Thermal self-shieding factors can be specified for each isotope taking on different values for various subregions. A correction is made to the epithermal absorption and removal cross sections to account for the U^{238} (Hf^{177}) resonances. A second procedure allows the fast cross sections of U^{235} and the isotopes in the U^{238} (Hf^{177}) chain to be fitted as the inverse of a bilinear function in the isotopic densities of U^{235} and U^{238} (Hf^{177}). Assuming that the "mixed number density" scheme is used in the thermal group, the cross sections of U^{238} (Hf^{177}), Xe^{135}, and Sm^{149} are fitted as linear functions of the density of U^{235}. In either of the schemes, explicit treatment of B^{10} plates is included by use of fictitious diffusion and absorption cross sections fitted as polynomials in the B^{10} density. Variable self-shielding factors are allowed for U^{235} and B^{10} fitted as the inverse of a linear function in the fraction of the isotope remaining at the various points in the mesh.

Maximum or maneuvering xenon calculations may be performed at various times in the calculation.

Provision is included for the study of fuel replacement. The *xy* version is also designed to provide the flux-weighted macroscopic data required to do the flux synthesis by the ZIP program.

6. Restrictions on the complexity of the problem: No more than 178 mesh subdivisions may be used along the horizontal axis or 201 mesh divisions along the vertical axis with a limit of 20,000 on the product of the two. A maximum of 150 material compositions or subregions of interest can be defined and 2, 3, or 4 lethargy groups can be used. Input is compatible with the other diffusion theory programs on the Philco-2000 computer such as WANDA-5, PDQ-4, CANDLE, etc. The program is intended to operate within the BKS System.
7. Typical running time: The typical running time for one time step is greater than that of the corresponding PDQ-4 problem by a factor of one-third.
8. Present status: In use
9. *References:* O. J. Marlowe, Nuclear reactor depletion programs for the Philco-2000 computer. WAPD-TM-221 (January 1961).
   R. B. Smith and C. H. Hunter, The BKS system for the Philco-2000 computer. WAPD-TM-233 (April 1961).
   W. R. Cadwell and H. P. Henderson, Input preparation for diffusion-depletion programs on the Philco-2000 computer. WAPD-TM-238 (January 1961).
   W. R. Cadwell, PDQ-4—A program for the solution of the neutron-diffusion equations in two dimensions on the Philco-2000. WAPD-TM-230 (June 1961).
   C. J. Pfeifer and F. R. Urbanus, ZIP-2—A one-dimensional few-group synthesis nuclear reactor depletion program for the Philco-2000 computer. WAPD-TM-228 (November 1961).
10. Material available from Philco:
    Binary program deck
    Symbolic program tape
    Referenced documents

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WANDA-5

1. Name of program: WANDA-5
2. Computer for which program is designed: Philco-2000
   Programming system: TAC
3. Nature of problem solved: Numerical solution of the one-dimensional few-group neutron diffusion equations. One to eight energy groups may be used and rectangular, cylindrical, or spherical geometry formulations are available. The flux or its derivative may be set to zero at the boundaries. The program will vary buckling or poison cross section in any subset of regions, or the position of one or more interfaces separating regions to find a specified critical eigenvalue. One iteration or fixed source problems may be calculated and adjoint solutions may be obtained. All one-group problems are treated as one iteration problems.
4. Method of solution: The diffusion equations are replaced by difference equations giving rise to a tridiagonal matrix inverted by Gauss elimination. Extrapolation procedures are incorporated in the source calculation to accelerate convergence.
5. Restrictions on the complexity of the problem: Limited to 500 points, 100 regions, eight groups, and 2000 group-points. This program is intended to operate within the BKS system.
6. Typical running time: 1 min
7. Present status: In use
8. *References:* O. J. Marlowe and M. C. Suggs, WANDA-5—A one-dimensional neutron diffusion equation program for the Philco-2000 computer. WAPD-TM-241 (November 1960).
   W. R. Cadwell and H. P. Henderson, Input preparation for diffusion-depletion programs on the Philco-2000 computer. WAPD-TM-238 (January 1961).
   R. B. Smith and C. H. Hunter, The BKS system for the Philco-2000 computer. WAPD-TM-233 (April 1961).
9. Material available from Philco:
   Binary program deck
   Symbolic program tape
   Referenced documents

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ZIP-2 and ZIP-3

1. Name of programs: ZIP-2, ZIP-3
2. Computer for which programs are designed: Philco-2000
   Programming system: TAC
3. Nature of problem solved: ZIP-2 and ZIP-3 are diffusion theory synthesis depletion programs for design calculations. The synthesis technique is a method of approximating a solution to the three-dimensional, few-group diffusion theory equations by "stacking" a