CPM-3, A STATE-OF-THE-ART NUCLEAR FUEL LATTICE PHYSICS BURNUP CODE

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ABSTRACT

1. **Program Name and Title:** CPM-3, a nuclear fuel lattice physics burnup code using arbitrary geometry modeling and deterministic transport theory methods.

2. **Computer for Which Program is Designed and Other Machine Versions Available:** CPM-3 has been developed to be portable to any computing platform that supports the Fortran-90 programming language.

3. **Problem Solved:** CPM-3 is a state-of-the-art, two-dimensional lattice physics burnup code that performs neutron flux, gamma-ray flux and eigenvalue calculations for light water reactor nuclear fuel assembly designs.

4. **Method of Solution:** CPM-3 couples nuclear transport theory methods with an arbitrary geometry modeling technique to provide a highly flexible and accurate tool for analyzing light water reactor nuclear fuel assembly lattices. CPM-3 supports a two-dimensional, multi-group nuclear transport theory method based upon the Method of Collision Probabilities. CPM-3 assumes transport-corrected isotropic scattering in its solution methodology. CPM-3 incorporates a sophisticated spatial treatment for the determination of Dancoff correction factors and self-shielding effects in multi-annulus and sectored pin cells. CPM-3's arbitrary geometry modeling capability based upon combinatorial geometry techniques handles fuel assembly lattices of regular and highly irregular geometry designs. CPM-3 also incorporates three isotopic depletion methods to provide very accurate time-dependent calculations for fuel exposure predictions. CPM-3 features a sophisticated energy model that calculates energy factors for seven energy terms. The energy model accounts for all energy produced and deposited in the fuel assembly lattice, including fuel and non-fuel regions. The CPM-3 power distribution model is based upon the true energy deposited in the fuel regions of the fuel assembly lattice. Exact and approximate models are included, depending upon the performance of an optional gamma-ray transport calculation.

5. **Restrictions on the Complexity of the Problem:** Geometry models are restricted to two-dimensions in the Cartesian coordinate system.

6. **Typical Running Time:** Run times are platform dependent. Execution of a depletion timestep of a typical problem on a current generation workstation takes one or two minutes.

7. **Unusual Features of the Program:** CPM-3 provides the following major capabilities:
   - Solves two-dimensional, multi-group nuclear transport theory using the Method of Collision Probabilities.
   - Arbitrary geometry modeling allowing the user to describe fuel assembly models of virtually any mechanical design and to any level of design detail. Linear and curvilinear surfaces are easily represented by the combination of primitive geometry elements that include arbitrary polyhedrons, rectangular parallelepipeds, right circular cylinders and right angle wedges.
   - Performs an arbitrary geometry Dancoff calculation using ray-tracing techniques. Dancoff factors are determined separately for several resonance absorber materials, including fuel materials, burnable absorber materials and burnable poison (control rod) materials. This allows fuel and lumped burnable absorber materials to be arbitrarily positioned anywhere in the fuel assembly lattice.
   - Performs a fundamental mode calculation to account for the effects of neutron leakage. The leakage spectrum data is then available to calculate nuclide reaction rates and to perform isotopic depletion calculations.
   - Provide nuclear data for over 300 nuclides. Nuclear cross section data is provided in 97 energy groups over the energy range 0-10 MeV in the ENDF/B-VI based nuclear data library. Gamma-ray cross section data is provided in 18 energy groups up to 10 MeV.
   - Performs isotopic depletion calculations for fuel and burnable absorber materials. Over 200 nuclides are represented in the fuel depletion chains. Special chains are provided for the gadolinium, hafnium, erbium and silver-indium-cadmium burnable absorbers.
   - User-selectable output edit capability. The user may select parts, regions, compositions and nuclides for which detailed spectra, cross sections, reaction rates and number densities will be edited.
   - Data output supports downstream reactor analysis codes and core simulation programs.

8. **Related and Auxiliary Programs:** CPM-2 is a predecessor code of CPM-3. CPM-3 generates data files for use as input to core simulation codes, such as EPRI's CORETRAN code.

9. **Status:** Current version of CPM-3 is Version 1.0, Release 1999.201, dated July 1999 for the DEC UNIX workstation. CPM-3 is currently in Design Review and is planned for control under 10CFR50 Appendix B criteria.

10. **References:** 1. Dean. Jones, et.al., "CPM-3 Computer Code Manual", EPRI Project WO3418, Revision 0, December 1999.

2. Dean. Jones, et.al., "CPM-2 Computer Code Manual", Part II, Chapter 6, Volumes 1-3, ARMP-02 Documentation, EPRI NP-4574, 1987.

3. I. Carlvik, "A Method for Calculating Collision Probabilities in General Cylindrical Geometry and Applications to Flux Distributions and Dancoff Factors", Proc. Int. Conf. on Peaceful Use of Atomic Energy, 1964, p. 681.

4. M. L. Williams and R. Raharjo, "Space-Dependent Resonance Self-Shielding," Nucl. Sci. & Engr., **126**, 1997, pp. 19-34.

11. **Hardware Requirements:** A UNIX workstation with a minimum of 512 MB of RAM and 2 GB of free hard disk space is recommended.

12. **Programming Languages:** Fortran 90.

13. **Operating System:** UNIX and UNIX-compatible systems, including Linux.

14. **Other Programming or Operating Information or Restrictions:** A single optional C routine is included to retrieve CPU seconds.

15. **Name and Affiliation of Author or Contributor:** Dean B. Jones, TransWare Enterprises Inc., (408) 227-7700.

16. **Material Available:** CPM-3 is available from EPRI. Brochures describing the CPM-3 code and support services are available from TransWare Enterprises Inc.

17. **Category:** A, B, and D

Keywords: Nuclear Transport Theory, Burnup Calculation, Lattice Physics, Arbitrary Geometry, Combinatorial Geometry.

18. **Sponsor:** CPM-3 was developed by TransWare Enterprises Inc. under funding provided by EPRI and a consortium of utilities.