Apros® Datasheet
1D- and 3D-Neutronics models

Apros® Nuclear product includes extensively validated 1D- and 3D-core neutronics models for safety analysis, engineering, and high-fidelity training purposes. The 3D-core neutronic models suite covers nodal, finite difference, and multi-group models. All core neutronic models are fully integrated to Apros® thermal hydraulics, and process models that may cover the entire reactor and turbine island including plant automation and electrical systems.

Neutronics

Apros 1D- and 3D-core neutronics models are based on two-group diffusion theory in homogenised nodes. For the 1D-reactor model the discretization of the basic equations results in a block tri-diagonal matrix equation, which is solved with a sparse matrix solver. The 3D-nodal and finite difference models use mode decomposition or finite difference approximation, respectively, and iterative solvers. The 3D-core neutronics models are applicable to both square (PWR, BWR) and hexagonal (VVER) lattice geometries.

The delayed neutrons are calculated in each cell using six groups. First order discretization for the time derivative is used in the solution of the delayed neutron precursor group concentrations. The burnable poison is included in the reactor parameters. The models include calculation of local iodine, xenon, promethium and samarium concentrations. The concentrations are obtained from the basic equations using first order discretization of the time derivative term. A user selectable speedup factor for the iodine/xenon concentration calculation has been included.

The models also include local decay heat calculations. The history of reactor operation can be considered in the calculation. The decay heat model is based ANSI-standard correlation that includes 23 decay heat precursors for each calculation cell.

The reactor core model takes into account the following reactivity effects: fuel (type and exposure), burnable poison, control rods, fuel temperature, moderator density, void fraction, fission product poisoning (Xenon, Promethium and Samarium) and neutron sources. Many of the feedback effects can be tuned with additional conservativity factors according to safety analysis needs. The control rods are described with cross sections; the control rod tip smoothening is included in the calculation.

Core Thermal Hydraulics

Calculation of fuel rod temperatures, coolant conditions and boric acid concentration is performed within the thermal hydraulic model of Apros® Nuclear. In radial direction a fuel rod consists of an optional central hole, fuel, gap and cladding.

Apros® Nuclear 3D-Core Models

Finite-Difference 3D-Core Model, since early 1990's

- **Safety analyses: VVER-1000, EPR**
- **Training simulator real-time 3D-core: VVER-440**

Nodal 3D-Core Model, since 2012

- **Loviisa 1/2 safety analysis (VVER-440),**
- **Olkiluoto 1/2 safety analysis (BWR)**

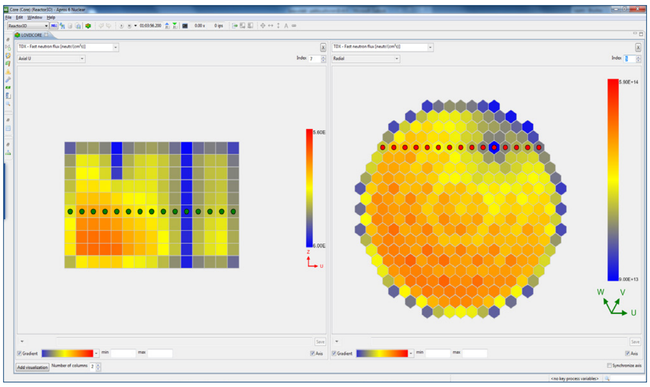
Multi-Group 3D-Core Model, available soon

- **Designed for GEN-IV applications**
- **Validation cases: SFR benchmarks**

Square and hexagonal lattice geometries are supported.

Ask for more details!

The five- and six-equation thermal hydraulics models can be selected in connection of both the 1D- and 3D-core neutronics models. In 3D-core models, the core thermal hydraulics is described with a number of one-dimensional thermal hydraulic flow channels extending from the whole core being described with one channel into each fuel assembly being described with its own channel. Each thermal hydraulic channel has its own thermal hydraulic properties. In addition to thermal hydraulic channels, the 3D-core models consist of fuel assemblies, reflector assemblies and control assemblies.



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Cross-Section Data in Apros® Nuclear

- Cross sections for PWR reactors are presented versus burn-up, for instance from 0 to 60 GWd/tU
- The cross sections are parameterized for VTT in-house code HEXBU-3D with utility programs CAXMAN and CRFIT7
- CAXMAN is a code used for preparation of cross section tables readable with other programs from the CASMO output
- CRFIT7 performs a polynomial fitting to the cross section data around the reference (or nominal) state
- The obtained feedback coefficients describe the dependence of the cross sections on the state parameters
- The cross section data produced with CRFIT7 can be directly used in HEXBU-3D code and with some adjustments in Apros

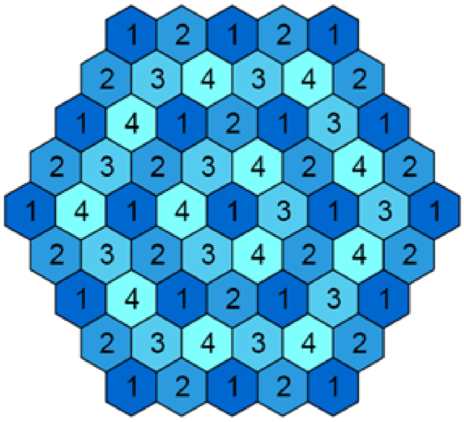
1D-Core Model Configuration

In 1D-core model the basic options available are the selection of the thermal hydraulic model, selection of the core axial division and selection of control rod description (control and scram group, or each control rod separately described). These selections have to be in accordance with the cross-section library with properly condensed data.

3D-Core Model Configuration

In 3D-core model, each assembly and control rod are described separately in most cases. The options available in the core construction are the choice of the thermal hydraulic model and the placement of the fuel assemblies into the thermal hydraulic flow channels (one or several assemblies per channel) and the axial division of the core. These choices depend on the accuracy and speed requirements set to the application. The 3D-core models are applicable to both square (PWR, BWR) and hexagonal (VVER) lattice geometries.

The 3D-core models use the cross-section libraries generated with standard fuel management codes. In three-dimensional finite-difference core model use of macro assemblies with appropriate cross section files is possible, too. Both 1D- and 3D-reactor calculations may include one or more hot channels or hot rods, which are calculated on-line. This feature can be used in sessions involving fuel bundles with partly blocked flow channels.



Process Model Connection

Either 1D- or 3D-reactor model can be directly connected to the nuclear power plant process model covering complete reactor island, turbine island , and balance of plant models. An operator training simulator may include both models: 1D-core model integrated to the process model, and the 3D-core model running parallel to it on a separate processor. This configuration ensures real-time performance without compromising the accuracy of the reactor core calculations.

Nodal 3D-Core Model

Apros® Nuclear 3D-Core Nodal model is based on extensively validated HEXTRAN and TRAB-3D codes developed at VTT. Neutronics is being solved for a mesh of homogenized nodes – each node corresponding typically to one fuel assembly in the radial plane with approx. 20 axial node layers. The 3D-core nodal model includes efficient iteration schemes including implicit methods employed in the time discretization of kinetic equations making the choice of time step very flexible.

Multi-Group Model

Multi-group kinetics model and connections to thermal hydraulics is currently being developed and tested. Material properties of different metallic coolant types has been added to Apros® Nuclear, required for Gen IV applications. Validation with various benchmarks and tests; e.g. SFR, LFR, and Phénix EOL tests.

For more information see brochure Generation IV Features.

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