RFSP Code Development

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Lattice Calculations

- PPV is based on a four-factor eigenvalue treatment, the Westcott formalism for thermal neutron flux spectra, and semi-empirical correlations for treatment of configuration-dependent quantities.
- WIMS-AECL is based on multigroup neutron transport calculations, treating neutronic effects at a fundamental level of detail. Isotopic cross sections are derived from evaluated nuclear data, and the treatment of lattice configurations is general. There are no CANDU-specific adjustments or corelations within WIMS-AECL.

Lattice Calculations

- Lattice-cell parameters from PPV are in a 1.5 energy-group form, while all data produced by WIMS-AECL is in a multigroup form.
- PPV is applicable to CANDU natural uranium lattices, reliable within the range of experimental validation. WIMS-AECL is a general-purpose lattice cell code, validated and applied over a wide range of lattices of which CANDU lattices are a subset. As the methods and data used within WIMS-AECL are common to worldwide state-of-the-art lattice cell calculations, external experience and validation is generally quite relevant.

Lattice Calculations

- PPV is primarily used to calculate CANDU lattice-cell parameters. WIMS-AECL is used for detailed 2-D analysis within lattices, and modelling of other devices besides fuel.
- PPV has only one level of detail in its neutron flux calculation. WIMS-AECL can be used with varying levels of detail and approximation, to address the differing requirements of normal production work and investigations of particular issues.
- PPV solves the neutron transport equation with several levels of approximation, involving considerable semi-empirical approximation. WIMS-AECL uses multigroup transport calculations.

Lattice Calculations

- There is a significant cost associated with going from the empirical approximations embodied in PPV to more explicit analysis methods. This cost is a hundred-fold increase in computation requirements, and is not specific to WIMS-AECL; in fact many modern alternatives to WIMS-AECL are much slower.
- WIMS-AECL is a general-purpose code, not primarily designed for preparing information required for RFSP. All information for application in RFSP is produced by post-processing with utility codes.

Lattice Calculations

- The accurate determination of the neutronic properties of CANDU lattices is the objective of WIMS-AECL model preparation. To do this we need to correctly represent
  - The volumes and configuration of major/significant structures within CANDU lattices, and
  - The neutronic properties of all materials. This includes the absorption properties of all isotopes, fission properties of actinides, and the scattering and moderation properties of materials.

Lattice Calculations

- Material spectral types (fuel, cladding, coolant and moderator) have to be specified properly for WIMS-AECL.
- The mesh in and around the fuel and fuel channels must be specified explicitly.
- WIMS-AECL analyses for CANDU cannot be treated as a 'black box'

Lattice Calculations

- The speed and physical details in PPV made it very simple and practical to use a constant irradiation increment in burnup calculations, typically 0.05 to 0.1 n/kb (5 to 10 day steps).
- The complexity of WIMS-AECL calculations with standard CANDU modelling techniques is much greater than those in PPV, and so using too many transport calculations is not effective (and the change in results normally does not normally justify the extra expense).

Lattice Calculations

- The General Steps Required to Use WIMS-AECL Properties in RFSP are
  - Build a WIMS-AECL model
  - Run WIMS-AECL, producing results on Tape16
  - Post-process results on Tape16, forming a 'fuel table' for use in RFSP
  - Transfer the 'fuel table' into RFSP

Lattice Calculations

- Tape 16 is a specification for a simple record-oriented binary file used to transfer WIMS-AECL results to applications. Each record is structured:

  key1, key2, n, (x(a), a=1,n)

  where key1 is the major key for the record

  key2 is the minor key of the record

  n is the number of words of data in the record

  x(a) is the a^{th} word of data in the record

Lattice Calculations

- **WIMS-AECL is used to generate information used in a wide range of applications, but provides no internal support for any specific application**
- **Tape 16 can be used with a set of modular processing utilities operating sequentially, for a range of applications**
- **Proc16 provides a simple interface for running WIMS-AECL and performing post-processing with a single point of control.**

Lattice Calculations

- Form microscopic cross sections for isotopes of interest, using Microburn. For basic fuel tables, isotopes are normally ^{135}Xe, ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu.
- Condense all data from 33 energy groups as used in WIMS-AECL transport calculations into 2 energy groups as required in RFSP, using Condens.

2-Group Properties

- The diffusion equation coded in RFSP is based on the 1 1/2 energy group convention.
  - Assumes no up-scattering
  - Fast fission is lumped into the thermal group
  - Thermal irradiation is tracked using thermal F factors
  - Reactor power is calculated with a multiplication of the thermal flux distribution by the H factors (power over mesh flux)
- The use of the *POWDERPUF module generates the fuel tables for a set of predefined local and global parameters

2-Group Properties

- Lattice properties are transfered under the FUEL PROPS index in the direct-access file.

- WIMS-AECL lattice properties can be generated and transfered to the direct-access file using a *READ CARD command.
  - The fuel tables can be transfered under the FUEL PROPS index for use in the 1-1/2 energy group convention.
  - The format used in RFSP for the 1-1/2 energy group fuel tables is:
    - 1st line: Name of the Fuel table (10 characters)
    - 2nd line: Number 0, followed by the number of irradiation steps (N)

2-Group Properties

- 3rd line: Irradiation step, followed by
  - N cross-section values for each of the following group
    - Fast transport, thermal transport, thermal absorption, removal, fast absorption, thermal absorption, F factor and H factor.

2-Group Properties

- RFSP was modified to handle the full-two-energy-group convention in the diffusion module.
- WIMS-AECL full-two-energy-group properties can be transfered to the direct-access file and used by RFSP.
  - Full-two-energy-group properties are transfered under the LATPROPS2G index.
  - The format used in RFSP for the 2-energy-group fuel tables is:
    - 1st line: Name of the fuel table (10 characters)
    - 2nd line: Number 0 followed by the number of irradiation steps (N)

2-Group Properties

- 3rd line: Irradiation step, followed by
  - N cross-section values for each of the following group
  - Fast absorption, thermal absorption, downscattering, upscattering, fast transport, thermal transport, fast production, thermal production, F factor, H_1 factor and H_2 factor.

2-Group Properties

- Selection of the 1-1/2 or the 2-energy-group convention used in the diffusion equation is determined with the use of the 2-group trailer card in the *SIMULATE module.
  - Default mode is the 1-1/2-energy-group convention.
- Incremental properties need to be defined in the same energy-group convention.
  - Incremental properties for the 1-1/2-energy-group convention are located in the MOVE PROPS record.

2-Group Properties

- Incremental properties for the full-two-energy-group convention are located in the MOVE PROPS2 record.

- Incremental properties can be calculated in three different manners.
  - The conventional MULTICELL methodology
    - ↑ Diffusion code using Current-to-flux ratios at the interfaces of strong absorbers.
  - Modified MULTICELL
    - ↑ Diffusion code that solves the neitron flux throughout the supercell
      - ↙ Requires the use of Superhomogenisation factors

2-Group Properties

- DRAGON (Developed by Ecole Polytechnique, Montreal)
  - Transport code with capabilities for 3-D modelling of the devices
  - Multi-energy-group library
- Existing 1-1/2-energy-group incremental cross sections are transfered to the 2-energy-group convention usin the *CONV2G module.
  - Sets the upscattering, fast production and H_1 factor to 0.

History-Based Simulations

- 2-group incremental properties are transfered to the direct-access file with the use of a *DATA 2-GROUP card.
- History-based simulations are used to track the fission-product inventory in each bundle
  - PPV-history-based simulations are practicle because the short time required by PPV to generate the lattice properties
  - WIMS-AECL required ~5 s per bundle
    - (5 s X 4560 bundles) X 3 outer loops = 20 h
    - not practicle

History-Based Simulations

- Simple-cell was developed to reproduce WIMS-AECL in a shorter time
  - ~0.05 s per bundle
  - (0.05 s X 4560 bundles) X 3 outer loops = 12 m
- Simple-cell is a called within *SIMULATE and requires the use of fuel tables located under the SCMTABLES index.
  - Simple-cell tables are generated with PROC16 that processes the TAPE16 file from WIMS-AECL.
  - Tables are generated for a specific range of local and global parameters.
  - Tables can be used within the defined range only.

History-Based Simulations

- RFSP was modified to link simple-cell in *SIMULATE
- A one-year core follow showed a standard fit to the vanadium ~2.5%
- *CERBERUS was also modified to allow transient simulations using the properties generated with simple-cell
- Exemple of a simple-cell history-based card:
  - *SIMULATE CANDU 6 0 0.0
    SCMHI ITER 3 \
    NGRO 2 \
    MODT 68.5 \
    EDIT 4

2-Group Modules

- The 2-group convention is being implemented throughout all the modules.
- 2-group convention has been implemented in:
  - *SIMULATE
  - *CERBERUS
  - *CERBRRS
  - *TIMEAVER
  - *INTREP
  - Bulk and Spatial Control

2-Group Modules

- 2-group implementation is being implemented in:
  - *MONIC
  - *ORTHOG
  - *MAPMATRIX
  - *MONIC
  - *INSTANTAN
  - *RIPPLE

Other Developments

- Other developments
  - Parallel Virtual Machine Mode
    - Reduces simple-cell history-based calculations by a factor of 7
    - Would allow the use of WIMS-AECL
  - Graphical Interface
    - View existing models
    - Plot the results
    - Build new models

Industry Standard Tool Set

- The objective of the IST project is to have one validated computer code used for reactor physics analyses of CANDU reactors
- In more details, the objectives are:
  - Qualify RFSP-IST such that
    - Qualify code is available when required
    - Verification demonstartes the tool's correctness and completeness
    - Documentation to assist the use and maintenance of the tool

Industry Standard Tool Set

- Adequate software tool configuration to
  - Protect the integrety of the tool
  - Track the lifecycle of the tool
  - Assist distributed use of the tools
- Merging activity started in 1998 to combine OHRFSP version R1.06 and RFSP version 2-17
- 7 modules from OHRFSP were brought in RFSP
  - *ANALYZE
  - *COLLAPSE
  - *FLUXMAP (OPGN's methodology)

Industry Standard Tool Set

  - *MODES
  - *SYSTEM
  - *UNFOLD
- Coding was added to read in a transparent manner the existing direct-access files from OHRFSP. The RFSP-IST version allows two types of direct-access files
  - OPGN's format
  - AECL's format

Industry Standard Tool Set

- The code will be validated by March 2001
  - A set of validation report listed in the validation plan.
  - A wrap-up document to summarize the results
  - A user's manual
  - Theory manual
  - Software theory design description
  - Software design description
  - Programmer's manual
  - Configuration management document
  - etc

Software Support

- An AECL's Web page has been designed to offer software support to the users
- The Web page is used for
  - On-line documentation
  - Course announcements
  - Bug reports
  - News forum
  - Updates on the qualification program

Software Support

- Used by code developers to store
  - Change requests
  - Change design paln
  - Change Plan Verification and Approval
- Demonstration of the Web page
  - Available only within AECL
    - Looking at the possibility to extend the use outside AECL