Release Notes for RELAP5-3D Version 4.0

Code Improvements from Version 2.4

The following is a brief description of improvements and new features in version 4.0. The associated material in the User Manuals is shown as an underline.

Turbine Specification Cards Modified

Modified Card CCC0400, Turbine Performance Data. Two new words were added (W7 and W8).

W7(R) User-specified control variable number for the multiplier on the user-specified form loss for the junction identified in W8.

W8(I) Junction number.

Modified Card CCC0401, Type-3 Turbine Performance Data. One new word added (W9).

W9(I) User-specified control variable number for the multiplier on the calculated efficiency.

<u>See Vol. 2, Appendix A, Section 7.</u>

Pump Specification Cards Modified

Modified Card CCC0301, Pump Index and Option. Two formats are now allowed. Previous code version only allowed 7 word format.

a) 7 word format – two-phase pump degradation multipliers as a function of void fraction only.

b) 9 word format – two-phase pump degradation multipliers as a function of void fraction and pressure.

Modified Cards CCCXX00 – CCCXX99, Pump Two-Phase Multiplier Tables.

a) Format for two-phase multiplier as a function of void fraction only. W1, W2, W3, repeat W2 and W3 up to 100 pairs.

b) Format for two-phase multiplier as a function of void fraction and pressure.

See Vol. 2, Appendix A, Section 7.

100, 103, and 104 cards modified

The input and output formats for plot files are declared on these cards: machine independent binary, ASCII, and machine dependent binary. Also, the restart format is now always machine dependent binary with no compression option (though the keywords are accepted for backward compatibility).

See Vol. 2, Appendix A, Section 1.

FORTRAN 95 Conversion

- Machine independence via F90/95 intrinsics
- Machine independent plot, strip, fluids files
    - Separation of restart from plot files (the default was formerly rstplt, the default for restart is 'restrt' and for plot is 'plofl')
    - Multiple formats for plot files
- Elimination of many memory restrictions
- Modernize code for longevity considerations
    - Modern language for current-day developers
    - Code easier to read and understand

ANS2005 Decay Heat Standard Added

The ANSI/ANS decay heat standard was revised in 2005. This decay heat standard is now incorporated in RELAP5-3D.

Modified Card 30000002, Fission Product Decay Information

W1(A) Fission product type now allows ANS05-1 and ANS05-4 as acceptable options.

See Vol. 2, Appendix A, Section 15.

Nodal Kinetics Upgrades

Krylov solver is recommended over LSOR

Card 30000003, Nodal Kinetics Control Information

W17(I) Set to 1 for Krylov solver

New features include

- Full steady-state and transient solution (with restart)
- 4 Energy group representation (up- and down-scatter)
- TPEN nodal solution
  - Slower, but higher accuracy over NEM
  - Useful for problems with steep flux gradients
- GMRES solver added as compliment to BiCGSTAB
  - Better performance for poorly-conditioned linear systems
- Rod Decusping Logic (TPEN only)
- Reactivity feedback edits

See Vol. 2, Appendix A, Section 15.

Time-step Inconsistency Correction

A new integer time-stepping algorithm was implemented in the RELAP5-3D code. This corrected many time-step inconsistencies in calculations.

Sound Speed Calculation Correction

RELAP5-3D code now has junction sound speed calculation method with noncondensables present consistent with volume sound speed calculation method with noncondensables present. The old calculation method is available with Card 1 Option 3.

See Vol. 2, Appendix A, Section 2.

Implementation of Viscous Effects

Some turbulent effects can be modeled using the MULTID component.

Controlled by Card 1 Option 31

PVM Coupling Junction

Created to eliminate the unused "from-volume" in PVM coupling problems and to reduce input.

See Vol. 2, Appendix A, Section 7.

New Fluids DowThermA, Pb, r134a, and vertrel

Fluids DowThermA, Pb, r134a, and vertrel were added to the list of available fluids.

See Vol. 2, Appendix A, Section 2.

MetaStable Extrapolation at Constant Temperature

Mass error can result in a bad liquid density extrapolation at constant pressure. Capability to extrapolate at constant temperature was added.

This capability is accessed with Card 1 Option 71.

See Vol. 2, Appendix A, Section 2.

Mass Error Edits

Various mass error edits were added for

- Total (liquid plus vapor)
- Liquid
- Vapor (includes the noncondensables)

- Noncondensables
- Boron

See Vol. 2, Appendix A, Section 4 for a listing of the new error edits.

Groeneveld CHF table fix

The Groeneveld CHF table was found to have erroneous values entered when compared with the original document. These errors were corrected in this version of the code.

Alternate Heat Structure – Fluid Coupling Model

Uses estimate of average temperature in the volume for heat flux computation. It is restricted to single phase vapor/gas conditions.

Card 1CCCG501 – 1CCCG599 and/or 1CCCG601 – 1CCCG699, Left and Right Boundary Condition.

W3(I) 5xxx

Allowed values of xxx are 001 and 1nn where values of 1nn are shown in Table 8.12-1 See Vol. 2, Appendix A, Section 8.

2D Conduction Model

The 2D conduction model is part of the reflood model – and uses the ADI technique. The model uses a fixed fine mesh model with 2 subdivisions per heat structure.

Card 1CCCG000, General Heat Structure Data

W6(I) Set to 3 for the 2D conduction model

See Vol. 2, Appendix A, Section 8.

Updates for Low Speed Flow

The current solution to the momentum equation is not accurate at low fluid velocities.

Specifically, the code currently limits the Reynolds number to 50 for the calculation of wall drag and the user-input form loss coefficient. The pressure drop associated with the input loss coefficient is not accurate when the junction velocity approaches 0.01 m/s. Also, the code limits the absolute value of the total pressure drop to 0.00004 Pa to limit spin up problems, which is not accurate for low flows in horizontal pipes. Updates were added to allow the user to obtain a more accurate solution to the momentum equation at low flows. With these updates, the minimum Reynolds number is set to 0.01, the minimum junction velocity used in the form loss pressure drop calculation is 1.0e-8 m/s, and no minimum is used for the absolute value of the pressure drop.

This capability is accessed with Card 1 Option 29.

See Vol. 2, Appendix A, Section 2.

Elimination of Volume Upper Limit for 3D Component

3D components were previously limited to 999 volumes for size concerns. This upper limit has been removed allowing for the possibility of using 88,209 volumes in 3D components.

Added Capability of Modeling a Heat Flux Boundary Condition with a Control Variable

The capability to model a heat flux boundary condition type with a control variable was added.

Card 1CCCG501 – 1CCCG599 and/or 1CCCG601 – 1CCCG699, Left and Right Boundary Condition.

W3(I)   -2xxxx

Allowed values of xxxx are between 1 and 9999 corresponding to the control variable number to be used to model the heat flux boundary condition.

See Vol. 2, Appendix A, Section 8.

Godunov Boron Tracking Model Corrected

An error in the Godunov Boron Tracking Model (Card 1 Option 23) was identified and corrected.

See Vol. 2, Appendix A, Section 2.

Alternate Steam Tables Added for h2o, h2on, h2o95 and na

Alternate steam tables were created for the light water fluid, h2o, based on the accuracy based method. Corresponding steam tables were also created for the other light water fluids, h2on, and h2o95.

An alternate property table for sodium was also created based on correlations from Argonne National Laboratory.

These alternate fluid properties for h2o, h2on, and h2o95 are now the default. The previous h2o fluid properties are included as tpfh2o2, tpfh2on2, and tpfh2o952. The sodium property table is unchanged, however the alternate property table is available to use as tpfna2.

Capability to Couple RELAP5-3D to STAR-CCM

Updates were added to RELAP5-3D to allow it to couple with CFD software STAR-CCM via a new STAR-CCM coupling methodology that does not use the PVM Executive.

Capability to Couple RELAP5-3D to PHISICS

Updates were added to RELAP5-3D to allow it to couple with reactor physics software PHISICS.

Kinetics Time-Step Control

This update implements an asynchronous advancement methodology, which allows the kinetics solution to advance independently of the thermal-hydraulics advancement.

Card 2200, Kinetics Time Step Control.

W1(I)   Kinetics time step control option.

W2(I) Kinetics time step format.

W3(I) Trip unit for locking time steps.

W4(I) Trip unit for unlocking time steps.

W5(I) Control variable unit number returning time step size.

W6(I) Flux extrapolation option.

W7(I) Time step data print flag.

Card 2201 – 2299, Kinetics Time Step Data.

W1(R) Kinetics end time for this set(s).

W2(R) Target kinetics time step size(s) or ratio (-).

See Vol. 2, Appendix A, Section 3.

Enhanced Flexibility of the Metal-Water Reaction Model

The metal-water reaction model can now be used with rectangular and spherical heat structures. In addition, various parameters can be user-input to allow the modeling of other metals (in addition to zirconium).

Card 1CCCG003, Metal-Water Reaction Control

W2(R) Cladding material density (kg/m^3).

W3(R) Activation Energy (cal/mole).

W4(R) Reaction rate constant (variable K) (m^2/s).

W5(R) Reaction heat release (J/kg-mole).

W6(R) Cladding material molecular weight (kg/kg-mole).

W7(R) Molecular weight of reaction product divided by Word 6.

W8(R) Initial oxide thickness on cladding's inner surface (m, ft).

Improved Accuracy for Two-Phase Downflow Scenarios

The EPRI drift flux correlation was judged to predict excessively high slip ratios for very high downflow in small and intermediate pipes and rod bundles. To correct this problem, the EPRI correlation is replaced by the Zuber-Findlay and Kataoka-Ishii correlations when the downflow mass flux exceeds 1500 kg/s-m^2 in small and intermediate pipes and rod bundles. The Zuber-Findlay and Kataoka-Ishii correlations are already applied for very high downflow in large pipes.

Modification to the Horizontal Stratified Entrainment Model

The model is only applied when the upstream volume mass flux is less than 3000 kg/s-m^2. Previously the model was applied when both the volume and junction mass fluxes were less than 3000 kg/s-m^2, but severe oscillations were observed when the junction mass flux crossed 3000 kg/s-m^2.

Critical Flow Model Corrections

The Henry-Fauske critical flow model was corrected so that the momentum flux terms would be calculated correctly regardless of whether the break junction was connected to an inlet or an outlet.

The equlibrium quality calculation was changed so that the calculated value was independent of whether crossflow junctions were connected to inlet or outlet faces.

Multipliers for Heat Transfer Coefficients can be User-Input

The user can now input multipliers for heat transfer coefficients for the forced, laminar, and free convection correlations. These multipliers allow the capability to better represent mixed convection heat transfer.

Cards 1CCCG801 through 1CCCG899, Additional Left Boundary (Twenty Word Format)

W12(R) Multiplier on turbulent forced convection heat transfer coefficient. The default value is 1.0.

W18(R) Multiplier on free (natural) convection heat transfer coefficient. The default value is 1.0.

W19(R) Multiplier on laminar forced convection heat transfer coefficient. The default value is 1.0.

See Vol. 2, Appendix A, Section 8.

Adaptation to Windows 7

The code now runs on Windows 7 platforms.

Faster 3D runtimes

The former default solver, MA18, has been made optional (number 35) because it runs slowly on 3D problems. Because 3D problems run much faster with BPLU, it has become the new default solver (formerly option 33). Problems with large numbers of PVM couplings have been corrected. Legacy input decks should eliminate option 33.

PVM Coupling made available to Source Code Members

PVM (Parallel Virtual Machine) is the methodology underlying the RELAP5-3D coupling technology that allows version 4.0 to combine with other codes (such as CFD codes, containment codes, instruments and controls codes, and neutronics codes) using domain decomposition and message passing. This optional code feature is available on Linux platforms. It is difficult to use and requires support from a very good computer center. Its use is not recommended except by those with PVM experience. INL will not provide debugging and consultative support for PVM issues usage except for superuser clients.