RELAP5-3D User Problems[a]

Richard A. Riemke

Bechtel BWXT Idaho, LLC
Idaho National Engineering and Environmental Laboratory
Idaho Falls, Idaho 83415-3890, USA

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The Reactor Excursion and Leak Analysis Program with 3D capability[1] (RELAP5-3D) is a reactor system analysis code that has been developed at the Idaho National Engineering and Environmental Laboratory (INEEL) for the U. S. Department of Energy (DOE). The 3D capability in RELAP5-3D includes 3D hydrodynamics[2] and 3D neutron kinetics[3,4]. Assessment, verification, and validation of the 3D capability in RELAP5-3D is discussed in the literature[5,6,7,8]. Additional assessment, verification, and validation of the 3D capability of RELAP5-3D will be presented in other papers at this users seminar. As with any software, user problems occur. User problems usually fall into the categories of input processing failure, code execution failure, restart/renodalization failure, unphysical result, and installation. This presentation will discuss some of the more generic user problems that have been reported on RELAP5-3D as well as their resolution.

Input Processing Failure 1

In running a plant simulation model that included a motor valve with an input junction area of zero, the calculation fails input processing with the error message that a zero input junction area is not allowed. The manual (Volume 2, Appendix A), however, indicates that a zero input junction area is allowed and that the code sets the junction area to the minimum of the adjoining volumes. A review of the code and manuals indicates that this inconsistency has been in the code

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and the manuals since RELAP5/MOD1.

This problem was verified on a modified typpwr input deck from the installation problems. The coding was reviewed, and the error message came from subroutine RVALVE where the valve CSUBV table is processed for motor and servo valves.

Discussions with analysts as well as the developer of the valves and the CSUBV table indicate the coding is as it was designed, however the manual is incorrect. The manual was changed to indicate that the input junction area must be greater than zero for motor or servo valves. No change was needed to the code.

Code Execution Failure 1

In running various calculations, execution failures occurred when the prizer component was used. The failures and corrections are as follows:

The first failure occurred when running the typpwr calculation with the prizer component. For this case, the code failed in the bottom of subroutine JPROP in the specialized coding for the prizer component. At the failure time, the index ix was incorrect. The fix for this was to modify subroutine JPROP to remove the do loop 188 coding which calculates the wrong index ix.

The second failure occurred when running a simple vertical pipe calculation using the level model with the prizer component. For this case, the code failed in the bottom of subroutine JPROP in the specialized coding for the prizer component. At the failure time, the indices ihh1 and ihh2 were both zero. The fix for this was to modify subroutine JPROP to skip the prizer coding when the variable “icheck” is 2 (level crossing).

The third failure occurred when running a simple vertical pipe calculation using the thermal front model with the prizer component. For this case, the code failed with a water property error at the minimum time step in an all-liquid volume. The volume had a reasonable pressure and liquid energy. The fix for this was to modify subroutine STATEP to add the following missing cards: “*in32 iprop”, “*in32 lprop”, and “*in32end”. These cards are needed to indicate the local integer variable “iprop” and the local logical variable “lprop” need to occupy the same space as real variables (use double precision) on the 32 bit workstations.

Code Execution Failure 2

(1) In various calculations with light water as the working fluid, code execution failures

occurred in the state properties subroutines. The failures occurred during the transient.

The problem was traced to the noncondensable appearance logic, where a call was made to the saturation line interpolating subroutines. It was found that the temperature used in the call was above the critical point. The problem was corrected by keeping the temperature between the triple point and the critical point before calling the saturation line interpolating subroutines.

(2) In running various calculations with new light water as the working fluid, code execution failures occurred. The failures and corrections are as follows:

The first failure occurred when adding more grid points above the critical pressure. It was found that the liquid temperature and liquid specific volume showed a discontinuity. The problem was corrected by using a better starting temperature and density for the iteration at high pressures above the critical pressure. The convergence criteria at low energy above the critical pressure were also changed.

The second failure occurred because the thermal conductivities and viscosities were calculated as negative. The problem was corrected temporarily by using the old thermal conductivities and viscosities when using the working fluid new light water if returned negative.

Code Execution Failure 3

(1) In running various calculations with helium as the working fluid, code execution failures occurred. The calculations were for DOE Generation IV pebble bed reactor analyses and DOE fusion safety analyses. The failures and corrections are as follows:

The first failure occurred because the maximum allowed pressure and temperature were too low for the operating conditions. The maximum pressure and temperature were increased in the coding and the helium input table to correct this problem.

The second failure occurred because of a negative liquid thermal conductivity. This was due to not calling the thermal conductivity and viscosity subroutines in subroutine STATEP when over the critical pressure. Adding the call to these subroutines corrected this problem.

The third failure occurred when air was added as the noncondensable to the helium working fluid. The problem was corrected by keeping the partial pressure of the working fluid less than the critical pressure before a saturation thermodynamic property table call.

The fourth failure occurred because the specific volume from the interpolation subroutine STRPU was not the same as the table (appears to be due to the cubic). Adding more helium input table points near the operating point fixed this problem.

The fifth failure occurred because the specific volume was not a function of pressure for liquid helium (only a function of temperature). A pressure dependent formulation was developed for subroutine STGHE based on Reynolds[9]. The pressure dependent specific volume uses an isothermal compressibility (κ) of 3.0×10^{-7} Pa^{-1}. This corrected the problem.

The sixth failure occurred because of a 3 K limit in subroutine PHANTV that was shutting off the interphase heat and mass transfer at 4 K for helium (the triple point temperature is 1 K and the critical point temperature is 5.2 K). Changing subroutine PHANTV to replace the 3 K limit by 0.01 of the difference between the critical and triple point temperatures corrected the problem.

(2) In running various calculations with lead bismuth as the working fluid, code execution failures occurred. The calculations were for DOE Generation IV lead bismuth fast breeder reactor analyses. The failures and corrections are as follows:

The first failure occurred because subroutine VISCOS was trying to take the log of a negative gas temperature. The problem was corrected by adding a test on negative or zero temperature in subroutine VISCOS before the log statement, flagging it as a thermodynamic property error if true (as is done with other working fluids), and then forcing the code to cut the time step. This allowed the calculation to run to completion.

The second failure occurred when air was added as the noncondensable to the lead bismuth working fluid. The failure was traced to subroutine NONCND (also in function PINTFC), where no call was made to the thermodynamic property tables for lead bismuth (or any working fluid other than light water, heavy water, or new light water). The problem was corrected by adding a call to subroutine STRPX from both subroutine NONCND and function PINTFC.

Unphysical Result 1

In running a LOFT calculation, it was noticed that abrupt area flag (a) was set to 2 in the major edits for only the first junction of the four junctions that was input using a multiple junction component. The input deck, however, set this flag to 2 for all four junctions. Specifying a = 2 means a partial abrupt area change (no K_{loss}, but includes area apportioning at a branch, restricted junction area, and extra interphase drag).

The problem was traced to subroutine RMTPLJ in do loop 59. A line of coding was added to this do loop to set the variable jcex as is done for the variable jc. This change corrected the problem.

Summary

This presentation has discussed some of the more generic user problems that have been reported on RELAP5-3D as well as their resolution. The input processing failure problem 1 resulted in corrected documentation for motor and servo valves. The code execution failure problem 1 resulted in code fixes to the prizer component. The code execution failure problem 2 resulted in code fixes to the working fluids light water and new light water. The code execution failure problem 3 resulted in code fixes to the working fluids helium and lead bismuth. The unphysical result problem 1 resulted in code fixes to the abrupt area model input for the multiple junction component.

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