# Restart and Backup Improvements

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*Numerous small errors in RELAP5-3D restart and backup have been found and fixed.*

## Background

The RELAP5-3D verification method, reported in the Newsletter from the third quarter 2013, is a form of regression testing called sequential verification. The code is run on a variety of test cases. Compressed data is written to a verification file on user-selected timesteps. Comparison of verification files from two different code runs can detect very small differences. Comparing verification files between two consecutive code versions either proves that calculations have not changed, or alerts developers to differences. Differences must be justified. Either they are the expected result of improvements from the code updates, or they must be treated as errors, tracked down and corrected.

Comparing the verification file can also check that restart, backup, and other code processes continue to work in a given version. By including extra tests in the verification test suite, testing of code processes expanded to include three modes of operation:

(A) RELAP5-3D standalone (all previous tests were in this mode)
(B) RELAP5-3D controlled by the PVM Executive program
(C) RELAP5-3D coupled to another program to solve a problem via domain decomposition

Three major categories of issues with restart and backup that were tracked down and corrected:

1. Differences in time (mostly in the 16th decimal place)
2. Failure to properly record an old time variable
3. Restart variable either not recorded or overwritten incorrectly

These issues were debugged in all three modes of operation. In version 4.1.3, the verification suite had 43 input decks that ran 125 different test cases and checked 194 code features. A number of cases failed to compare exactly and have been corrected:

| Test Problems | Failures cases in 4.1.3 | Failures in 4.3.1 |
|---|---|---|
| Null Testing | 6/125 | 0/145 |
| Restart Testing | 52/125 | 0/145 |
| Backup Testing | 62/125 | 0/145 |

These issues in version 4.1.3 have been tracked down and fixed as of 4.3.1. Twenty new input decks, each with a single input case, have been added to the verification suite to test previously untested sections of the code and potentially expose issues not previously discovered. Some issues were discovered and all of these have been debugged and corrected. High-level descriptions of the issues and code corrections are reported in the next three sections.

## 1. Time differences

Differences in the final bit of the cumulative time variable caused many restart problems to differ very slightly at startup. The time for the restart problem was taken directly from the timecard and its floating point representation was as exact as possible. The corresponding time on the base run was calculated after many time steps and sometimes its floating point representation differed from the restart timecard value in the final bit. This caused some problems to drift apart but had no effect on many others.

There are many solutions. One involves recalibrating cumulative time every time the code makes a minor or major edit or writes a record on the restart or plot file. Quadruple precision was used to convert between the underlying integer time and the floating point time. When implemented in the timestep routine of RELAP5-3D, it caused some PVM installation problems to fail. Putting the same timestep updates into the timestep routine of PVM Executive program allowed all the PVM installation problems to run correctly again.

For coupling problems of category (C) above, the problems occurred with the edit times. The most important was the explicit information exchange time. All edit time conversions between integer and real were promoted to quadruple precision, just as was done for cumulative time. This resolved all issues for hydrodynamic time. A similar fix was installed for heat transfer time.

## 2. Old Time Values

If water packing, flow reversal, or a noncondensable appears in a volume or junction, a better solution is possible if the system of equations is modified to account for the condition in the control volume or junction associated with it. Therefore, the code backs up to the beginning of the timestep, rebuilds the equations, and solves the new system. A time-step backup requires the values in data to match the values at the end of the previous timestep. Therefore, old-time variables record these values at the end of each timestep.

Backup issues related to these old-time variables. Either an old time variable did not exist, did not receive its updated value at the end of the previous timestep, was backed up in the wrong place, or was not used to restore the new time variable when backup was invoked.

Ideally, all backup transfers after an advancement or due to a backup should occur in subroutine MOVER. Unfortunately was not the correct place for every variable. Special cases had to be resolved outside MOVER. All of these have been tracked down and solved.

Just as with time differences, coupling provided special backup issues. The primary issue was that the PVM transferred data was not stored in old time variables after it was received. This resulted in the code using values from before the PVM data transfer which caused differences. These backup issues have also been solved.

## 3. Restart Values

On restart, the code reads values from a user-selected record on the restart file. In some cases, the code behaved differently because the restart value was not recorded on the restart file. These variables were tracked down and added. In a couple of cases, there was no restart write or read program in the FORTRAN module for reading and writing to the restart file, so these were created.

In a few cases, variables were read correctly but were incorrectly overwritten by calculations during input processing that should only be performed when the hydrodynamic system actually changes but the system had not changed. Most of these relate to cards the input manual states should not be included in restart decks, such as 100, 115, 119, and 120-129 cards. The subroutines that read these, RNONCN and RMFLDS have been modified to write a message and set the fail flag so that the problem will not run if one of these is present on restart.

## 4. Conclusion

All code issues revealed by verification testing for restart and backup in the three major modes of operation, standalone, controlled by PVM Executive, and coupled, have been solved at INL. Use of this verification test method can prevent future errors from being introduced into the code by new updates.