Addition of New H2O95N Fluid Properties to RELAP5-3D

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Development of Pressure, Internal Energy Fluid Properties with Metastable Conditions based on the NIST H2ON and H2O95 Properties

Introduction

The RELAP5-3D team has recently undergone an effort to produce a hybrid fluid property table based on the NBS/NRC Steam Tables[1] from 1984 (H2ON) and the NIST/ASME Steam Tables[2] from 1995 (H2O95). The new fluid table is referred to as H2O95N. It has as independent parameters pressure (P) and specific internal energy (U) and extend into the metastable regions as do the H2ON tables. However, the properties are generated using the property generators defined by Harvey in Reference 2, which are used in the H2O95 fluid table.

Method

The effort required multiple small steps to be accomplished, these are listed below:

1. Update the H2O95 fluid property generator
2. Develop the H2O95N fluid property generator
3. Modify RELAP5-3D to recognize the H2O95N fluid property
4. Update the accuracy based generation methodology[3] to test the new fluid
5. Update the polate[4] utility to test the new fluid
6. Test the new fluid using the verification test suite[5], accuracy based generation methodology, polate, and modified developmental assessment (DA) scripts.

Implementation

The H2O95 steam table is currently created from an ASCII file and the sta2b utility. The NIST/ASME STEAM properties database and table generator had not been compiled using current compilers and hardware. Additionally, modifications[3] made in 2011 added transport properties to the ASCII file after the properties were generated. The H2095 fluid property generator was updated to compile on current platforms and to include modifications made in 2011 to add the transport properties.

A new H2O95N fluid property generator was developed which is a combination of the H2ON and H2O95 fluid property generators. The resulting H2O95N fluid property file is formatted like the H2ON tables and uses the H2ON interpolators within RELAP5-3D. However, it generates the properties using H2O95 property generators.

RELAP5-3D was modified to add a new fluid 'h2o95n' with fluid number 31. Fluid number 31 uses the same methods and interpolators that H2ON fluid number 12 uses.

Several utilities that were previously developed for RELAP5-3D were modified to work with the new fluid and test the results. The accuracy based generation methodology[4, 5] was modified to work with H2O95N and extended to include metastable regions. Program POLATED was modified to allow use of absolute pressure and temperature and a new program POLATEM was developed to compare pressure and internal energy input in the metastable states. Existing scripts were modified to compare H2ON vs H2O95N and H2O95 vs H2O95N.

Creation of the new fluid required updating the H2O95 fluid property generator, which resulted in a new H2O95 fluid property table for use with RELAP5-3D. Creation of the new fluid required adaptation of portions of the H2ON fluid property generator, which resulted in the discovery of a solution to an issue causing bad properties at high pressures and low temperatures. This error was corrected and an improved H2ON fluid property table was generated for use with RELAP5-3D.

Testing

The new fluid was tested in a variety of ways. These include the verification test suite[5], accuracy based generation methodology[3], use of program POLATED[4], and the developmental assessment suite[6]. The verification test suite was used to confirm that changes made to RELAP5-3D to introduce the new fluid had not altered previous results for the other fluids. The accuracy based generation methodology was used to compare the accuracy of the generated properties versus the interpolated properties for each box in the thermodynamic grid. The POLATED utility was used to compare the three fluids in all of the liquid and vapor regions defined by the accuracy based generation method. The POLATEM utility was used to compare the three fluids in all of the metastable regions defined by the accuracy based generation method.

The verification suite was used to confirm that the changes made to implement the new H2O95N fluid had not altered any other RELAP5-3D results. The verification suite was run on both the original 4.3.4t version and the modified 4.3.4t. The resulting verification directories and all of their contents were compared using a diff and the only differences detected were in the time stamps and CPU clock cycles. Additionally, the verification suite includes four models which test the H2ON fluid. These were also compared and found to have differences only in time stamp and CPU clock cycles.

The accuracy based generation methodology was extended to work with H2O95, H2ON, and H2O95N, but was only thoroughly tested with H2O95N. The average and maximum errors were generally similar between H2O and H2O95N. H2ON and H2O95 output were not compared using the methodology.

The POLATED utility was modified to provide testing capability for the new fluid table and scripts were created to provide comparisons of the POLATE output between the three fluid tables. The functionality was created to allow POLATED to use absolute temperature and internal energy values as input. During this modification, minor script errors within the utility were identified and corrected. The results from this comparison also revealed a potential error in the RELAP5-3D interpolation routines, which was

submitted as a user trouble report. It was discovered that POLATED was inadequate to test the metastable regions. Because of this, POLATEM was developed based on POLATED, in order to use a pressure and internal energy call to test the metastable states using pressure and internal energy interpolators.

The DA scripts were modified to compare the new fluid to both H2ON and H2O95. The results from the DA comparisons showed that most of the 319 plots showed negligible differences. More significant differences were noted in two of the plots (LOBI and LOFT L2-5 1D). These differences were related to quenching of heater/fuel rods in the core which have exhibited sensitivity to code changes in the past. The code was not quite as robust with H2O95N; these two cases ran to completion with H2ON but failed with H2O95N. They ran successfully after minor improvements to the input models. The code was more robust with H2O95N than with H2O95, as eight cases failed when run with H2O95.

Conclusions

A hybrid fluid property table based on the NBS/NRC Steam Tables[1] from 1984 (H2ON) and the NIST/ASME Steam Tables[2] from 1995 (H2O95) called H2O95N was developed. H2O95N has independent parameters P and U. It extends into the metastable regions similar to the H2ON tables. The properties of the new fluid are generated using the property generators defined by Harvey in Reference 2 which are used in the H2O95 fluid table.

All updated fluid files, scripts, input models, and subroutines have been submitted to the code custodian for inclusion in the next release of RELAP5-3D.

REFERENCES

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