Title:        Release Notes for Whisper-1.1

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# Release Notes for Whisper-1.1

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Contents

## 1.0  Introduction  & Overview

Whisper is a statistical analysis package developed in 2014 to support nuclear criticality safety (NCS) validation [1-3]. It uses the sensitivity profile data for an application as computed by MCNP6 [4-6] along with covariance files [7,8] for the nuclear data to determine a baseline upper-subcritical-limit (USL) for the application. Whisper version 1.0 was first developed and used at LANL in 2014 [3]. During 2015-2016, Whisper was updated to version 1.1 [9] and is to be included with the upcoming release of MCNP6.2.

This document describes the Whisper-1.1 package that will be included with the MCNP6.2 release during 2017. Specific details are provided on the computer systems supported, the software quality assurance (SQA) procedures, installation, and testing.

This document does <u>not</u> address other important topics, such as the importance of sensitivity-uncertainty (SU) methods to NCS validation, the theory underlying SU methodology, tutorials on the usage of MCNP-Whisper, practical approaches to using SU methodology to support and extend traditional validation, etc. There are over 50 documents included with Whisper-1.1 and available in the MCNP Reference Collection on the MCNP website (mcnp.lanl.gov) that address all of those topics and more. In this document, however, a complete bibliography of relevant MCNP-Whisper references is provided.

### 1.1  Methodology

Standard approaches to validation rely on the selection of benchmarks based upon expert judgment. For a particular NCS application, Whisper uses SU methods to select the most relevant benchmarks from a catalog of over 1100 ICSBEP benchmarks. Using the selected benchmarks, Whisper computes a calculational margin from an extreme value distribution. In NCS, a margin of subcriticality (MOS) accounts for unknowns about the analysis. Typically, this MOS is prescribed by institutional requirements and/or derived from expert judgment, encompassing many aspects of criticality safety. Whisper will attempt to quantify the portion of the MOS due to two sources of potential unknowns, errors in the software and uncertainties in nuclear data. The Whisper-derived calculational margin and MOS may be used to set a baseline USL for a particular area of applicability (AOA), and additional margin may be applied by the NCS analyst as appropriate to ensure subcriticality for a specific application in the AOA. The combination of repeatable, quantifiable, physics-based results from MCNP-Whisper calculations plus the experience and expert judgment of NCS analysts has the potential to significantly improve the NCS validation process.

**Figure 1.  MCNP-Whisper methodology for NCS validation**
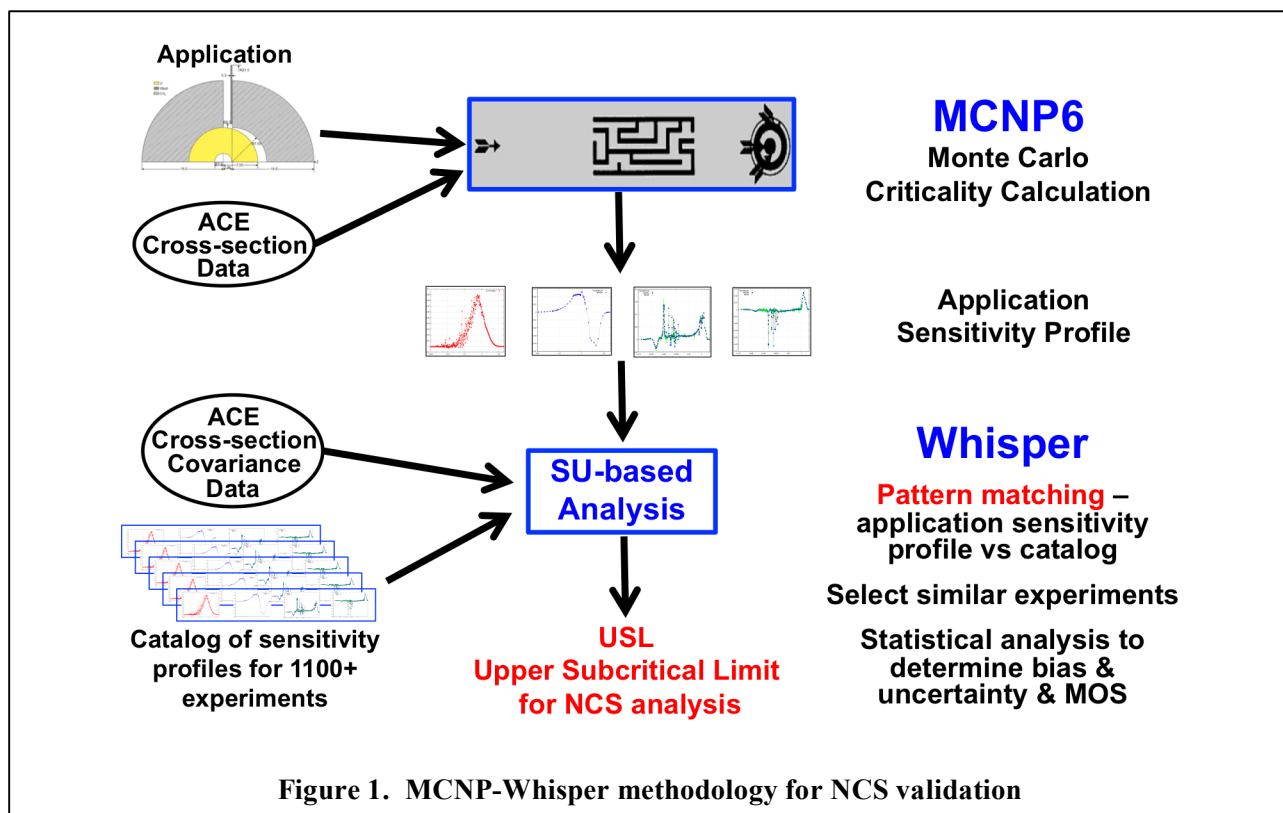
**Figure 1** illustrates the methodology for MCNP-Whisper based NCS validation. MCNP6 is used to determine the sensitivity profile for an application, typically 10-20 thousand numbers that give the sensitivity of $k_{eff}$ for a problem to 12 different reactions as a function of energy bins for each isotope in the problem. The application sensitivity profile is matched against a precomputed catalog of over 1100 ICSBEP [10] benchmark sensitivity profiles. Whisper selects the benchmarks most neutronically-similar to the application based on correlation coefficients that make use of the covariance data. The number of benchmarks selected varies according to the similarity and must meet requirements for performing a valid statistical analysis. The selected benchmarks are weighted according to their correlation coefficients and then used in a nonparametric Extreme Value Theory statistical approach to determine the appropriate bias and bias uncertainty for the application. A GLLS-based method is then used to estimate an additional margin of subcriticality (MOS) due to nuclear data covariances. NCS analysts may then use this baseline USL from Whisper along with their expert judgment to help set the USL for a range of normal and credible abnormal conditions. **Figure 2** shows some of the analysis results of applying the MCNP6-Whisper methodology to a typical NCS application, a plutonium cylinder with 1-inch water side reflector.

## 2.0  Availability, Computer Requirements, SQA

### 2.1 Availability

Whisper-1.1 and its associated benchmark files are developed and maintained as part of MCNP6.2, and will be distributed with all future MCNP6 distributions. Updates to the Whisper portion of MCNP6 may occur more frequently than updates to MCNP6, particularly considering the addition of new benchmark files or improved covariance data.

```
   Calculating application nuclear data uncertainties ...
        application                                adjusted   prior
        pu-hd-1.0                                   0.00075    0.01385

    Calculating upper subcritical limits ...
                                                   calc       data unc     baseline    k(calc)
        application                                margin     (1-sigma)    USL         > USL
        pu-hd-1.0                                   0.01443    0.00075      0.97863     -0.14353

        Benchmark population    =    43
        Population weight       =  25.30973
        Maximum similarity      =   0.99691

        Bias                    =   0.00850
        Bias uncertainty        =   0.00593
        Nuc Data uncert margin  =   0.00075
        Software/method margin  =   0.00500
        Non-coverage penalty    =   0.00000

        benchmark                             ck           weight
        pu-met-fast-036-001.i                 0.9969       1.0000
        pu-met-fast-024-001.i                 0.9966       0.9916
        pu-met-fast-022-001.i                 0.9948       0.9386
        pu-met-fast-023-001.i                 0.9931       0.8887
        pu-met-fast-044-005.i                 0.9931       0.8870
        . . . . . . . . .
        mix-met-fast-007-022.i                0.9724       0.2824
        mix-met-fast-007-023.i                0.9693       0.1915
        pu-met-fast-045-005.i                 0.9670       0.1240
        pu-met-fast-003-103.i                 0.9662       0.1021
        mix-met-fast-001-001.i                0.9650       0.0664
```

**For this application, 43 of the 1101 benchmarks were selected as neutronically similar & sufficient for valid statistical analysis**

**Benchmark rankings shown below**

**Excellent $c_k$'s In range .96 - .99**

**Figure 2. Example of Whisper results for a typical NCS application, plutonium cylinder with 1-inch water reflector on sides**

## 2.2 Computer Requirements

Whisper-1.1 is completely portable to Mac OS X, Linux, and Windows computer systems. A few supporting utility scripts are included with Whisper-1.1, to simplify using MCNP6-Whisper for common NCS usage. These scripts are portable to Mac OS X, Linux, and Windows systems, as long as the *perl* program is available.

- Whisper-1.1 has been built and tested with the specific operating systems and compilers listed below. However, Whisper-1.1 is 100% compliant with Fortran-2003 standards and does not make use of any machine- or system-dependent features. It should be portable to any 64-bit Mac, Linux, or Windows system.

    - Mac:          64-bit, Intel-based Macs, OS X 10.11.6, Intel Fortran 17.0.0

    - Linux:        64-bit, LLNL *chaos* (based on Red Hat), Intel Fortran 17.0.1

    - Windows:      64-bit, Windows 7, Intel Fortran 17.0.1

- Executables are included with the Whisper-1.1 distribution for Mac, Linux, and Windows systems. It is not necessary to have a Fortran compiler or to build the code from source.

- The *perl* program must be available to use any of the utility scripts associated with Whisper-1.1.

    - *Perl* is standard on Linux and Mac OS X systems, and no user action is needed for the scripts.

    - On Windows systems, some version of *perl* must be available. For Windows systems where the Cygwin package is installed, users should make sure that *perl* was included in the installation, and if not, add it. To check, open a command window and type "`perl --version`". For Windows systems without Cygwin, the ActivePerl Community Edition package can be downloaded  for free from www.activestate.com/downloads, and is easy to install. After

installation, open a command window and type "`perl --version`" to verify that it was installed.

## 2.3 Software Quality Assurance

Whisper SQA is extensive: Whisper uses the same rigorous procedures for revision control, change tracking, testing, verification, etc., as MCNP6.

- Revision control:      git repository at tf.lanl.gov, project *MCNP*, repository *whisper*.

- Change tracking:      TeamForge, with change tracking linked to git repository

- Testing:      installation tests, included with distribution

- SQA & Verification:      See the Whisper section of the MCNP Reference Collection, or the Whisper Bibliography in Appendix A.

- Documentation:      There is an extensive collection of documents supporting Whisper SQA including theory, user manual, verification, code inspection, and more available on the MCNP website and included with the Whisper distribution. The Whisper Bibliography in Appendix A lists the current contents.

The Whisper validation suite is now included with MCNP6. This suite consists of 1101 ICSBEP benchmarks including their sensitivity profiles. These benchmark problems are maintained under the same SQA procedures as the Whisper source coding. There are plans to expand this suite over time to include benchmarks from other sites.

## 3.0  Installation

The Whisper-1.1 code package is optional software included with the MCNP6.2 release. It includes the Whisper coding, benchmark catalog, low-fidelity covariance data, executable code, and utility scripts needed for using Whisper. For both installation and testing, a log file is created and used to record the progress and results.

Installation separate from MCNP6.2 is supported:

On DVD-1 of the MCNP6.2 distribution, use a file manager to locate the WHISPER directory:

```
Windows:              MCNP_CODE_620\WHISPER

Mac/Linux/Cygwin:     MCNP_CODE_620/WHISPER
```

Copy the WHISPER directory & its contents into a suitable directory (or folder) denoted here as *install_dir*. (Or, drag-and-drop in a file manager.) Note that the full pathname for *install_dir* should not contain blanks.

```
Windows:              xcopy /E    MCNP_CODE\WHISPER   install_dir

Mac/Linux/Cygwin:     cp -R       MCNP_CODE/WHISPER   install_dir
```

If  MCNP6.2 has been installed into a directory denoted here as *my_mcnp*, then the WHISPER directory was included, and the *install_dir* pathname is:

```
Windows:              my_mcnp\MCNP_CODE\

Mac/Linux/Windows:    my_mcnp/MCNP_CODE
```

To then install Whisper (whether from the MCNP6.2 installation or separately):

```
Windows:              cd    install_dir\WHISPER
                      INSTALL_whisper.pl

Mac/Linux/Cygwin:     cd install_dir/WHISPER
                      ./INSTALL_whisper_pl
```

Installation should only take a few minutes. The compressed Whisper zip file is 215 MB, and the expanded contents require about 2.7 GB of disk space.

After installation, the Whisper installation test should be run:

```
Windows:              cd    install_dir\WHISPER

                      INSTALL_whisper.pl  test



Mac/Linux/Cygwin:     cd install_dir/WHISPER

                      ./INSTALL_whisper_pl  test
```

The directory structure for the Whisper-1.1 files is:

```
WHISPER/
      Makefile
      bin/
            linux/
            macosx/
            windows/
      Benchmarks/
            Correlations/
            Exclude/
            Inputs/
            Sensitivities/
            TOC/
      CovarianceData/
            BLO-44g/
                  Data/
                  Adjusted/
      Documentation/
      Testing/
      Source/
```

The Whisper-1.1 installation includes executables for Mac OS X, Windows, and Linux systems, and the proper executable is copied into the WHISPER/bin directory during installation. It is not necessary to compile the *whisper* executable.

If, however, changes are made to the Whisper-1.1 source coding (for corrections or user-desired enhancements), then a Fortran compiler is necessary. The Intel Fortran compiler (versions 15 or 17) is the only one used to date. Since Whisper-1.1 adheres completely to the Fortran 2003 international standard, other compilers such as *gfortran* could probably be used. The Whisper-1.1 build system relies on GNU *make*, which is standard on Linux and Mac OS X systems. Building on Windows requires the Cygwin environment. To build Whisper-1.1 from source coding:

```
cd    install_dir/WHISPER
make  build
```

After building a new executable, the Whisper-1.1 installation test should be run to verify the build.

**4.0 Change History for Whisper-1.1**

Whisper-1.0 was developed during 2014 [1-3] to meet urgent needs for an upgrade to the NCS computational capabilities at LANL. In April, 2015, all components of whisper-1.0 were placed under version control (initially CVS, then migrated to git), and all subsequent development that led to whisper-1.1 was carried out under the MCNP SQA procedures.

- The Whisper Benchmark Catalog of 1101 ICSBEP benchmark problems is included with the distribution. The list of benchmark problems is given in Appendix B.

- The Whisper covariance data is now supplied in the new ACE covariance file format [8]. A listing of the available covariance data is given in Appendix C.

A summary of changes made in going from whisper-1.0 to whisper-1.1 includes:

- Robust numerics, to avoid memory problems on Mac & Windows
  - Explicit threaded loops, to replace many instances of Fortran-2003 matrix operators
  - Replaced Linpack coding by modern Fortran-2003
  - Additional threading for some slow sections
  - No change to any results

- Methods
  - Chi-square & benchmark rejection changed from based on $\Delta k$ to $\Delta k/k$. Gives some very minor differences in the list of rejected benchmarks.
  - For USL determination, the printed list of benchmarks selected is sorted by weight (or $C_k$)
  - Filenames can be up to   256-characters long
  - Whisper prints a list of all files in use, using full pathnames
  - TOC files permit blank lines & comment lines
    - BenchmarkTOC.dat,  ExcludedBenchmarks.dat,  BenchmarkCorrel.dat
  - Deprecate the use of environment variables for filenames. Instead use explicit command-line options (for whisper)
    - revised scripts handle this automatically

- Build & test procedures were completely revised, to be similar to mcnp6
  - Previous C-shell scripts replaced by portable *perl* scripts
  - *Whimcnp* replaced by *whisper_mcnp.pl*,   *ww* replaced by *whisper_usl.pl*
  - Modifications to *mcnp_pstudy.pl*, to run on Windows & support Whisper scripts

- Benchmarks
  - Updated 27 benchmark files (per NCS), to correct minor differences from ICSBEP
  - 1 error was significant, the other 26 produced only trivial $\Delta k$ changes
  - Added 15 new benchmark files
  - Reran 42 benchmarks
    - new sensitivity profiles
    - new BenchmarkTOC.dat & ExcludedBenchmarks.dat
    - new adjusted covariance data files

**5.0  Conclusions**

Sensitivity-uncertainty methods for NCS validation have been under development for nearly 20 years. While there were notable successes for multigroup Monte Carlo approaches such as SCALE-Tsunami [9], continuous-energy Monte Carlo codes such as MCNP could not determine adjoint-weighted tallies for sensitivity profiles. The introduction of the iterated fission probability method (IFP) into MCNP [10] led to the rapid development of sensitivity analysis capabilities for MCNP6 and the development of Whisper in 2014. As a result, there are now 2 independent computational methods available in the US for applying SU-based methods to NCS

validation: MCNP-Whisper and SCALE-Tsunami. The entire NCS community benefits from comparing the 2 approaches, and such efforts are planned for the near term.

SU-based methods represent the future for NCS validation – making full use of today's computer power to codify past approaches based largely on expert judgment. Validation results are defensible, auditable, and repeatable as needed with different assumptions and process models. The NCS community is by nature conservative, so the next few years will necessarily involve performing NCS validation using both traditional and new methods. The new SU-based methods can supplement, support, and extend traditional validation approaches. In today's environment of audits, reviews, and "justify everything," it is prudent to make use of the best available tools to provide state-of-the-art calculations for NCS analyses.

As the use of SU methods for NCS validation grows over the next few years, much experience will be gained, many lessons will be learned, bugs will be found and fixed, and enhancements will be developed. All users are encouraged to share their experiences with other users and the Whisper developers.

**Acknowledgments**

**References**

**All references with a LANL report number, LA-UR-…, are included with the Whisper-1.1 Release and are also available from the MCNP Reference Collection on the MCNP website, mcnp.lanl.gov.**

1.  B.C. Kiedrowski, F.B. Brown, et al., "Whisper: Sensitivity/Uncertainty-Based Computational Methods and Software for Determining Baseline Upper Subcritical Limits", Nucl. Sci. Eng. **181**, 17-47, [also LA-UR-14-26558] (2015).

2.  B.C. Kiedrowski, "User Manual for Whisper (v1.0.0), Software for Sensitivity- and Uncertainty-Based Nuclear Criticality Safety Validation", LA-UR-14-26436 (2014).

3.  B.C. Kiedrowski, et al., "Validation of MCNP6.1 for Criticality Safety of Pu-Metal, -Solution, and -Oxide Systems", LA-UR-14-23352 (2014).

4.  J.T. Goorley, et al., "Initial MCNP6 Release Overview," *Nuclear Technology*, **180**, 298 (2012).

5.  J.T. Goorley, "MCNP6.1.1-Beta Release Notes," LA-UR-14-24680 (2014).

6.  M.B. Chadwick, et al., "ENDF/B-VII.1 Nuclear Data for Science and Technology: Cross Sections, Covariances, Fission Product Yields and Decay Data," LA-UR 11-05121, Los Alamos National Laboratory, also: *Nuclear Data Sheets*, **112** Issue 12, pg. 2887-2996 (Dec 2011).

7.  R.C. Little, T.Kawano, et al., "Low-fidelity Covariance Project", *Nuclear Data Sheets* **109**, 2828-2833 [also LA-UR-08-7732] (2008).

8.  F.B. Brown, M.E. Rising, "Covariance Data File Formats for Whisper-1.0 & Whisper-1.1", LA-UR-17-20098 (2017).

9.  F.B. Brown, M.E. Rising, J.L. Alwin, "User Manual for Whisper-1.1", LA-UR-17-20453 (2017).

10. International Handbook of Evaluated Criticality Safety Benchmark Experiments, NEA No. 7231, OECD Nuclear Energy Agency (2014).

11. B.T. Rearden, et. al., "Sensitivity and Uncertainty Analysis Capabilities and Data in SCALE," *Nucl. Technol.*, **174**, 236-288 (2011).

12. B.C. Kiedrowski & F.B. Brown, "Adjoint-Based k-Eigenvalue Sensitivity Coefficients to Nuclear Data Using Continuous-Energy Monte Carlo", *Nucl. Sci. Eng.* **174**, 227-244 [also LA-UR-12-22089] (2013).

13. M.L. Williams & B.T. Rearden, "SCALE 6 Sensitiivity/Uncertainty Methods and Covariance Data", *Nuclear Data Sheets* **109**, 2796-2800 (2008).

# Appendix A - Whisper Bibliography

## Overview

Whisper - abstract from LANL TeamForge Tracker system, Artifact artf36407 (2015)

F.B. Brown, M.E. Rising, J.L. Alwin, "MCNP-WHISPER Methodology for Nuclear Criticality Safety Validation", brief overview, LA-UR-16-23757 (2016)

F.B. Brown, M.E. Rising, J.L. Alwin, "MCNP Progress for NCS", presentation at DOE-Nuclear Criticality Safety Program Technical Review, Sandia National Laboratory, 14-15 March 2016, LA-UR-16-21302 (2016)

## Theory

B.C. Kiedrowski, F.B. Brown, et al., "Whisper: Sensitivity/Uncertainty-Based Computational Methods and Software for Determining Baseline Upper Subcritical Limits", Nuc. Sci. Eng. Sept. 2015, LA-UR-14-26558 (2014)

B.C. Kiedrowski, "Methodology for Sensitivity and Uncertainty-Based Criticality Safety Validation", LA-UR-14-23202 (2014)

F.B. Brown, M.E. Rising, J.L. Alwin, "Lecture Notes on Criticality Safety Validation Using MCNP & Whisper", LA-UR-16-21659 (2016)

J.L. Alwin, F.B. Brown, M.E. Rising, "Lecture Notes on i Sensitivity-Uncertainty Based Nuclear Criticality Safety Validation", LA-UR-16-23533 (2016)

F.B. Brown, M.E. Rising, J.L. Alwin, D.E. Mueller, "Sensitivity and Uncertainty Techniques for Use in Nuclear Criticality Safety ", workshop at the EFCOG-NFS 2016 meeting at ANL, August 2016, LA-UR-16-25648 (2016)

## User Manual

F.B. Brown, M.E. Rising, J.L. Alwin, "User Manual for Whisper-1.1", LA-UR-17-20453 (2017).

B.C. Kiedrowski, "User Manual for Whisper (v1.0.0), Software for Sensitivity- and Uncertainty-Based Nuclear Criticality Safety Validation", LA-UR-14-26436 (2014)

B.C. Kiedrowski, "MCNP6.1 k-Eigenvalue Sensitivity Capability: A Users Guide", LA-UR-13-22251 (2013)

## Application

F.B. Brown, J.A. Miller, S.J. Henderson, M.E. Rising, J.L. Alwin, "LANL-SNL Collaboration on NCS Validation", ANS 2017 summer meeting, LA-UR-17-20453 (2017)

N. Glazener, A.J. Yamanaka, T.N. Stewart, "Whisper Statistics Study", submitted to ANS 2017 summer meeting, LA-UR-16-29594 (2016)

B.C. Kiedrowski, et al., "Validation of MCNP6.1 for Criticality Safety of Pu-Metal, -Solution, and -Oxide Systems", LA-UR-14-23352 (2014)

J.J. Kuropatwinski, T.N. Stewart, "Practical Use of Whisper During the Performance of a Criticality Safety Evaluation", EFCOG-NFS 2016 Workshop, Argonne National Laboratory, August 2016, LA-UR-16-24692 (2016)

N. Zhang, M.V. Mitchell, D.K. Miko, "A Practical Assessment of the Effect of Water Interspersed with

Plutonium Metal Hemishells", LA-UR-16-24471 (2016)

N. Glazener, J.J. Kuropatwinski, A.J. Yamanaka, R.F. Sartor, "Heat Source Plutonium: A Case Study in Applying Whisper", LA-UR-16-24667 (2016)

J.L. Alwin, N. Zhang, "Plutonium Critical Mass Curve Comparison to Mass at Upper Subcritical Limit (USL) Using Whisper", LA-UR-16-27371 (2016)

## Nuclear Data & Covariances

R.C. Little, T. Kawano, et al., "Low-Fidelity Covariance Project", Nuclear Data Sheets, Vol 109, Issue 12, 2828-2833, Dec 2008, LA-UR-08-7732 (2008)

F.B. Brown, M.E. Rising, "Covariance Data File Formats for Whisper-1.0 & Whisper-1.1", LA-UR-17-20098 (2017).

J.L. Conlin, et al., "Listing of Available ACE Data Tables", LA-UR-13-21822 rev-4 (2014)

F.B. Brown, "Status of Cross-section Data Libraries for MCNP", LA-UR-13-23040 (2013).

## Software Quality Assurance

R.F. Sartor, F.B. Brown, "Whisper Program Suite Validation and Verification Report", LA-UR-15-23972 (2015-05-28)

R.F. Sartor, F.B. Brown, "Whisper Source Code Inspection Report", LA-UR-15-23986 (2015-05-28)

R.F. Sartor, B.A. Greenfield, F.B. Brown, "MCNP6 Criticality Calculations Verification and Validation Report", LA-UR-15-23266 (2015-04-30)

Monte Carlo Codes Group (XCP-3), "Whisper - Software for Sensitivity-Uncertainty-based Nuclear Criticality Safety Validation", LANL TeamForge Tracker system, Artifact artf36407 (2015)

Monte Carlo Codes Group (XCP-3), WHISPER module in LANL TeamForge GIT repository (2015)

Monte Carlo Codes Group (XCP-3), MCNP6 module in LANL TeamForge GIT repository

Monte Carlo Codes Group (XCP-3), "MCNP Process Documents", LANL Teamforge wiki for MCNP

Monte Carlo Codes Group (XCP-3), "Software Quality Assurance", LANL Teamforge wiki for MCNP, P1040-rev9 requirements

## Recent MCNP6 & ENDF/B-VII.1 Verification/Validation

F.B. Brown, M.R. Rising, "Verification of MCNP6.1, MCNP6.1.1, and MCNP6.2-pre for Criticality Safety Applications", LA-UR-16-24308 (2016).

F.B. Brown, "The MCNP6 Analytic Criticality Benchmark Suite", LA-UR-16-24255 (2016).

F.B. Brown, "New Version of the MCNP Analytic Criticality Benchmark Suite", Trans. ANS, ANS 2016 Winter Meeting, LA-UR-16-24254 (2016).

F.B. Brown, "MCNP6 Optimization and Testing for Criticality Safety Calculations", Trans. ANS 111, LA-UR-15-20422 (2015)

F.B. Brown, B.C. Kiedrowski, J.S. Bull, "Verification of MCNP6.1 and MCNP6.1.1 for Criticality Safety Applications", LA-UR-14-22480 (2014).

F.B. Brown, B.C. Kiedrowski, J.S. Bull, "Verification of MCNP5-1.60 and MCNP6.1 for Criticality Safety Applications", LA-UR-13-22196 (2013).

L.J. Cox, S.D. Matthews, "MCNP6 Release 1.0: Creating and Testing the Code Distribution", LA-UR-13-24008 (2013)

R.D. Mosteller, F.B. Brown, B.C. Kiedrowski, "An Expanded Criticality Validation Suite for MCNP", LA-UR-11-00240 (2011).

R.D. Mosteller, "An Expanded Criticality Validation Suite for MCNP", LA-UR-10-06230 (2010).

R.C. Little, "V&V of MCNP and Data Libraries at Los Alamos", LA-UR-12-26307 (2012)

A. Sood, R.A. Forster, D.K. Parsons, "Analytic Benchmark Test Set for Criticality Code Verification", LA-13511 and LA-UR-01-3082 (2001)

XCP Data Team, "LANL Data Testing Support for ENDF/B-VII.1", LA-UR-12-20002 LA- UR-12-20002 (2012)

## General References on Adjoints, Perturbation, and Sensitivity Analysis

B.C. Kiedrowski, F.B. Brown, et al., "MCNP Sensitivity/Uncertainty Accomplishments for the Nuclear Criticality Safety Program", Trans. Am. Nuc. Soc 111, Nov 2014, LA-UR-14-24458 (2014)

B.C. Kiedrowski, "Adjoint Weighting Methods Applied to Monte Carlo Simulations of Applications and Experiments in Nuclear Criticality" seminar at University of Michigan, March 2014, LA-UR-14-21608 (2014)

B.C. Kiedrowski, "MCNP Continuous-Energy Sensitivity and Uncertainty Progress and Application", Presentation at DOE-NNSA Nuclear Criticality Safety Program Technical Review, 26-27 March 2014, LA-UR-14-21919 (2014)

B.C. Kiedrowski, "Application of Covariance Data in Nuclear Criticality", Nuclear Data Covariance Workshop, April 28 - May 1, Santa Fe, NM, LA-UR-14-22972 (2014)

B.C. Kiedrowski & F.B. Brown, "Applications of Adjoint-Based Techniques in Continuous-Energy Monte Carlo Criticality Calculations", Supercomputing in Nuclear Applications and Monte Carlo 2013, Paris, Oct 27-31, LA-UR-13-27002 (2013)

B.C. Kiedrowski, "Importance of Scattering Distributions on Criticality", ANS NCSD-2013, Wilmington, NC, Sept 29 - Oct 1, LA-UR-13-24254 (2013).

B.C. Kiedrowski, A.C. Kahler, M.E. Rising, "Status of MCNP Sensitivity/Uncertainty Capabilities for Criticality", ANS NCSD-2013, Wilmington, NC, Sept 29 - Oct 1, LA-UR-13-24090 (2013)

B.C. Kiedrowski, "K-Eigenvalue Sensitivity Coefficients to Legendre Scattering Moments", ANS 2013 Winter Meeting, LANL report LA-UR-13-22431 (2013)

B.C. Kiedrowski, F.B. Brown, "Applications of Adjoint-Based Techniques in Continuous-Energy Monte Carlo Criticality Calculations", submitted to SNA+MC-2013, Paris, France [also LA-UR-12-26436] (2012)

B.C. Kiedrowski, F.B. Brown, "K-Eigenvalue Sensitivities of Secondary Distributions of Continuous-Energy Data," M&C 2013, Sun Valley, ID, May 2013, report LA-UR-12-25966, talk LA-UR-13-23208 (2013)

B.C. Kiedrowski, F.B. Brown, "Methodology, Verification, and Performance of the Continuous-Energy Nuclear Data Sensitivity Capability in MCNP6," M&C 2013, Sun Valley, ID, May 2013, report LA-UR-12-25947, talk LA-UR-13-23199 (2012)

B.C. Kiedrowski, F.B. Brown, "MCNP6 Nuclear Data Sensitivity Capability: Current Status and Future Prospects", presentation at MCNP/ENDF/NJOY Workshop, 2012-10-30, LANL, LA-UR-12-25560 (2012)

B.C. Kiedrowski, F.B. Brown, "Nuclear Data Sensitivities in Fast Critical Assemblies", presentation at NECDC-2012, LA-UR-12-25144 (2012)

B.C. Kiedrowski, F.B. Brown, "Adjoint-Based k-Eigenvalue Sensitivity Coefficients to Nuclear Data

Using Continuous-Energy Monte Carlo", submitted to Nuclear Science & Engineering [also LA-UR-12-22089] (2012)

B.C. Kiedrowski, "MCNP6 Results for the Phase III Sensitivity Benchmark of the OCED/NEA Expert Group on Uncertainty Analysis for Criticality Safety Assessment", LA-UR-12-21048 (2012)

B.C. Kiedrowski & F.B. Brown, "Continuous-Energy Sensitivity Coefficient Capability in MCNP6", Trans. Am. Nuc. Soc. 107, LA-UR-12-21010,

presentation at 2012 ANS Winter Meeting, San Diego, CA, LA-UR-12-25949 (2012)

B.C. Kiedrowski & F.B. Brown, "Comparison Of The Monte Carlo Adjoint-Weighted And Differential Operator Perturbation Methods", SNA+MC-2010, Tokyo, Oct 17-20, LA-UR-10-05215 (2010)

B.C. Kiedrowski, J.A. Favorite, & F.B. Brown, "Verification of K-eigenvalue Sensitivity Coefficient Calculations Using Adjoint-Weighted Perturbation Theory in MCNP", Trans. Am. Nuc. Soc, 103, Nov 2010, LA-UR-10-04285 (2010)

B.C. Kiedrowski, F.B. Brown, & P. Wilson, "Adjoint-Weighted Tallies for k-Eigenvalue Calculations with Continuous-Energy Monte Carlo", Nucl. Sci. Eng. 168, 38-50, 2011, LA-UR-10-01824, (2010).

B.C. Kiedrowski & F.B. Brown, "Adjoint-Weighting for Critical Systems with Continuous Energy Monte Carlo", ANS NCSD-2009, Richland, WA, Sept 13-17, paper LA-UR-09-2594, presentation LA-UR-09-5624 (2009)

# Appendix B - Whisper-1.1 Benchmark Catalog

The benchmark catalog table-of-contents is contained in the file

        WHISPER/Benchmarks/TOC/BenchmarkTOC.dat

The file is listed below, with each line corresponding to the name of a benchmark file, the experimental Keff and standard deviation, and the MCNP6-computed Keff and standard deviation. The entries are group in the following categories, with the number of benchmarks listed for each category:

```
        HEU-COMP-INTER        1
        HEU-COMP-THERM       25
        HEU-MET-FAST        251
        HEU-MET-INTER         4
        HEU-MET-MIXED         8
        HEU-MET-THERM         4
        HEU-SOL-THERM        93
        IEU-COMP-THERM        1
        IEU-MET-FAST         12
        LEU-COMP-THERM      182
        LEU-SOL-THERM        27
        MIX-COMP-FAST         2
        MIX-COMP-INTER        1
        MIX-COMP-THERM       15
        MIX-MET-FAST         33
        MIX-MET-MIXED         1
        MIX-SOL-THERM        21
        PU-COMP-FAST          1
        PU-COMP-INTER         1
        PU-COMP-MIXED        34
        PU-MET-FAST          68
        PU-SOL-THERM        158
        U233-COMP-THERM       9
        U233-MET-FAST        10
        U233-SOL-INTER       33
        U233-SOL-THERM      106
        NEW BENCHMARKS      (15)  (all included in PU-MET-FAST above)

        Total              1101


Whisper benchmarks TOC file,  fbrown, 2016-02-23
#------------------------------------------------------------------------------------------
#
# First line is now title, used to be location of sensitivity data files.
# Blank lines & lines starting with "#" are ignored or comment lines.
# Total line length must be <= 256 chars.
# The four numbers are Keff-measured, Kstd-measured, Keff-mcnp, Kstd-mcnp
#
#------------------------------------------------------------------------------------------
#
# Unless otherwise noted, all files below were prepared in early 2014 for
# the work described in LA-UR-14-23352:
#    Kiedrowski, Conlin, Favorite, Kahler, Kersting, Parsons, Walker,
#       "Validation of MCNP6.1 for Criticality Safety of Pu-Metal,
#       -Solution, and -Oxide Systems", LA-UR-14-23352,  2014-05-13
# The date for the benchmark files for that report is  2014-06-08.
#
#------------------------------------------------------------------------------------------
#
# Note that this file includes estimated values for std-dev on measurements
# for the cases where 0 is given in ICSBEP:
#   heu-met-fast-004-001, ieu-met-fast-004-(001..004)
#
#------------------------------------------------------------------------------------------
```

```
# HEU-COMP-THERM
  heu-comp-inter-003-006.i                      1.0000    0.0047    0.99558   0.00011
  heu-comp-therm-002-001.i                      1.0011    0.0069    1.01150   0.00013
  heu-comp-therm-002-002.i                      1.0011    0.0069    1.01385   0.00013
  heu-comp-therm-002-003.i                      1.0011    0.0069    1.01666   0.00012
  heu-comp-therm-002-004.i                      1.0011    0.0069    1.01599   0.00012
  heu-comp-therm-002-005.i                      1.0011    0.0069    1.01700   0.00013
  heu-comp-therm-002-006.i                      1.0011    0.0069    1.01718   0.00011
  heu-comp-therm-002-007.i                      1.0011    0.0069    1.01738   0.00011
  heu-comp-therm-002-008.i                      1.0011    0.0069    1.01748   0.00011
  heu-comp-therm-002-009.i                      1.0011    0.0069    1.01882   0.00010
  heu-comp-therm-002-010.i                      1.0011    0.0069    1.01562   0.00010
  heu-comp-therm-002-011.i                      1.0011    0.0053    1.01446   0.00013
  heu-comp-therm-002-012.i                      1.0011    0.0055    1.01370   0.00012
  heu-comp-therm-002-013.i                      1.0011    0.0055    1.01791   0.00012
  heu-comp-therm-002-014.i                      1.0011    0.0055    1.01767   0.00011
  heu-comp-therm-002-015.i                      1.0011    0.0055    1.01916   0.00011
  heu-comp-therm-002-016.i                      1.0011    0.0053    1.01879   0.00010
  heu-comp-therm-002-017.i                      1.0011    0.0053    1.02344   0.00010
  heu-comp-therm-002-018.i                      1.0020    0.0043    1.01569   0.00013
  heu-comp-therm-002-019.i                      1.0020    0.0043    1.01291   0.00012
  heu-comp-therm-002-020.i                      1.0020    0.0043    1.01552   0.00011
  heu-comp-therm-002-021.i                      1.0020    0.0043    1.01677   0.00012
  heu-comp-therm-002-022.i                      1.0020    0.0043    1.01724   0.00011
  heu-comp-therm-002-023.i                      1.0008    0.0085    1.01438   0.00012
  heu-comp-therm-002-024.i                      1.0008    0.0085    1.01501   0.00012
  heu-comp-therm-002-025.i                      1.0008    0.0085    1.01358   0.00012


#------------------------------------------------------------------------------------
# HEU-MET-FAST
  heu-met-fast-001-001.i                        1.0000    0.0010    1.00000   0.00008
  heu-met-fast-002-001.i                        1.0000    0.0030    1.00150   0.00009
  heu-met-fast-002-002.i                        1.0000    0.0030    1.00193   0.00009
  heu-met-fast-002-003.i                        1.0000    0.0030    1.00037   0.00009
  heu-met-fast-002-004.i                        1.0000    0.0030    0.99946   0.00009
  heu-met-fast-002-005.i                        1.0000    0.0030    1.00000   0.00009
  heu-met-fast-002-006.i                        1.0000    0.0030    1.00129   0.00009
  heu-met-fast-003-001.i                        1.0000    0.0050    0.99492   0.00009
  heu-met-fast-003-002.i                        1.0000    0.0050    0.99434   0.00009
  heu-met-fast-003-003.i                        1.0000    0.0050    0.99916   0.00009
  heu-met-fast-003-004.i                        1.0000    0.0030    0.99718   0.00009
  heu-met-fast-003-005.i                        1.0000    0.0030    1.00158   0.00009
  heu-met-fast-003-006.i                        1.0000    0.0030    1.00150   0.00009
  heu-met-fast-003-007.i                        1.0000    0.0030    1.00199   0.00009
  heu-met-fast-003-008.i                        1.0000    0.0050    1.00220   0.00009
  heu-met-fast-003-009.i                        1.0000    0.0050    1.00267   0.00009
  heu-met-fast-003-010.i                        1.0000    0.0050    1.00491   0.00009
  heu-met-fast-003-011.i                        1.0000    0.0050    1.00875   0.00009
  heu-met-fast-003-012.i                        1.0000    0.0030    1.00864   0.00009
  #-----> heu-met-fast-004-001:  estimated std-measured replaces 0 from ICSBEP
  heu-met-fast-004-001.i                        0.9985    0.0030    0.99406   0.00011
  heu-met-fast-005-001.i                        1.0000    0.0036    0.99510   0.00009
  heu-met-fast-005-002.i                        1.0007    0.0036    0.99795   0.00010
  heu-met-fast-005-003.i                        0.9996    0.0036    1.00046   0.00010
  heu-met-fast-005-004.i                        0.9989    0.0036    0.99438   0.00011
  heu-met-fast-005-005.i                        0.9980    0.0036    0.99909   0.00010
  heu-met-fast-005-006.i                        0.9987    0.0036    0.99792   0.00009
  heu-met-fast-007-001.i                        0.9950    0.0024    0.99245   0.00009
  heu-met-fast-007-002.i                        0.9964    0.0014    0.99832   0.00009
  heu-met-fast-007-003.i                        0.9990    0.0013    0.99976   0.00010
  heu-met-fast-007-004.i                        0.9948    0.0013    0.99766   0.00010
  heu-met-fast-007-005.i                        0.9978    0.0018    0.99971   0.00010
  heu-met-fast-007-006.i                        1.0006    0.0013    1.00560   0.00009
  heu-met-fast-007-007.i                        0.9974    0.0014    1.00118   0.00010
  heu-met-fast-007-008.i                        0.9973    0.0013    0.99925   0.00010
  heu-met-fast-007-009.i                        0.9995    0.0056    1.00209   0.00010
  heu-met-fast-007-010.i                        0.9981    0.0012    0.99901   0.00011
  heu-met-fast-007-011.i                        0.9958    0.0013    0.99725   0.00011
  heu-met-fast-007-012.i                        0.9932    0.0012    0.99280   0.00012
  heu-met-fast-007-013.i                        0.9990    0.0012    1.00088   0.00013
  heu-met-fast-007-014.i                        0.9964    0.0012    0.99703   0.00012
  heu-met-fast-007-015.i                        0.9959    0.0012    0.99671   0.00012
  heu-met-fast-007-016.i                        0.9969    0.0012    0.99723   0.00012
  heu-met-fast-007-017.i                        0.9953    0.0012    0.99584   0.00013
  heu-met-fast-007-018.i                        0.9972    0.0012    0.99818   0.00013
  heu-met-fast-007-019.i                        0.9956    0.0015    0.99614   0.00009
  heu-met-fast-007-020.i                        0.9950    0.0017    0.99776   0.00010
  heu-met-fast-007-021.i                        0.9956    0.0018    0.99845   0.00010
  heu-met-fast-007-022.i                        0.9963    0.0019    0.99926   0.00011
  heu-met-fast-007-023.i                        0.9962    0.0017    0.99902   0.00010
  heu-met-fast-007-024.i                        0.9970    0.0018    0.99954   0.00011
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heu-met-fast-007-025.i                    0.9959   0.0018   0.99811   0.00011
heu-met-fast-007-026.i                    0.9966   0.0017   0.99837   0.00012
heu-met-fast-007-027.i                    0.9948   0.0014   0.99673   0.00010
heu-met-fast-007-028.i                    0.9970   0.0023   0.99804   0.00010
heu-met-fast-007-029.i                    0.9961   0.0014   0.99865   0.00011
heu-met-fast-007-030.i                    0.9964   0.0021   0.99730   0.00011
heu-met-fast-007-031.i                    0.9996   0.0022   1.00107   0.00012
heu-met-fast-007-032.i                    0.9941   0.0012   1.00450   0.00009
heu-met-fast-007-033.i                    0.9977   0.0019   1.01394   0.00009
heu-met-fast-007-034.i                    0.9959   0.0017   1.01733   0.00010
heu-met-fast-007-035.i                    1.0003   0.0018   0.99489   0.00011
heu-met-fast-007-036.i                    0.9999   0.0007   1.00354   0.00012
heu-met-fast-007-037.i                    0.9988   0.0008   1.00182   0.00012
heu-met-fast-007-038.i                    1.0000   0.0008   1.00267   0.00011
heu-met-fast-007-039.i                    1.0018   0.0014   1.00636   0.00011
heu-met-fast-007-040.i                    1.0013   0.0008   1.00598   0.00011
heu-met-fast-007-041.i                    0.9994   0.0009   1.00093   0.00012
heu-met-fast-007-042.i                    1.0016   0.0009   1.00292   0.00012
heu-met-fast-007-043.i                    0.9998   0.0008   1.00040   0.00013
heu-met-fast-008-001.i                    0.9989   0.0016   0.99583   0.00008
heu-met-fast-009-001.i                    0.9992   0.0015   0.99763   0.00009
heu-met-fast-009-002.i                    0.9992   0.0015   0.99649   0.00009
heu-met-fast-010-001.i                    0.9992   0.0015   0.99829   0.00009
heu-met-fast-010-002.i                    0.9992   0.0015   0.99789   0.00009
heu-met-fast-011-001.i                    0.9989   0.0015   0.99887   0.00011
heu-met-fast-012-001.i                    0.9992   0.0018   0.99823   0.00009
heu-met-fast-013-001.i                    0.9990   0.0015   0.99752   0.00009
heu-met-fast-014-001.i                    0.9989   0.0017   0.99777   0.00009
heu-met-fast-015-001.i                    0.9996   0.0017   0.99470   0.00009
heu-met-fast-016-001.i                    0.9996   0.0018   1.00163   0.00009
heu-met-fast-016-002.i                    0.9996   0.0018   1.00263   0.00009
heu-met-fast-017-001.i                    0.9993   0.0014   1.00058   0.00010
heu-met-fast-018-002.i                    1.0000   0.0014   0.99971   0.00008
heu-met-fast-019-001.i                    1.0000   0.0030   1.00708   0.00009
heu-met-fast-020-002.i                    1.0000   0.0028   1.00063   0.00010
heu-met-fast-021-002.i                    1.0000   0.0024   0.99760   0.00009
heu-met-fast-022-002.i                    1.0000   0.0019   0.99763   0.00009
heu-met-fast-025-001.i                    0.9987   0.0014   0.99907   0.00009
heu-met-fast-025-002.i                    0.9990   0.0016   1.00124   0.00009
heu-met-fast-025-003.i                    0.9991   0.0016   1.00369   0.00009
heu-met-fast-025-004.i                    0.9995   0.0016   1.00544   0.00009
heu-met-fast-025-005.i                    0.9991   0.0016   1.00557   0.00009
heu-met-fast-026-011.i                    1.0000   0.0038   1.00330   0.00011
heu-met-fast-027-001.i                    1.0000   0.0025   1.00058   0.00009
heu-met-fast-028-001.i                    1.0000   0.0030   1.00298   0.00009
heu-met-fast-029-001.i                    1.0000   0.0020   1.00572   0.00009
heu-met-fast-030-001.i                    1.0000   0.0009   1.00219   0.00010
heu-met-fast-031-001.i                    1.0000   0.0059   1.00487   0.00010
heu-met-fast-032-001.i                    1.0000   0.0016   1.00411   0.00009
heu-met-fast-032-002.i                    1.0000   0.0027   1.00487   0.00009
heu-met-fast-032-003.i                    1.0000   0.0017   1.00017   0.00009
heu-met-fast-032-004.i                    1.0000   0.0017   1.00100   0.00009
heu-met-fast-033-001.i                    0.9991   0.0014   0.99902   0.00011
heu-met-fast-033-002.i                    0.9991   0.0014   0.99769   0.00011
heu-met-fast-034-001.i                    0.9990   0.0012   0.99703   0.00011
heu-met-fast-034-002.i                    0.9990   0.0012   0.99873   0.00011
heu-met-fast-034-003.i                    0.9990   0.0012   0.99767   0.00011
heu-met-fast-036-001.i                    0.9993   0.0015   0.99908   0.00011
heu-met-fast-036-002.i                    0.9993   0.0013   0.99837   0.00010
heu-met-fast-037-001.i                    0.9997   0.0011   1.00215   0.00011
heu-met-fast-037-002.i                    0.9997   0.0011   0.99779   0.00011
heu-met-fast-038-001.i                    0.9999   0.0007   1.00303   0.00010
heu-met-fast-038-002.i                    0.9999   0.0009   1.00186   0.00010
heu-met-fast-040-001.i                    0.9991   0.0011   1.00453   0.00009
heu-met-fast-041-001.i                    1.0013   0.0030   1.00687   0.00009
heu-met-fast-041-002.i                    1.0022   0.0043   1.00517   0.00011
heu-met-fast-041-003.i                    1.0006   0.0029   1.00240   0.00009
heu-met-fast-041-004.i                    1.0006   0.0025   1.00725   0.00009
heu-met-fast-041-005.i                    1.0006   0.0031   1.00287   0.00009
heu-met-fast-041-006.i                    1.0006   0.0045   1.00434   0.00010
heu-met-fast-043-001.i                    0.9995   0.0018   0.99900   0.00008
heu-met-fast-043-002.i                    0.9995   0.0019   0.99821   0.00009
heu-met-fast-043-003.i                    0.9995   0.0021   0.99880   0.00009
heu-met-fast-043-004.i                    0.9995   0.0015   0.99725   0.00009
heu-met-fast-043-005.i                    0.9995   0.0015   0.99826   0.00009
heu-met-fast-044-001.i                    0.9995   0.0019   1.00000   0.00008
heu-met-fast-044-002.i                    0.9995   0.0017   0.99962   0.00008
heu-met-fast-044-003.i                    0.9995   0.0019   0.99993   0.00009
heu-met-fast-044-004.i                    0.9995   0.0014   0.99931   0.00009
heu-met-fast-044-005.i                    0.9995   0.0015   0.99989   0.00008
heu-met-fast-049-001.i                    0.9990   0.0016   0.99808   0.00009
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heu-met-fast-049-002.i                          0.9994    0.0015    0.99963    0.00009
heu-met-fast-049-003.i                          0.9994    0.0016    0.99886    0.00009
heu-met-fast-050-001.i                          0.9990    0.0012    0.99803    0.00009
heu-met-fast-051-001.i                          0.9971    0.0005    0.99505    0.00009
heu-met-fast-051-002.i                          0.9968    0.0005    0.99546    0.00009
heu-met-fast-051-003.i                          0.9974    0.0005    0.99497    0.00009
heu-met-fast-051-004.i                          0.9969    0.0005    0.99517    0.00009
heu-met-fast-051-009.i                          0.9982    0.0002    0.99489    0.00009
heu-met-fast-051-014.i                          0.9996    0.0002    0.99861    0.00008
heu-met-fast-051-015.i                          0.9998    0.0001    0.99805    0.00008
heu-met-fast-051-016.i                          0.9981    0.0001    0.99636    0.00009
heu-met-fast-051-017.i                          0.9969    0.0001    0.99546    0.00008
heu-met-fast-051-018.i                          0.9984    0.0002    0.99387    0.00009
heu-met-fast-057-001.i                          1.0000    0.0020    0.98964    0.00009
heu-met-fast-057-002.i                          1.0000    0.0023    0.99824    0.00009
heu-met-fast-057-003.i                          1.0000    0.0032    1.01718    0.00010
heu-met-fast-057-004.i                          1.0000    0.0040    0.98783    0.00009
heu-met-fast-057-005.i                          1.0000    0.0019    1.02180    0.00009
heu-met-fast-057-006.i                          1.0000    0.0029    0.99667    0.00009
heu-met-fast-058-001.i                          1.0000    0.0026    1.00323    0.00012
heu-met-fast-058-002.i                          1.0000    0.0035    1.00499    0.00010
heu-met-fast-058-003.i                          1.0000    0.0027    1.00285    0.00011
heu-met-fast-058-004.i                          1.0000    0.0021    1.00208    0.00009
heu-met-fast-058-005.i                          1.0000    0.0033    1.00098    0.00009
heu-met-fast-063-001.i                          0.9993    0.0049    1.00064    0.00009
heu-met-fast-063-002.i                          0.9988    0.0047    1.00094    0.00009
heu-met-fast-064-001.i                          0.9996    0.0008    0.99537    0.00009
heu-met-fast-064-002.i                          0.9996    0.0010    0.99562    0.00009
heu-met-fast-064-003.i                          0.9996    0.0009    0.99360    0.00009
heu-met-fast-065-002.i                          0.9995    0.0013    0.99812    0.00009
heu-met-fast-066-001.i                          1.0030    0.0033    1.00374    0.00010
heu-met-fast-066-002.i                          1.0023    0.0029    1.00192    0.00010
heu-met-fast-066-003.i                          1.0023    0.0026    1.00466    0.00010
heu-met-fast-066-004.i                          1.0043    0.0043    1.00496    0.00011
heu-met-fast-066-005.i                          1.0030    0.0033    1.00431    0.00010
heu-met-fast-066-006.i                          1.0028    0.0030    1.00343    0.00010
heu-met-fast-066-007.i                          1.0048    0.0039    1.00578    0.00011
heu-met-fast-066-008.i                          1.0039    0.0040    1.00458    0.00011
heu-met-fast-066-009.i                          1.0027    0.0036    1.00289    0.00010
heu-met-fast-067-001.i                          1.0086    0.0004    1.00112    0.00008
heu-met-fast-067-002.i                          0.9938    0.0024    0.99620    0.00008
heu-met-fast-072-001.i                          0.9991    0.0024    1.00867    0.00010
heu-met-fast-072-003.i                          1.0016    0.0069    1.01221    0.00009
heu-met-fast-073-001.i                          1.0004    0.0016    1.00806    0.00009
heu-met-fast-077-001.i                          1.0001    0.0031    1.00068    0.00010
heu-met-fast-077-002.i                          0.9995    0.0027    1.00068    0.00010
heu-met-fast-077-003.i                          0.9995    0.0040    0.99787    0.00011
heu-met-fast-077-004.i                          0.9998    0.0032    0.99836    0.00010
heu-met-fast-077-005.i                          0.9994    0.0027    1.00012    0.00009
heu-met-fast-077-006.i                          0.9996    0.0033    0.99969    0.00010
heu-met-fast-077-007.i                          0.9994    0.0056    1.00057    0.00010
heu-met-fast-077-008.i                          0.9994    0.0035    0.99833    0.00010
heu-met-fast-078-001.i                          0.9995    0.0018    0.99457    0.00011
heu-met-fast-078-003.i                          0.9994    0.0022    0.99591    0.00010
heu-met-fast-078-005.i                          0.9991    0.0019    0.99636    0.00010
heu-met-fast-078-007.i                          1.0000    0.0019    0.99845    0.00011
heu-met-fast-078-009.i                          0.9997    0.0022    0.99568    0.00010
heu-met-fast-078-011.i                          0.9995    0.0015    0.99582    0.00010
heu-met-fast-078-013.i                          1.0000    0.0017    0.99727    0.00010
heu-met-fast-078-015.i                          0.9991    0.0018    0.99655    0.00010
heu-met-fast-078-017.i                          0.9995    0.0018    0.99657    0.00010
heu-met-fast-078-023.i                          0.9992    0.0022    0.99824    0.00009
heu-met-fast-078-025.i                          0.9992    0.0025    0.99742    0.00010
heu-met-fast-078-027.i                          0.9992    0.0021    0.99595    0.00009
heu-met-fast-078-029.i                          1.0000    0.0025    1.00212    0.00010
heu-met-fast-078-031.i                          0.9994    0.0020    0.99519    0.00010
heu-met-fast-078-033.i                          0.9996    0.0026    0.99588    0.00009
heu-met-fast-078-035.i                          0.9991    0.0022    0.99445    0.00010
heu-met-fast-078-037.i                          0.9986    0.0021    0.99620    0.00009
heu-met-fast-078-039.i                          0.9989    0.0021    0.99694    0.00010
heu-met-fast-078-041.i                          0.9992    0.0025    0.99664    0.00009
heu-met-fast-078-043.i                          1.0000    0.0019    0.99765    0.00009
heu-met-fast-079-001.i                          0.9996    0.0015    0.99984    0.00008
heu-met-fast-079-002.i                          0.9996    0.0014    0.99921    0.00009
heu-met-fast-079-003.i                          0.9996    0.0015    1.00009    0.00009
heu-met-fast-079-004.i                          0.9996    0.0014    1.00113    0.00009
heu-met-fast-079-005.i                          0.9996    0.0015    0.99981    0.00009
heu-met-fast-084-001.i                          0.9994    0.0019    0.99881    0.00009
heu-met-fast-084-002.i                          0.9994    0.0021    0.99948    0.00009
heu-met-fast-084-003.i                          0.9993    0.0021    0.99988    0.00009
heu-met-fast-084-004.i                          0.9994    0.0020    0.99868    0.00009
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  heu-met-fast-084-005.i                          0.9993    0.0021    1.00497    0.00009
  heu-met-fast-084-006.i                          0.9994    0.0024    0.99858    0.00008
  heu-met-fast-084-007.i                          0.9995    0.0020    0.99740    0.00009
  heu-met-fast-084-008.i                          0.9994    0.0034    1.00840    0.00009
  heu-met-fast-084-009.i                          0.9993    0.0054    1.00246    0.00009
  heu-met-fast-084-010.i                          0.9993    0.0022    1.00106    0.00009
  heu-met-fast-084-011.i                          0.9995    0.0019    1.00146    0.00010
  heu-met-fast-084-012.i                          0.9994    0.0020    0.99740    0.00009
  heu-met-fast-084-013.i                          0.9994    0.0022    0.99897    0.00009
  heu-met-fast-084-014.i                          0.9994    0.0019    0.99987    0.00009
  heu-met-fast-084-015.i                          0.9995    0.0021    0.99790    0.00009
  heu-met-fast-084-016.i                          0.9994    0.0020    0.99912    0.00009
  heu-met-fast-084-017.i                          0.9995    0.0019    1.00036    0.00009
  heu-met-fast-084-018.i                          0.9995    0.0022    0.99743    0.00008
  heu-met-fast-084-019.i                          0.9996    0.0019    0.99768    0.00009
  heu-met-fast-084-020.i                          0.9995    0.0025    1.00304    0.00009
  heu-met-fast-084-021.i                          0.9995    0.0045    1.00023    0.00009
  heu-met-fast-084-022.i                          0.9994    0.0020    0.99824    0.00009
  heu-met-fast-084-023.i                          0.9993    0.0024    0.99956    0.00010
  heu-met-fast-084-024.i                          0.9996    0.0018    0.99862    0.00009
  heu-met-fast-084-025.i                          0.9995    0.0020    0.99808    0.00008
  heu-met-fast-084-026.i                          0.9993    0.0022    1.00039    0.00009
  heu-met-fast-084-027.i                          0.9994    0.0020    0.99769    0.00009
  heu-met-fast-087-001.i                          0.9987    0.0013    0.99840    0.00009
  heu-met-fast-088-001.i                          0.9993    0.0008    0.99681    0.00010
  heu-met-fast-088-002.i                          0.9993    0.0007    0.99672    0.00011
  heu-met-fast-089-001.i                          0.9991    0.0014    1.00008    0.00009
  heu-met-fast-090-001.i                          0.9994    0.0007    1.00567    0.00011
  heu-met-fast-090-002.i                          0.9993    0.0007    1.00226    0.00011
  heu-met-fast-091-001.i                          0.9996    0.0009    0.99957    0.00011
  heu-met-fast-092-001.i                          0.9986    0.0011    1.00105    0.00008
  heu-met-fast-092-002.i                          0.9989    0.0013    1.00279    0.00009
  heu-met-fast-092-003.i                          0.9993    0.0012    1.00397    0.00009
  heu-met-fast-092-004.i                          0.9993    0.0013    1.00361    0.00009
  heu-met-fast-093-001.i                          0.9978    0.0012    1.00328    0.00008
  heu-met-fast-094-001.i                          0.9994    0.0012    1.00347    0.00010
  heu-met-fast-094-002.i                          0.9993    0.0010    1.00366    0.00010
  heu-met-fast-100-001.i                          1.0031    0.0007    1.00486    0.00008
  heu-met-fast-100-002.i                          0.9966    0.0007    0.99878    0.00008

#-------------------------------------------------------------------------------
# HEU-MET-INTER
  heu-met-inter-006-001.i                         0.9977    0.0008    0.99293    0.00010
  heu-met-inter-006-002.i                         1.0001    0.0008    0.99682    0.00011
  heu-met-inter-006-003.i                         1.0015    0.0009    1.00071    0.00011
  heu-met-inter-006-004.i                         1.0016    0.0008    1.00728    0.00011

#-------------------------------------------------------------------------------
# HEU-MET-MIXED
  heu-met-mixed-001-001.i                         0.9995    0.0013    1.00227    0.00011
  heu-met-mixed-002-001.i                         1.0000    0.0037    1.00647    0.00012
  heu-met-mixed-003-001.i                         1.0000    0.0038    1.00760    0.00011
  heu-met-mixed-004-001.i                         0.9999    0.0009    1.00249    0.00009
  heu-met-mixed-015-001.i                         0.9996    0.0008    0.99701    0.00012
  heu-met-mixed-016-001.i                         0.9995    0.0008    1.00156    0.00012
  heu-met-mixed-016-002.i                         0.9995    0.0007    1.00250    0.00011
  heu-met-mixed-017-001.i                         0.9995    0.0008    0.99547    0.00011

#-------------------------------------------------------------------------------
# HEU-MET-THERM
  heu-met-therm-010-001.i                         1.0065    0.0072    1.00875    0.00012
  heu-met-therm-012-001.i                         0.9971    0.0025    1.00919    0.00012
  heu-met-therm-014-001.i                         0.9939    0.0015    1.00795    0.00013
  heu-met-therm-031-001.i                         1.0037    0.0024    1.00850    0.00011

#-------------------------------------------------------------------------------
# HEU-SOL-THERM
 #----> next benchmark was replaced on 2016-02-23
 #heu-sol-therm-001-001.i                         1.0000    0.0025    0.99828    0.00016
  heu-sol-therm-001-001.i                         1.0000    0.0025    0.99828    0.00016
  heu-sol-therm-001-002.i                         1.0000    0.0025    0.99603    0.00015
  heu-sol-therm-001-003.i                         1.0000    0.0025    1.00177    0.00016
  heu-sol-therm-001-004.i                         1.0000    0.0025    0.99852    0.00015
  heu-sol-therm-001-005.i                         1.0000    0.0025    0.99868    0.00014
  heu-sol-therm-001-006.i                         1.0000    0.0025    1.00196    0.00013
  heu-sol-therm-001-007.i                         1.0000    0.0025    0.99779    0.00014
  heu-sol-therm-001-008.i                         1.0000    0.0025    0.99823    0.00015
  heu-sol-therm-001-009.i                         1.0000    0.0025    0.99435    0.00015
  heu-sol-therm-001-010.i                         1.0000    0.0025    0.99257    0.00013
  heu-sol-therm-009-001.i                         0.9990    0.0043    1.00215    0.00014
  heu-sol-therm-009-002.i                         1.0000    0.0039    1.00249    0.00014
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heu-sol-therm-009-003.i                    1.0000    0.0036    1.00211    0.00013
heu-sol-therm-010-001.i                    1.0000    0.0029    1.00115    0.00012
heu-sol-therm-011-001.i                    1.0000    0.0023    1.00481    0.00012
heu-sol-therm-011-002.i                    1.0000    0.0023    1.00072    0.00011
heu-sol-therm-012-001.i                    0.9999    0.0058    1.00088    0.00008
heu-sol-therm-013-001.i                    1.0012    0.0026    0.99862    0.00008
heu-sol-therm-013-002.i                    1.0007    0.0036    0.99781    0.00008
heu-sol-therm-013-003.i                    1.0009    0.0036    0.99415    0.00010
heu-sol-therm-013-004.i                    1.0003    0.0036    0.99600    0.00010
heu-sol-therm-019-001.i                    0.9991    0.0041    0.99737    0.00014
heu-sol-therm-019-002.i                    0.9991    0.0041    0.99895    0.00013
heu-sol-therm-019-003.i                    0.9991    0.0067    0.99459    0.00013
heu-sol-therm-025-001.i                    1.0002    0.0025    1.00093    0.00012
heu-sol-therm-025-002.i                    1.0007    0.0025    1.00048    0.00011
heu-sol-therm-025-003.i                    1.0002    0.0064    0.99527    0.00010
heu-sol-therm-025-004.i                    1.0003    0.0027    1.00083    0.00012
heu-sol-therm-025-005.i                    1.0013    0.0030    1.00309    0.00012
heu-sol-therm-025-006.i                    1.0002    0.0067    1.00858    0.00011
heu-sol-therm-025-007.i                    1.0009    0.0073    1.01263    0.00010
heu-sol-therm-025-008.i                    1.0000    0.0067    1.01005    0.00010
heu-sol-therm-025-009.i                    1.0002    0.0065    1.00398    0.00011
heu-sol-therm-025-010.i                    1.0003    0.0043    1.00818    0.00011
heu-sol-therm-025-011.i                    1.0002    0.0045    1.00745    0.00011
heu-sol-therm-025-012.i                    1.0002    0.0045    1.00581    0.00011
heu-sol-therm-025-013.i                    1.0009    0.0047    1.01360    0.00010
heu-sol-therm-025-014.i                    1.0008    0.0053    1.00491    0.00011
heu-sol-therm-025-015.i                    1.0002    0.0058    0.99913    0.00011
heu-sol-therm-025-016.i                    1.0002    0.0049    1.00921    0.00011
heu-sol-therm-025-017.i                    1.0009    0.0055    1.00108    0.00012
heu-sol-therm-025-018.i                    1.0000    0.0061    0.99863    0.00011
heu-sol-therm-032-001.i                    1.0015    0.0026    0.99945    0.00005
heu-sol-therm-038-001.i                    1.0000    0.0025    0.99497    0.00015
heu-sol-therm-038-002.i                    1.0000    0.0025    0.99721    0.00014
heu-sol-therm-038-003.i                    1.0000    0.0025    0.99782    0.00014
heu-sol-therm-038-004.i                    1.0000    0.0025    0.99514    0.00014
heu-sol-therm-038-005.i                    1.0000    0.0025    0.99544    0.00014
heu-sol-therm-038-006.i                    1.0000    0.0025    0.99635    0.00013
heu-sol-therm-038-007.i                    1.0000    0.0032    0.99803    0.00014
heu-sol-therm-038-008.i                    1.0000    0.0026    0.99823    0.00013
heu-sol-therm-038-009.i                    1.0000    0.0033    0.99854    0.00015
heu-sol-therm-038-010.i                    1.0000    0.0026    0.99742    0.00014
heu-sol-therm-038-011.i                    1.0000    0.0025    0.99637    0.00014
heu-sol-therm-038-012.i                    1.0000    0.0025    0.99573    0.00014
heu-sol-therm-038-013.i                    1.0000    0.0050    1.00081    0.00014
heu-sol-therm-038-014.i                    1.0000    0.0050    1.00131    0.00014
heu-sol-therm-038-015.i                    1.0000    0.0050    1.00082    0.00015
heu-sol-therm-038-016.i                    1.0000    0.0050    1.00018    0.00014
heu-sol-therm-038-017.i                    1.0000    0.0026    0.99681    0.00014
heu-sol-therm-038-018.i                    1.0000    0.0032    0.99541    0.00014
heu-sol-therm-038-019.i                    1.0000    0.0032    0.99716    0.00015
heu-sol-therm-038-020.i                    1.0000    0.0032    0.99721    0.00014
heu-sol-therm-038-021.i                    1.0000    0.0025    0.99693    0.00014
heu-sol-therm-038-022.i                    1.0000    0.0027    0.99749    0.00015
heu-sol-therm-038-023.i                    1.0000    0.0027    0.99694    0.00014
heu-sol-therm-038-024.i                    1.0000    0.0026    0.99711    0.00014
heu-sol-therm-038-025.i                    1.0000    0.0032    0.99741    0.00014
heu-sol-therm-038-026.i                    1.0000    0.0032    0.99748    0.00014
heu-sol-therm-038-027.i                    1.0000    0.0032    0.99718    0.00014
heu-sol-therm-038-028.i                    1.0000    0.0025    0.99749    0.00014
heu-sol-therm-042-001.i                    0.9957    0.0039    0.99664    0.00007
heu-sol-therm-042-002.i                    0.9965    0.0036    0.99660    0.00007
heu-sol-therm-042-003.i                    0.9994    0.0028    1.00067    0.00005
heu-sol-therm-042-004.i                    1.0000    0.0034    1.00228    0.00004
heu-sol-therm-042-005.i                    1.0000    0.0034    0.99992    0.00004
heu-sol-therm-042-006.i                    1.0000    0.0037    1.00050    0.00004
heu-sol-therm-042-007.i                    1.0000    0.0036    1.00145    0.00004
heu-sol-therm-042-008.i                    1.0000    0.0035    1.00204    0.00003
heu-sol-therm-043-001.i                    0.9986    0.0031    0.99479    0.00015
heu-sol-therm-043-002.i                    0.9995    0.0026    1.00515    0.00009
heu-sol-therm-043-003.i                    0.9990    0.0025    1.00100    0.00008
heu-sol-therm-050-001.i                    0.9953    0.0086    1.00714    0.00015
heu-sol-therm-050-002.i                    0.9987    0.0083    1.00278    0.00015
heu-sol-therm-050-003.i                    0.9984    0.0079    1.00473    0.00015
heu-sol-therm-050-004.i                    0.9987    0.0084    1.00452    0.00015
heu-sol-therm-050-005.i                    0.9985    0.0085    1.00073    0.00015
heu-sol-therm-050-006.i                    0.9985    0.0081    1.00902    0.00015
heu-sol-therm-050-007.i                    0.9978    0.0078    0.99803    0.00015
heu-sol-therm-050-008.i                    0.9975    0.0084    0.99791    0.00015
heu-sol-therm-050-009.i                    0.9966    0.0082    0.99724    0.00014
heu-sol-therm-050-010.i                    0.9960    0.0090    0.97986    0.00014
heu-sol-therm-050-011.i                    0.9964    0.0089    0.99113    0.00015
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#-------------------------------------------------------------------------------
# IEU-COMP-THERM
  ieu-comp-therm-002-003.i                   1.0017    0.0044    1.00417    0.00010


#-------------------------------------------------------------------------------
# IEU-MET-FAST
  #-----> ieu-met-fast-001-(001..004):  estimated std-measured replaces 0 from ICSBEP
  ieu-met-fast-001-001.i                      0.9988    0.0026    1.00013    0.00009
  ieu-met-fast-001-002.i                      0.9988    0.0026    1.00022    0.00009
  ieu-met-fast-001-003.i                      0.9990    0.0026    1.00048    0.00009
  ieu-met-fast-001-004.i                      0.9990    0.0025    1.00140    0.00008
  ieu-met-fast-002-001.i                      1.0000    0.0030    0.99891    0.00009
  ieu-met-fast-003-001.i                      1.0000    0.0017    1.00215    0.00009
  ieu-met-fast-004-001.i                      1.0000    0.0030    1.00752    0.00009
  ieu-met-fast-005-001.i                      1.0000    0.0021    1.00184    0.00009
  ieu-met-fast-006-001.i                      1.0000    0.0023    0.99612    0.00008
  ieu-met-fast-007-001.i                      1.0045    0.0007    1.00435    0.00007
  ieu-met-fast-008-001.i                      1.0000    0.0018    1.00539    0.00009
  ieu-met-fast-009-001.i                      1.0000    0.0053    1.01058    0.00011


#-------------------------------------------------------------------------------
# LEU-COMP-THERM
  leu-comp-therm-001-001.i                    0.9998    0.0031    0.99959    0.00009
  leu-comp-therm-001-002.i                    0.9998    0.0031    0.99878    0.00010
  leu-comp-therm-001-003.i                    0.9998    0.0030    0.99846    0.00010
  leu-comp-therm-001-004.i                    0.9998    0.0030    0.99912    0.00009
  leu-comp-therm-001-005.i                    0.9998    0.0030    0.99691    0.00010
  leu-comp-therm-001-006.i                    0.9998    0.0030    0.99899    0.00009
  leu-comp-therm-001-007.i                    0.9998    0.0030    0.99811    0.00009
  leu-comp-therm-001-008.i                    0.9998    0.0030    0.99718    0.00009
  leu-comp-therm-002-001.i                    0.9997    0.0020    0.99865    0.00010
  leu-comp-therm-002-002.i                    0.9997    0.0020    0.99980    0.00010
  leu-comp-therm-002-003.i                    0.9997    0.0020    0.99923    0.00010
  leu-comp-therm-002-004.i                    0.9997    0.0020    0.99883    0.00011
  leu-comp-therm-002-005.i                    0.9997    0.0020    0.99798    0.00011
  leu-comp-therm-005-001.i                    1.0000    0.0023    1.00275    0.00011
  leu-comp-therm-005-002.i                    1.0000    0.0021    0.99962    0.00011
  leu-comp-therm-005-003.i                    1.0000    0.0029    0.99914    0.00010
  leu-comp-therm-005-004.i                    1.0000    0.0025    0.99778    0.00011
  leu-comp-therm-005-005.i                    1.0000    0.0047    1.00498    0.00011
  leu-comp-therm-005-006.i                    1.0000    0.0042    1.00536    0.00011
  leu-comp-therm-005-007.i                    1.0000    0.0043    1.00137    0.00011
  leu-comp-therm-005-008.i                    1.0000    0.0021    1.00162    0.00011
  leu-comp-therm-005-009.i                    1.0000    0.0040    1.00216    0.00011
  leu-comp-therm-005-010.i                    1.0000    0.0028    1.00115    0.00011
  leu-comp-therm-005-011.i                    1.0000    0.0043    1.00172    0.00011
  leu-comp-therm-005-012.i                    1.0000    0.0066    1.00657    0.00011
  leu-comp-therm-005-013.i                    1.0000    0.0064    1.01207    0.00010
  leu-comp-therm-006-001.i                    1.0000    0.0030    0.99993    0.00010
  leu-comp-therm-006-002.i                    1.0000    0.0030    1.00050    0.00011
  leu-comp-therm-006-003.i                    1.0000    0.0030    1.00027    0.00010
  leu-comp-therm-006-004.i                    1.0000    0.0030    1.00021    0.00010
  leu-comp-therm-006-005.i                    1.0000    0.0030    0.99971    0.00010
  leu-comp-therm-006-006.i                    1.0000    0.0030    1.00033    0.00010
  leu-comp-therm-006-007.i                    1.0000    0.0030    1.00000    0.00011
  leu-comp-therm-006-008.i                    1.0000    0.0030    1.00014    0.00010
  leu-comp-therm-006-009.i                    1.0000    0.0030    0.99983    0.00010
  leu-comp-therm-006-010.i                    1.0000    0.0030    0.99977    0.00010
  leu-comp-therm-006-011.i                    1.0000    0.0030    0.99990    0.00010
  leu-comp-therm-006-012.i                    1.0000    0.0030    0.99978    0.00010
  leu-comp-therm-006-013.i                    1.0000    0.0030    0.99952    0.00009
  leu-comp-therm-006-014.i                    1.0000    0.0030    0.99977    0.00010
  leu-comp-therm-006-015.i                    1.0000    0.0030    0.99967    0.00010
  leu-comp-therm-006-016.i                    1.0000    0.0030    0.99973    0.00010
  leu-comp-therm-006-017.i                    1.0000    0.0030    0.99939    0.00010
  leu-comp-therm-006-018.i                    1.0000    0.0030    0.99948    0.00010
  leu-comp-therm-007-001.i                    1.0000    0.0014    0.99765    0.00012
  leu-comp-therm-007-002.i                    1.0000    0.0008    0.99889    0.00012
  leu-comp-therm-007-003.i                    1.0000    0.0007    0.99764    0.00010
  leu-comp-therm-007-004.i                    1.0000    0.0008    0.99806    0.00009
  leu-comp-therm-007-005.i                    1.0000    0.0014    0.99688    0.00011
  leu-comp-therm-007-006.i                    1.0000    0.0008    0.99877    0.00011
  leu-comp-therm-007-007.i                    1.0000    0.0007    0.99848    0.00010
  leu-comp-therm-007-008.i                    1.0000    0.0014    0.99820    0.00011
  leu-comp-therm-007-009.i                    1.0000    0.0008    0.99815    0.00011
  leu-comp-therm-007-010.i                    1.0000    0.0007    0.99858    0.00010
  leu-comp-therm-008-001.i                    1.0007    0.0012    1.00057    0.00009
  leu-comp-therm-008-002.i                    1.0007    0.0012    1.00108    0.00009
  leu-comp-therm-008-005.i                    1.0007    0.0012    1.00034    0.00010
  leu-comp-therm-008-007.i                    1.0007    0.0012    1.00006    0.00009
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leu-comp-therm-008-008.i                    1.0007    0.0012    0.99980    0.00010
leu-comp-therm-008-011.i                    1.0007    0.0012    1.00136    0.00010
leu-comp-therm-009-001.i                    1.0000    0.0021    0.99911    0.00010
leu-comp-therm-009-002.i                    1.0000    0.0021    0.99894    0.00010
leu-comp-therm-009-003.i                    1.0000    0.0021    0.99828    0.00010
leu-comp-therm-009-004.i                    1.0000    0.0021    0.99931    0.00010
leu-comp-therm-009-005.i                    1.0000    0.0021    0.99960    0.00011
leu-comp-therm-009-006.i                    1.0000    0.0021    0.99910    0.00010
leu-comp-therm-009-007.i                    1.0000    0.0021    0.99995    0.00011
leu-comp-therm-009-008.i                    1.0000    0.0021    0.99888    0.00011
leu-comp-therm-009-010.i                    1.0000    0.0021    0.99884    0.00010
leu-comp-therm-009-011.i                    1.0000    0.0021    0.99900    0.00010
leu-comp-therm-009-013.i                    1.0000    0.0021    0.99944    0.00011
leu-comp-therm-009-015.i                    1.0000    0.0021    0.99966    0.00011
leu-comp-therm-009-016.i                    1.0000    0.0021    0.99893    0.00010
leu-comp-therm-009-017.i                    1.0000    0.0021    0.99951    0.00010
leu-comp-therm-009-018.i                    1.0000    0.0021    0.99864    0.00010
leu-comp-therm-009-019.i                    1.0000    0.0021    0.99958    0.00010
leu-comp-therm-009-020.i                    1.0000    0.0021    0.99893    0.00011
leu-comp-therm-009-021.i                    1.0000    0.0021    0.99960    0.00010
leu-comp-therm-009-022.i                    1.0000    0.0021    0.99927    0.00011
leu-comp-therm-009-023.i                    1.0000    0.0021    1.00000    0.00011
leu-comp-therm-009-024.i                    1.0000    0.0021    0.99889    0.00010
leu-comp-therm-009-025.i                    1.0000    0.0021    0.99910    0.00011
leu-comp-therm-009-026.i                    1.0000    0.0021    0.99932    0.00010
leu-comp-therm-009-027.i                    1.0000    0.0021    0.99934    0.00010
leu-comp-therm-010-001.i                    1.0000    0.0021    1.00472    0.00010
leu-comp-therm-010-002.i                    1.0000    0.0021    1.00512    0.00010
leu-comp-therm-010-003.i                    1.0000    0.0021    1.00428    0.00011
leu-comp-therm-010-004.i                    1.0000    0.0021    0.99677    0.00011
leu-comp-therm-010-005.i                    1.0000    0.0021    0.99969    0.00010
leu-comp-therm-010-006.i                    1.0000    0.0021    1.00036    0.00010
leu-comp-therm-010-007.i                    1.0000    0.0021    1.00139    0.00010
leu-comp-therm-010-008.i                    1.0000    0.0021    0.99800    0.00010
leu-comp-therm-010-009.i                    1.0000    0.0021    0.99964    0.00010
leu-comp-therm-010-010.i                    1.0000    0.0021    1.00030    0.00011
leu-comp-therm-010-011.i                    1.0000    0.0021    1.00049    0.00010
leu-comp-therm-010-012.i                    1.0000    0.0021    0.99973    0.00011
leu-comp-therm-010-013.i                    1.0000    0.0021    0.99761    0.00010
leu-comp-therm-011-002.i                    1.0009    0.0032    0.99804    0.00009
leu-comp-therm-011-003.i                    1.0009    0.0032    0.99799    0.00010
leu-comp-therm-011-007.i                    1.0009    0.0032    0.99841    0.00010
leu-comp-therm-011-009.i                    1.0009    0.0032    0.99817    0.00010
leu-comp-therm-011-015.i                    1.0010    0.0018    0.99619    0.00009
leu-comp-therm-017-001.i                    1.0000    0.0031    1.00136    0.00009
leu-comp-therm-017-002.i                    1.0000    0.0031    1.00127    0.00009
leu-comp-therm-017-003.i                    1.0000    0.0031    0.99967    0.00009
leu-comp-therm-017-004.i                    1.0000    0.0031    0.99820    0.00009
leu-comp-therm-017-005.i                    1.0000    0.0031    0.99967    0.00009
leu-comp-therm-017-006.i                    1.0000    0.0031    0.99998    0.00009
leu-comp-therm-017-007.i                    1.0000    0.0031    0.99976    0.00009
leu-comp-therm-017-008.i                    1.0000    0.0031    0.99807    0.00009
leu-comp-therm-017-009.i                    1.0000    0.0031    0.99767    0.00009
leu-comp-therm-017-010.i                    1.0000    0.0031    0.99824    0.00009
leu-comp-therm-017-011.i                    1.0000    0.0031    0.99855    0.00009
leu-comp-therm-017-012.i                    1.0000    0.0031    0.99860    0.00009
leu-comp-therm-017-013.i                    1.0000    0.0031    0.99895    0.00009
leu-comp-therm-017-014.i                    1.0000    0.0031    0.99935    0.00009
leu-comp-therm-022-001.i                    1.0000    0.0046    1.00304    0.00012
leu-comp-therm-022-002.i                    1.0000    0.0046    1.00694    0.00011
leu-comp-therm-022-003.i                    1.0000    0.0036    1.00775    0.00011
leu-comp-therm-022-004.i                    1.0000    0.0037    1.00799    0.00011
leu-comp-therm-022-005.i                    1.0000    0.0038    1.00334    0.00011
leu-comp-therm-022-006.i                    1.0000    0.0046    1.00143    0.00009
leu-comp-therm-022-007.i                    1.0000    0.0046    1.00394    0.00009
leu-comp-therm-024-001.i                    1.0000    0.0054    1.00125    0.00012
leu-comp-therm-024-002.i                    1.0000    0.0054    1.00842    0.00011
leu-comp-therm-025-001.i                    1.0000    0.0041    0.98838    0.00011
leu-comp-therm-025-002.i                    1.0000    0.0044    0.99581    0.00011
leu-comp-therm-025-003.i                    1.0000    0.0047    1.00055    0.00011
leu-comp-therm-025-004.i                    1.0000    0.0052    1.00258    0.00010
leu-comp-therm-027-001.i                    1.0000    0.0011    1.00425    0.00010
leu-comp-therm-027-002.i                    1.0000    0.0011    1.00664    0.00011
leu-comp-therm-027-003.i                    1.0000    0.0011    1.00699    0.00011
leu-comp-therm-027-004.i                    1.0000    0.0011    1.00921    0.00011
leu-comp-therm-028-001.i                    0.9998    0.0047    0.99816    0.00011
leu-comp-therm-028-002.i                    1.0001    0.0054    0.99927    0.00011
leu-comp-therm-028-003.i                    0.9999    0.0051    0.99872    0.00011
leu-comp-therm-028-004.i                    1.0000    0.0043    1.00117    0.00010
leu-comp-therm-028-005.i                    1.0002    0.0048    1.00000    0.00010
leu-comp-therm-028-006.i                    1.0001    0.0045    1.00114    0.00010
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  leu-comp-therm-028-007.i                      0.9998    0.0047    0.99618    0.00011
  leu-comp-therm-028-008.i                      0.9998    0.0052    0.99401    0.00010
  leu-comp-therm-028-009.i                      0.9998    0.0047    0.99263    0.00011
  leu-comp-therm-028-010.i                      1.0004    0.0045    0.99754    0.00010
  leu-comp-therm-028-011.i                      1.0002    0.0045    0.99794    0.00010
  leu-comp-therm-028-012.i                      1.0000    0.0049    0.99616    0.00010
  leu-comp-therm-028-013.i                      0.9998    0.0050    0.99506    0.00010
  leu-comp-therm-028-014.i                      1.0001    0.0047    0.99292    0.00010
  leu-comp-therm-028-015.i                      0.9997    0.0044    0.99781    0.00009
  leu-comp-therm-028-016.i                      1.0000    0.0049    0.99836    0.00008
  leu-comp-therm-028-017.i                      1.0000    0.0047    0.99832    0.00010
  leu-comp-therm-028-018.i                      0.9999    0.0047    0.99868    0.00010
  leu-comp-therm-028-019.i                      1.0002    0.0046    0.99800    0.00009
  leu-comp-therm-028-020.i                      1.0001    0.0046    0.99575    0.00009
  leu-comp-therm-035-001.i                      1.0000    0.0018    0.99993    0.00010
  leu-comp-therm-035-002.i                      1.0000    0.0019    0.99918    0.00011
  leu-comp-therm-035-003.i                      1.0000    0.0022    0.99533    0.00010
  leu-comp-therm-039-001.i                      1.0000    0.0014    0.99737    0.00011
  leu-comp-therm-039-002.i                      1.0000    0.0014    0.99793    0.00011
  leu-comp-therm-039-003.i                      1.0000    0.0014    0.99739    0.00012
  leu-comp-therm-039-004.i                      1.0000    0.0014    0.99642    0.00012
  leu-comp-therm-039-005.i                      1.0000    0.0009    0.99752    0.00011
  leu-comp-therm-039-006.i                      1.0000    0.0009    0.99725    0.00011
  leu-comp-therm-039-007.i                      1.0000    0.0012    0.99675    0.00012
  leu-comp-therm-039-008.i                      1.0000    0.0012    0.99722    0.00011
  leu-comp-therm-039-009.i                      1.0000    0.0012    0.99681    0.00012
  leu-comp-therm-039-010.i                      1.0000    0.0012    0.99762    0.00011
  leu-comp-therm-060-001.i                      0.9990    0.0026    0.99866    0.00013
  leu-comp-therm-060-002.i                      0.9977    0.0026    0.99731    0.00014
  leu-comp-therm-060-003.i                      1.0001    0.0026    0.99984    0.00014
  leu-comp-therm-060-004.i                      1.0017    0.0026    0.99947    0.00016
  leu-comp-therm-060-005.i                      1.0009    0.0026    1.00148    0.00015
  leu-comp-therm-060-006.i                      0.9894    0.0027    0.98869    0.00018
  leu-comp-therm-079-001.i                      0.9999    0.0016    0.99818    0.00011
  leu-comp-therm-079-002.i                      1.0002    0.0016    0.99851    0.00011
  leu-comp-therm-079-003.i                      1.0005    0.0016    0.99900    0.00011
  leu-comp-therm-079-004.i                      1.0004    0.0016    0.99950    0.00011
  leu-comp-therm-079-005.i                      1.0004    0.0016    0.99962    0.00012
  leu-comp-therm-079-006.i                      0.9994    0.0008    0.99837    0.00011
  leu-comp-therm-079-007.i                      1.0003    0.0008    0.99778    0.00011
  leu-comp-therm-079-008.i                      1.0008    0.0008    0.99904    0.00011
  leu-comp-therm-079-009.i                      1.0003    0.0008    0.99858    0.00011
  leu-comp-therm-079-010.i                      1.0009    0.0008    0.99951    0.00011

#-------------------------------------------------------------------------------
# LEU-SOL-THERM
  leu-sol-therm-002-001.i                       1.0038    0.0040    0.99994    0.00008
  leu-sol-therm-002-002.i                       1.0024    0.0037    0.99586    0.00009
  leu-sol-therm-004-001.i                       0.9994    0.0008    1.00042    0.00010
  leu-sol-therm-004-002.i                       0.9999    0.0009    1.00178    0.00009
  leu-sol-therm-004-003.i                       0.9999    0.0009    0.99968    0.00009
  leu-sol-therm-004-004.i                       0.9999    0.0010    1.00194    0.00008
  leu-sol-therm-004-005.i                       0.9999    0.0010    1.00190    0.00009
  leu-sol-therm-004-006.i                       0.9994    0.0011    1.00107    0.00008
  leu-sol-therm-004-007.i                       0.9996    0.0011    1.00118    0.00008
  leu-sol-therm-007-001.i                       0.9994    0.0008    0.99539    0.00010
  leu-sol-therm-007-002.i                       0.9994    0.0008    0.99742    0.00010
  leu-sol-therm-007-003.i                       0.9994    0.0008    0.99617    0.00009
  leu-sol-therm-007-004.i                       0.9994    0.0008    0.99866    0.00009
  leu-sol-therm-007-005.i                       0.9994    0.0008    0.99742    0.00009
  leu-sol-therm-007-014.i                       0.9961    0.0009    0.99479    0.00010
  leu-sol-therm-007-030.i                       0.9973    0.0009    0.99741    0.00009
  leu-sol-therm-007-032.i                       0.9985    0.0010    0.99626    0.00009
  leu-sol-therm-007-036.i                       0.9988    0.0011    0.99902    0.00009
  leu-sol-therm-007-049.i                       0.9983    0.0011    0.99753    0.00008
  leu-sol-therm-020-001.i                       0.9995    0.0010    1.00007    0.00009
  leu-sol-therm-020-002.i                       0.9996    0.0010    0.99959    0.00008
  leu-sol-therm-020-003.i                       0.9997    0.0012    0.99898    0.00007
  leu-sol-therm-020-004.i                       0.9998    0.0012    1.00005    0.00007
  leu-sol-therm-021-001.i                       0.9983    0.0009    0.99775    0.00009
  leu-sol-therm-021-002.i                       0.9985    0.0010    0.99821    0.00008
  leu-sol-therm-021-003.i                       0.9989    0.0011    0.99732    0.00008
  leu-sol-therm-021-004.i                       0.9993    0.0012    0.99947    0.00007

#-------------------------------------------------------------------------------
# MIX-COMP-FAST
  mix-comp-fast-001-001.i                       0.9866    0.0023    0.98716    0.00007
  mix-comp-fast-002-001.i                       0.9874    0.0022    0.98544    0.00007

#-------------------------------------------------------------------------------
# MIX-COMP-INTER
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  mix-comp-inter-005-001.i                     1.1602    0.0055    1.16715    0.00009


#------------------------------------------------------------------------------
# MIX-COMP-THERM
  mix-comp-therm-001-001.i                     1.0000    0.0025    1.00086    0.00012
  mix-comp-therm-001-002.i                     1.0000    0.0026    0.99988    0.00011
  mix-comp-therm-001-003.i                     1.0000    0.0032    0.99968    0.00012
  mix-comp-therm-001-004.i                     1.0000    0.0039    1.00138    0.00011
  mix-comp-therm-002-001.i                     1.0010    0.0059    1.00099    0.00011
  mix-comp-therm-002-002.i                     1.0009    0.0045    1.00155    0.00011
  mix-comp-therm-002-003.i                     1.0024    0.0029    1.00242    0.00011
  mix-comp-therm-002-004.i                     1.0024    0.0021    1.00594    0.00011
  mix-comp-therm-002-005.i                     1.0038    0.0022    1.00348    0.00010
  mix-comp-therm-003-001.i                     1.0000    0.0071    1.00010    0.00011
  mix-comp-therm-003-002.i                     1.0000    0.0057    1.00067    0.00012
  mix-comp-therm-003-003.i                     1.0000    0.0052    1.00346    0.00013
  mix-comp-therm-003-004.i                     1.0000    0.0024    1.00003    0.00012
  mix-comp-therm-003-005.i                     1.0000    0.0028    1.00030    0.00011
  mix-comp-therm-003-006.i                     1.0000    0.0020    1.00096    0.00011


#------------------------------------------------------------------------------
# MIX-MET-FAST
  mix-met-fast-001-001.i                       1.0000    0.0016    0.99951    0.00008
  mix-met-fast-002-001.i                       1.0000    0.0042    1.00529    0.00010
  mix-met-fast-002-002.i                       1.0000    0.0044    1.00520    0.00010
  mix-met-fast-002-003.i                       1.0000    0.0048    1.00549    0.00010
  mix-met-fast-003-001.i                       0.9993    0.0017    1.00080    0.00009
  mix-met-fast-004-001.i                       0.9993    0.0013    1.00050    0.00009
  mix-met-fast-004-002.i                       0.9993    0.0013    0.99939    0.00009
 #-----> next benchmark was replaced on 2016-02-23
 #mix-met-fast-005-001.i                       0.9990    0.0017    1.00393    0.00009
  mix-met-fast-005-001.i                       0.9990    0.0017    1.00393    0.00009
  mix-met-fast-007-001.i                       1.0000    0.0045    1.00313    0.00011
  mix-met-fast-007-002.i                       1.0000    0.0023    1.00794    0.00011
  mix-met-fast-007-003.i                       1.0000    0.0028    1.00645    0.00010
  mix-met-fast-007-004.i                       1.0000    0.0028    1.00536    0.00010
  mix-met-fast-007-005.i                       1.0000    0.0032    1.00246    0.00009
  mix-met-fast-007-006.i                       1.0000    0.0035    1.00101    0.00009
  mix-met-fast-007-007.i                       1.0000    0.0032    1.00611    0.00011
  mix-met-fast-007-008.i                       1.0000    0.0030    1.00507    0.00011
  mix-met-fast-007-009.i                       1.0000    0.0028    1.00510    0.00010
  mix-met-fast-007-010.i                       1.0000    0.0027    1.00506    0.00010
  mix-met-fast-007-011.i                       1.0000    0.0026    1.00373    0.00010
  mix-met-fast-007-012.i                       1.0000    0.0030    1.00261    0.00009
  mix-met-fast-007-013.i                       1.0000    0.0033    1.00073    0.00009
  mix-met-fast-007-014.i                       1.0000    0.0032    1.00804    0.00010
  mix-met-fast-007-015.i                       1.0000    0.0032    1.00757    0.00010
  mix-met-fast-007-016.i                       1.0000    0.0028    1.00588    0.00009
  mix-met-fast-007-017.i                       1.0000    0.0028    1.00594    0.00009
  mix-met-fast-007-018.i                       1.0000    0.0030    1.00798    0.00009
  mix-met-fast-007-019.i                       1.0000    0.0034    1.00696    0.00009
  mix-met-fast-007-020.i                       1.0000    0.0030    1.00473    0.00009
  mix-met-fast-007-021.i                       1.0000    0.0031    1.00504    0.00009
  mix-met-fast-007-022.i                       1.0000    0.0030    1.00403    0.00009
  mix-met-fast-007-023.i                       1.0000    0.0028    1.00336    0.00009
  mix-met-fast-009-001.i                       1.0000    0.0010    1.00006    0.00008
  mix-met-fast-010-001.i                       1.0000    0.0009    0.99980    0.00009


#------------------------------------------------------------------------------
# MIX-MET-MIXED
  mix-met-mixed-001-001.i                       0.9991    0.0013    0.99973    0.00012


#------------------------------------------------------------------------------
# MIX-SOL-THERM
  mix-sol-therm-001-001.i                       1.0000    0.0016    0.99514    0.00013
  mix-sol-therm-001-002.i                       1.0000    0.0016    0.99507    0.00012
  mix-sol-therm-001-003.i                       1.0000    0.0016    0.98879    0.00013
  mix-sol-therm-001-004.i                       1.0000    0.0016    0.99435    0.00012
  mix-sol-therm-001-005.i                       1.0000    0.0016    0.99793    0.00012
  mix-sol-therm-001-006.i                       1.0000    0.0016    0.99557    0.00012
  mix-sol-therm-001-007.i                       1.0000    0.0016    1.00026    0.00013
  mix-sol-therm-001-008.i                       1.0000    0.0016    0.99963    0.00013
  mix-sol-therm-001-009.i                       1.0000    0.0016    0.99913    0.00012
  mix-sol-therm-001-010.i                       1.0000    0.0016    0.99971    0.00012
  mix-sol-therm-001-011.i                       1.0000    0.0052    1.03581    0.00012
  mix-sol-therm-003-001.i                       0.9985    0.0020    1.01250    0.00013
  mix-sol-therm-003-002.i                       0.9960    0.0020    1.01012    0.00013
  mix-sol-therm-003-003.i                       0.9935    0.0020    1.00927    0.00013
  mix-sol-therm-003-004.i                       0.9909    0.0020    1.00201    0.00013
  mix-sol-therm-003-005.i                       0.9981    0.0022    1.00386    0.00011
  mix-sol-therm-003-006.i                       0.9959    0.0022    1.00708    0.00012
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   mix-sol-therm-003-007.i                  0.9935    0.0020    1.00231    0.00012
   mix-sol-therm-003-008.i                  0.9988    0.0025    1.00655    0.00009
   mix-sol-therm-003-009.i                  0.9958    0.0025    1.00328    0.00010
   mix-sol-therm-003-010.i                  0.9964    0.0025    1.00337    0.00009


#-------------------------------------------------------------------------------
# PU-COMP-FAST
   pu-comp-fast-004-001.i                   1.0004    0.0044    0.99324    0.00009


#-------------------------------------------------------------------------------
# PU-COMP-INTER
   pu-comp-inter-001-001.i                  1.0000    0.0110    1.01174    0.00007


#-------------------------------------------------------------------------------
# PU-COMP-MIXED
 #-----> next benchmark was replaced on 2016-02-23
 #pu-comp-mixed-001-001.i                   0.9986    0.0041    1.02477    0.00009
  pu-comp-mixed-001-001.i                   0.9986    0.0041    1.02461    0.00009
 #-----> next benchmark was replaced on 2016-02-23
 #pu-comp-mixed-001-002.i                   1.0000    0.0068    1.02778    0.00013
  pu-comp-mixed-001-002.i                   1.0000    0.0068    1.02764    0.00013
 #-----> next benchmark was replaced on 2016-02-23
 #pu-comp-mixed-001-003.i                   0.9990    0.0067    1.02390    0.00013
  pu-comp-mixed-001-003.i                   0.9990    0.0067    1.02383    0.00015
 #-----> next benchmark was replaced on 2016-02-23
 #pu-comp-mixed-001-004.i                   1.0000    0.0066    0.99344    0.00013
  pu-comp-mixed-001-004.i                   1.0000    0.0066    0.99315    0.00014
 #-----> next benchmark was replaced on 2016-02-23
 #pu-comp-mixed-001-005.i                   0.9989    0.0072    0.98030    0.00014
  pu-comp-mixed-001-005.i                   0.9989    0.0072    1.00865    0.00014
  pu-comp-mixed-002-001.i                   0.9990    0.0046    1.03110    0.00012
  pu-comp-mixed-002-002.i                   0.9990    0.0046    1.02940    0.00012
  pu-comp-mixed-002-003.i                   0.9990    0.0046    1.02466    0.00011
  pu-comp-mixed-002-004.i                   0.9990    0.0046    1.01474    0.00012
  pu-comp-mixed-002-005.i                   0.9990    0.0046    1.01479    0.00012
  pu-comp-mixed-002-006.i                   1.0000    0.0075    1.02531    0.00012
  pu-comp-mixed-002-007.i                   1.0000    0.0075    1.02368    0.00012
  pu-comp-mixed-002-008.i                   1.0000    0.0075    1.02227    0.00013
  pu-comp-mixed-002-009.i                   1.0000    0.0075    1.02258    0.00013
  pu-comp-mixed-002-010.i                   1.0000    0.0073    1.03211    0.00013
  pu-comp-mixed-002-011.i                   1.0000    0.0073    1.02949    0.00013
  pu-comp-mixed-002-012.i                   1.0000    0.0073    1.02973    0.00012
  pu-comp-mixed-002-013.i                   1.0000    0.0073    1.02782    0.00014
  pu-comp-mixed-002-014.i                   1.0000    0.0073    1.03191    0.00013
  pu-comp-mixed-002-015.i                   1.0000    0.0073    1.02977    0.00013
  pu-comp-mixed-002-016.i                   1.0000    0.0073    1.02553    0.00013
  pu-comp-mixed-002-017.i                   0.9988    0.0055    1.00738    0.00013
  pu-comp-mixed-002-018.i                   0.9988    0.0055    1.01126    0.00012
  pu-comp-mixed-002-019.i                   0.9988    0.0055    1.01046    0.00013
  pu-comp-mixed-002-020.i                   0.9988    0.0055    1.01050    0.00013
  pu-comp-mixed-002-021.i                   0.9988    0.0055    1.01119    0.00012
  pu-comp-mixed-002-022.i                   0.9988    0.0055    1.01511    0.00013
  pu-comp-mixed-002-023.i                   1.0000    0.0068    1.00690    0.00012
  pu-comp-mixed-002-024.i                   1.0000    0.0068    1.00761    0.00013
  pu-comp-mixed-002-025.i                   1.0000    0.0068    1.00764    0.00014
  pu-comp-mixed-002-026.i                   1.0000    0.0068    1.00871    0.00014
  pu-comp-mixed-002-027.i                   1.0000    0.0068    1.00917    0.00013
  pu-comp-mixed-002-028.i                   1.0000    0.0068    1.00916    0.00013
  pu-comp-mixed-002-029.i                   1.0000    0.0068    1.01014    0.00013


#-------------------------------------------------------------------------------
# PU-MET-FAST
   pu-met-fast-001-001.i                    1.0000    0.0020    1.00001    0.00008
   pu-met-fast-002-001.i                    1.0000    0.0020    1.00000    0.00008
 #-----> next benchmark was replaced on 2016-02-23
 #pu-met-fast-003-103.i                     1.0000    0.0030    0.99873    0.00009
  pu-met-fast-003-103.i                     1.0000    0.0030    0.99873    0.00009
   pu-met-fast-005-001.i                    1.0000    0.0013    1.00125    0.00009
   pu-met-fast-006-001.i                    1.0000    0.0030    1.00107    0.00010
   pu-met-fast-008-001.i                    1.0000    0.0006    0.99814    0.00008
   pu-met-fast-009-001.i                    1.0000    0.0027    1.00573    0.00009
   pu-met-fast-010-001.i                    1.0000    0.0018    0.99968    0.00009
   pu-met-fast-011-001.i                    1.0000    0.0010    1.00014    0.00011
   pu-met-fast-012-001.i                    1.0009    0.0021    1.00300    0.00010
   pu-met-fast-013-001.i                    1.0034    0.0023    1.00820    0.00009
   pu-met-fast-014-001.i                    1.0037    0.0031    1.00646    0.00010
   pu-met-fast-015-001.i                    1.0041    0.0026    0.99995    0.00009
   pu-met-fast-016-001.i                    0.9976    0.0042    1.01764    0.00012
   pu-met-fast-016-002.i                    1.0000    0.0038    1.00711    0.00011
   pu-met-fast-016-003.i                    1.0000    0.0033    1.00513    0.00011
   pu-met-fast-016-004.i                    1.0000    0.0030    1.00478    0.00011
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  pu-met-fast-016-005.i                         1.0000      0.0034      1.00455     0.00011
  pu-met-fast-016-006.i                         1.0000      0.0032      1.00681     0.00010
#-----> next benchmark was replaced on 2016-02-23
#pu-met-fast-018-001.i                          1.0000      0.0030      0.99938     0.00009
  pu-met-fast-018-001.i                         1.0000      0.0030      0.99942     0.00010
#-----> next benchmark was replaced on 2016-02-23
#pu-met-fast-019-001.i                          0.9992      0.0015      1.00098     0.00010
  pu-met-fast-019-001.i                         0.9992      0.0015      1.00098     0.00010
  pu-met-fast-020-001.i                         0.9993      0.0017      0.99789     0.00009
  pu-met-fast-021-001.i                         1.0000      0.0026      1.00458     0.00009
  pu-met-fast-021-002.i                         1.0000      0.0026      0.99341     0.00010
  pu-met-fast-022-001.i                         1.0000      0.0021      0.99830     0.00008
#-----> next benchmark was replaced on 2016-02-23
#pu-met-fast-023-001.i                          1.0000      0.0022      0.99998     0.00009
  pu-met-fast-023-001.i                         1.0000      0.0022      0.99998     0.00009
#-----> next benchmark was replaced on 2016-02-23
#pu-met-fast-024-001.i                          1.0000      0.0022      1.00176     0.00009
  pu-met-fast-024-001.i                         1.0000      0.0022      1.00176     0.00009
  pu-met-fast-025-001.i                         1.0000      0.0022      0.99886     0.00009
  pu-met-fast-026-001.i                         1.0000      0.0022      0.99867     0.00009
#-----> next benchmark was replaced on 2016-02-23
#pu-met-fast-027-001.i                          1.0000      0.0024      1.00321     0.00010
  pu-met-fast-027-001.i                         1.0000      0.0024      1.00321     0.00010
  pu-met-fast-028-001.i                         1.0000      0.0024      0.99911     0.00009
  pu-met-fast-029-001.i                         1.0000      0.0024      0.99580     0.00008
  pu-met-fast-030-001.i                         1.0000      0.0023      1.00325     0.00009
  pu-met-fast-031-001.i                         1.0000      0.0023      1.00441     0.00010
  pu-met-fast-032-001.i                         1.0000      0.0022      0.99855     0.00009
  pu-met-fast-035-001.i                         1.0000      0.0016      0.99770     0.00008
  pu-met-fast-036-001.i                         1.0000      0.0031      1.00639     0.00009
  pu-met-fast-038-001.i                         1.0007      0.0019      1.00253     0.00010
  pu-met-fast-039-001.i                         1.0000      0.0022      0.99220     0.00009
  pu-met-fast-040-001.i                         1.0000      0.0038      0.99667     0.00009
#-----> next benchmark was replaced on 2016-02-23
#pu-met-fast-041-001.i                          1.0000      0.0016      1.00584     0.00010
  pu-met-fast-041-001.i                         1.0000      0.0016      1.00574     0.00010
  pu-met-fast-044-001.i                         0.9977      0.0021      1.00054     0.00009
  pu-met-fast-044-002.i                         0.9980      0.0022      0.99997     0.00010
  pu-met-fast-044-003.i                         0.9927      0.0021      0.99938     0.00010
  pu-met-fast-044-004.i                         0.9978      0.0026      1.00002     0.00010
  pu-met-fast-044-005.i                         0.9977      0.0024      0.99927     0.00011
  pu-met-fast-045-001.i                         1.0000      0.0047      1.00164     0.00009
  pu-met-fast-045-002.i                         1.0000      0.0046      1.00785     0.00010
  pu-met-fast-045-003.i                         1.0000      0.0044      1.00536     0.00009
  pu-met-fast-045-004.i                         1.0000      0.0046      1.00462     0.00009
  pu-met-fast-045-005.i                         1.0000      0.0045      1.00858     0.00009
  pu-met-fast-045-006.i                         1.0000      0.0049      1.00483     0.00009
  pu-met-fast-045-007.i                         1.0000      0.0050      1.00541     0.00009


#---------------------------------------------------------------------------------------
# PU-SOL-THERM
  pu-sol-therm-001-001.i                        1.0000      0.0050      1.00578     0.00013
  pu-sol-therm-001-002.i                        1.0000      0.0050      1.00730     0.00012
  pu-sol-therm-001-003.i                        1.0000      0.0050      1.01135     0.00013
  pu-sol-therm-001-004.i                        1.0000      0.0050      1.00441     0.00013
  pu-sol-therm-001-005.i                        1.0000      0.0050      1.00870     0.00013
  pu-sol-therm-001-006.i                        1.0000      0.0050      1.00955     0.00014
  pu-sol-therm-002-001.i                        1.0000      0.0047      1.00384     0.00012
  pu-sol-therm-002-002.i                        1.0000      0.0047      1.00475     0.00013
  pu-sol-therm-002-003.i                        1.0000      0.0047      1.00385     0.00013
  pu-sol-therm-002-004.i                        1.0000      0.0047      1.00667     0.00012
  pu-sol-therm-002-005.i                        1.0000      0.0047      1.00941     0.00012
  pu-sol-therm-002-006.i                        1.0000      0.0047      1.00518     0.00012
  pu-sol-therm-002-007.i                        1.0000      0.0047      1.00772     0.00012
  pu-sol-therm-003-001.i                        1.0000      0.0047      1.00268     0.00012
  pu-sol-therm-003-002.i                        1.0000      0.0047      1.00238     0.00012
  pu-sol-therm-003-003.i                        1.0000      0.0047      1.00513     0.00012
  pu-sol-therm-003-004.i                        1.0000      0.0047      1.00433     0.00012
  pu-sol-therm-003-005.i                        1.0000      0.0047      1.00568     0.00012
  pu-sol-therm-003-006.i                        1.0000      0.0047      1.00605     0.00012
  pu-sol-therm-003-007.i                        1.0000      0.0047      1.00668     0.00012
  pu-sol-therm-003-008.i                        1.0000      0.0047      1.00536     0.00011
  pu-sol-therm-004-001.i                        1.0000      0.0047      1.00399     0.00011
  pu-sol-therm-004-002.i                        1.0000      0.0047      0.99870     0.00011
  pu-sol-therm-004-003.i                        1.0000      0.0047      1.00090     0.00011
  pu-sol-therm-004-004.i                        1.0000      0.0047      0.99898     0.00011
  pu-sol-therm-004-005.i                        1.0000      0.0047      0.99983     0.00011
  pu-sol-therm-004-006.i                        1.0000      0.0047      1.00186     0.00011
  pu-sol-therm-004-007.i                        1.0000      0.0047      1.00564     0.00011
  pu-sol-therm-004-008.i                        1.0000      0.0047      1.00117     0.00010
  pu-sol-therm-004-009.i                        1.0000      0.0047      1.00069     0.00011
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pu-sol-therm-004-010.i                              1.0000    0.0047    1.00234   0.00011
pu-sol-therm-004-011.i                              1.0000    0.0047    1.00086   0.00012
pu-sol-therm-004-012.i                              1.0000    0.0047    1.00309   0.00012
pu-sol-therm-004-013.i                              1.0000    0.0047    1.00035   0.00011
pu-sol-therm-005-001.i                              1.0000    0.0047    1.00233   0.00012
pu-sol-therm-005-002.i                              1.0000    0.0047    1.00299   0.00012
pu-sol-therm-005-003.i                              1.0000    0.0047    1.00354   0.00011
pu-sol-therm-005-004.i                              1.0000    0.0047    1.00504   0.00011
pu-sol-therm-005-005.i                              1.0000    0.0047    1.00615   0.00011
pu-sol-therm-005-006.i                              1.0000    0.0047    1.00584   0.00012
pu-sol-therm-005-007.i                              1.0000    0.0047    1.00420   0.00012
pu-sol-therm-005-008.i                              1.0000    0.0047    0.99941   0.00011
pu-sol-therm-005-009.i                              1.0000    0.0047    1.00215   0.00011
pu-sol-therm-006-001.i                              1.0000    0.0035    1.00073   0.00011
pu-sol-therm-006-002.i                              1.0000    0.0035    1.00202   0.00011
pu-sol-therm-006-003.i                              1.0000    0.0035    1.00158   0.00011
pu-sol-therm-007-002.i                              1.0000    0.0047    1.00956   0.00012
pu-sol-therm-007-003.i                              1.0000    0.0047    1.00361   0.00013
pu-sol-therm-007-005.i                              1.0000    0.0047    1.00928   0.00013
pu-sol-therm-007-006.i                              1.0000    0.0047    1.00313   0.00013
pu-sol-therm-007-007.i                              1.0000    0.0047    1.00524   0.00013
pu-sol-therm-007-008.i                              1.0000    0.0047    0.99868   0.00013
pu-sol-therm-007-009.i                              1.0000    0.0047    0.99730   0.00013
pu-sol-therm-007-010.i                              1.0000    0.0047    1.00092   0.00012
pu-sol-therm-009-003.i                              1.0000    0.0033    1.01926   0.00006
pu-sol-therm-010-001.i                              1.0000    0.0048    1.01812   0.00013
pu-sol-therm-010-002.i                              1.0000    0.0048    1.01428   0.00013
pu-sol-therm-010-003.i                              1.0000    0.0048    1.00818   0.00013
pu-sol-therm-010-004.i                              1.0000    0.0048    1.01261   0.00013
pu-sol-therm-010-005.i                              1.0000    0.0048    1.01057   0.00012
pu-sol-therm-010-006.i                              1.0000    0.0048    1.00954   0.00012
pu-sol-therm-010-007.i                              1.0000    0.0048    1.00241   0.00012
pu-sol-therm-010-008.i                              1.0000    0.0048    1.00377   0.00011
pu-sol-therm-010-009.i                              1.0000    0.0048    1.01445   0.00012
pu-sol-therm-010-010.i                              1.0000    0.0048    1.00259   0.00012
pu-sol-therm-010-011.i                              1.0000    0.0048    1.00985   0.00012
pu-sol-therm-010-012.i                              1.0000    0.0048    1.00953   0.00012
pu-sol-therm-010-013.i                              1.0000    0.0048    1.01576   0.00011
pu-sol-therm-010-014.i                              1.0000    0.0048    1.00967   0.00011
pu-sol-therm-011-161.i                              1.0000    0.0052    1.00962   0.00012
pu-sol-therm-011-162.i                              1.0000    0.0052    1.01483   0.00013
pu-sol-therm-011-163.i                              1.0000    0.0052    1.01657   0.00013
pu-sol-therm-011-164.i                              1.0000    0.0052    1.00927   0.00012
pu-sol-therm-011-165.i                              1.0000    0.0052    1.00642   0.00013
pu-sol-therm-011-181.i                              1.0000    0.0052    0.99435   0.00012
pu-sol-therm-011-182.i                              1.0000    0.0052    1.00045   0.00012
pu-sol-therm-011-183.i                              1.0000    0.0052    0.99679   0.00011
pu-sol-therm-011-184.i                              1.0000    0.0052    0.99366   0.00011
pu-sol-therm-011-185.i                              1.0000    0.0052    1.00372   0.00012
pu-sol-therm-011-186.i                              1.0000    0.0052    1.00025   0.00012
pu-sol-therm-011-187.i                              1.0000    0.0052    0.99970   0.00011
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-001.i                             1.0000    0.0043    1.00536   0.00009
 pu-sol-therm-012-001.i                             1.0000    0.0043    1.00536   0.00009
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-002.i                             1.0000    0.0043    1.00615   0.00008
 pu-sol-therm-012-002.i                             1.0000    0.0043    1.00615   0.00008
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-003.i                             1.0000    0.0058    1.00736   0.00008
 pu-sol-therm-012-003.i                             1.0000    0.0058    1.00736   0.00008
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-004.i                             1.0000    0.0058    1.00746   0.00007
 pu-sol-therm-012-004.i                             1.0000    0.0058    1.00746   0.00007
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-005.i                             1.0000    0.0058    1.00981   0.00006
 pu-sol-therm-012-005.i                             1.0000    0.0058    1.00981   0.00006
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-006.i                             1.0000    0.0007    1.00659   0.00013
 pu-sol-therm-012-006.i                             1.0000    0.0007    1.00659   0.00013
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-007.i                             1.0000    0.0013    1.00537   0.00013
 pu-sol-therm-012-007.i                             1.0000    0.0013    1.00537   0.00013
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-008.i                             1.0000    0.0013    1.00417   0.00012
 pu-sol-therm-012-008.i                             1.0000    0.0013    1.00417   0.00012
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-009.i                             1.0000    0.0043    1.00966   0.00011
 pu-sol-therm-012-009.i                             1.0000    0.0043    1.00966   0.00011
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-010.i                             1.0000    0.0043    1.00409   0.00010
 pu-sol-therm-012-010.i                             1.0000    0.0043    1.00409   0.00010
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#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-011.i                         1.0000     0.0043     1.00670     0.00010
 pu-sol-therm-012-011.i                         1.0000     0.0043     1.00670     0.00010
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-012.i                         1.0000     0.0043     1.00721     0.00009
 pu-sol-therm-012-012.i                         1.0000     0.0043     1.00721     0.00009
#-----> next benchmark was replaced on 2016-02-23
#pu-sol-therm-012-013.i                         1.0000     0.0058     1.00964     0.00007
 pu-sol-therm-012-013.i                         1.0000     0.0058     1.00964     0.00007
 pu-sol-therm-018-001.i                         1.0000     0.0034     1.00849     0.00013
 pu-sol-therm-018-002.i                         1.0000     0.0034     1.01189     0.00012
 pu-sol-therm-018-003.i                         1.0000     0.0032     1.00938     0.00012
 pu-sol-therm-018-004.i                         1.0000     0.0030     1.00765     0.00012
 pu-sol-therm-018-005.i                         1.0000     0.0030     1.00654     0.00011
 pu-sol-therm-018-006.i                         1.0000     0.0031     1.00462     0.00012
 pu-sol-therm-018-007.i                         1.0000     0.0032     1.00399     0.00010
 pu-sol-therm-018-008.i                         1.0000     0.0033     1.00356     0.00011
 pu-sol-therm-018-009.i                         1.0000     0.0034     1.00176     0.00010
 pu-sol-therm-022-001.i                         1.0000     0.0020     0.99953     0.00013
 pu-sol-therm-022-002.i                         1.0000     0.0016     1.00205     0.00013
 pu-sol-therm-022-003.i                         1.0000     0.0015     1.00071     0.00012
 pu-sol-therm-022-004.i                         1.0000     0.0017     1.00135     0.00012
 pu-sol-therm-022-005.i                         1.0000     0.0019     1.00225     0.00011
 pu-sol-therm-022-006.i                         1.0000     0.0021     1.00269     0.00011
 pu-sol-therm-022-007.i                         1.0000     0.0021     1.00423     0.00011
 pu-sol-therm-022-008.i                         1.0000     0.0023     1.00505     0.00010
 pu-sol-therm-022-009.i                         1.0000     0.0024     1.00368     0.00010
 pu-sol-therm-028-001.i                         1.0000     0.0012     1.00788     0.00012
 pu-sol-therm-028-002.i                         1.0000     0.0012     1.00708     0.00012
 pu-sol-therm-028-003.i                         1.0000     0.0012     1.00890     0.00012
 pu-sol-therm-028-004.i                         1.0000     0.0012     1.00871     0.00012
 pu-sol-therm-028-005.i                         1.0000     0.0012     1.00991     0.00012
 pu-sol-therm-028-006.i                         1.0000     0.0012     1.01070     0.00011
 pu-sol-therm-028-007.i                         1.0000     0.0012     1.00815     0.00012
 pu-sol-therm-028-008.i                         1.0000     0.0012     1.00826     0.00012
 pu-sol-therm-028-009.i                         1.0000     0.0012     1.00989     0.00012
 pu-sol-therm-032-001.i                         1.0000     0.0019     0.99617     0.00013
 pu-sol-therm-032-002.i                         1.0000     0.0019     1.00142     0.00012
 pu-sol-therm-032-003.i                         1.0000     0.0019     1.00264     0.00012
 pu-sol-therm-032-004.i                         1.0000     0.0019     1.00255     0.00012
 pu-sol-therm-032-005.i                         1.0000     0.0019     1.00439     0.00012
 pu-sol-therm-032-006.i                         1.0000     0.0019     1.00477     0.00011
 pu-sol-therm-032-007.i                         1.0000     0.0019     1.00496     0.00011
 pu-sol-therm-032-008.i                         1.0000     0.0019     1.00440     0.00011
 pu-sol-therm-032-009.i                         1.0000     0.0019     1.00326     0.00011
 pu-sol-therm-032-010.i                         1.0000     0.0019     1.00514     0.00011
 pu-sol-therm-032-011.i                         1.0000     0.0019     1.00448     0.00010
 pu-sol-therm-032-012.i                         1.0000     0.0019     1.00347     0.00010
 pu-sol-therm-032-013.i                         1.0000     0.0019     1.00230     0.00012
 pu-sol-therm-032-014.i                         1.0000     0.0019     1.00212     0.00012
 pu-sol-therm-032-015.i                         1.0000     0.0019     1.00402     0.00011
 pu-sol-therm-032-016.i                         1.0000     0.0019     1.00382     0.00011
 pu-sol-therm-032-017.i                         1.0000     0.0019     1.00389     0.00011
 pu-sol-therm-034-001.i                         1.0000     0.0062     0.99995     0.00013
 pu-sol-therm-034-002.i                         1.0000     0.0044     1.00148     0.00012
 pu-sol-therm-034-003.i                         1.0000     0.0040     0.99950     0.00012
 pu-sol-therm-034-004.i                         1.0000     0.0039     1.00248     0.00012
 pu-sol-therm-034-005.i                         1.0000     0.0040     0.99991     0.00010
 pu-sol-therm-034-006.i                         1.0000     0.0042     1.00114     0.00010
 pu-sol-therm-034-007.i                         1.0000     0.0057     0.99870     0.00012
 pu-sol-therm-034-008.i                         1.0000     0.0055     0.99889     0.00012
 pu-sol-therm-034-009.i                         1.0000     0.0052     0.99776     0.00011
 pu-sol-therm-034-010.i                         1.0000     0.0052     0.99732     0.00012
 pu-sol-therm-034-011.i                         1.0000     0.0048     0.99902     0.00011
 pu-sol-therm-034-012.i                         1.0000     0.0042     0.99847     0.00011
 pu-sol-therm-034-013.i                         1.0000     0.0043     0.99696     0.00010
 pu-sol-therm-034-014.i                         1.0000     0.0044     0.99681     0.00011
 pu-sol-therm-034-015.i                         1.0000     0.0042     0.99717     0.00011
 pu-sol-therm-038-001.i                         1.0005     0.0015     1.00318     0.00009
 pu-sol-therm-038-002.i                         1.0005     0.0015     1.00365     0.00009
 pu-sol-therm-038-003.i                         1.0005     0.0018     1.00359     0.00007
 pu-sol-therm-038-004.i                         1.0005     0.0013     1.00173     0.00007
 pu-sol-therm-038-005.i                         1.0005     0.0013     1.00192     0.00007


#------------------------------------------------------------------------------------
# U233-COMP-THERM
 u233-comp-therm-001-001.i                      1.0006     0.0027     0.99947     0.00013
 u233-comp-therm-001-002.i                      1.0015     0.0025     1.00208     0.00014
 u233-comp-therm-001-003.i                      1.0000     0.0024     1.00220     0.00015
 u233-comp-therm-001-004.i                      1.0007     0.0025     1.00063     0.00012
 u233-comp-therm-001-005.i                      1.0015     0.0026     1.00018     0.00012
```

```
  u233-comp-therm-001-006.i                    1.0015    0.0028    0.99874   0.00013
  u233-comp-therm-001-007.i                    0.9995    0.0027    1.00172   0.00014
  u233-comp-therm-001-008.i                    1.0004    0.0028    0.99948   0.00013
  u233-comp-therm-004-001.i                    1.0017    0.0018    0.99795   0.00009


#------------------------------------------------------------------------------------
# U233-MET-FAST
  u233-met-fast-001-001.i                      1.0000    0.0010    0.99986   0.00008
  u233-met-fast-002-001.i                      1.0000    0.0010    0.99874   0.00008
  u233-met-fast-002-002.i                      1.0000    0.0011    1.00022   0.00009
  u233-met-fast-003-001.i                      1.0000    0.0010    0.99923   0.00008
  u233-met-fast-003-002.i                      1.0000    0.0010    0.99961   0.00009
  u233-met-fast-004-001.i                      1.0000    0.0007    0.99847   0.00009
  u233-met-fast-004-002.i                      1.0000    0.0008    0.99571   0.00010
  u233-met-fast-005-001.i                      1.0000    0.0010    0.99608   0.00009
  u233-met-fast-005-002.i                      1.0000    0.0030    0.99510   0.00010
  u233-met-fast-006-001.i                      1.0000    0.0014    0.99902   0.00010


#------------------------------------------------------------------------------------
# U233-SOL-INTER
  u233-sol-inter-001-001.i                     1.0000    0.0083    0.98507   0.00016
  u233-sol-inter-001-002.i                     1.0000    0.0085    0.98099   0.00015
  u233-sol-inter-001-003.i                     1.0000    0.0066    0.98188   0.00016
  u233-sol-inter-001-004.i                     1.0000    0.0061    0.99343   0.00015
  u233-sol-inter-001-005.i                     1.0000    0.0082    0.98486   0.00015
  u233-sol-inter-001-006.i                     1.0000    0.0061    0.98657   0.00015
  u233-sol-inter-001-007.i                     1.0000    0.0059    0.98249   0.00016
  u233-sol-inter-001-008.i                     1.0000    0.0056    0.98182   0.00016
  u233-sol-inter-001-009.i                     1.0000    0.0068    0.97966   0.00016
  u233-sol-inter-001-010.i                     1.0000    0.0053    0.97897   0.00017
  u233-sol-inter-001-011.i                     1.0000    0.0057    0.98069   0.00017
  u233-sol-inter-001-012.i                     1.0000    0.0091    0.98156   0.00015
  u233-sol-inter-001-013.i                     1.0000    0.0071    0.98258   0.00016
  u233-sol-inter-001-014.i                     1.0000    0.0052    0.99135   0.00015
  u233-sol-inter-001-015.i                     1.0000    0.0075    0.98048   0.00015
  u233-sol-inter-001-016.i                     1.0000    0.0028    0.98186   0.00015
  u233-sol-inter-001-017.i                     1.0000    0.0055    0.98956   0.00015
  u233-sol-inter-001-018.i                     1.0000    0.0057    0.97879   0.00015
  u233-sol-inter-001-019.i                     1.0000    0.0083    0.97595   0.00016
  u233-sol-inter-001-020.i                     1.0000    0.0056    0.98080   0.00016
  u233-sol-inter-001-021.i                     1.0000    0.0050    0.97333   0.00016
  u233-sol-inter-001-022.i                     1.0000    0.0049    0.97873   0.00016
  u233-sol-inter-001-023.i                     1.0000    0.0047    0.99031   0.00016
  u233-sol-inter-001-024.i                     1.0000    0.0081    0.99265   0.00015
  u233-sol-inter-001-025.i                     1.0000    0.0081    0.98564   0.00015
  u233-sol-inter-001-026.i                     1.0000    0.0065    0.98949   0.00015
  u233-sol-inter-001-027.i                     1.0000    0.0051    0.99137   0.00016
  u233-sol-inter-001-028.i                     1.0000    0.0061    0.98406   0.00016
  u233-sol-inter-001-029.i                     1.0000    0.0098    0.97766   0.00015
  u233-sol-inter-001-030.i                     1.0000    0.0053    0.97875   0.00016
  u233-sol-inter-001-031.i                     1.0000    0.0071    0.99140   0.00017
  u233-sol-inter-001-032.i                     1.0000    0.0053    0.97609   0.00016
  u233-sol-inter-001-033.i                     1.0000    0.0046    0.99414   0.00016


#------------------------------------------------------------------------------------
# U233-SOL-THERM
  u233-sol-therm-001-001.i                     1.0000    0.0031    1.00126   0.00008
  u233-sol-therm-001-002.i                     1.0005    0.0033    1.00140   0.00008
  u233-sol-therm-001-003.i                     1.0006    0.0033    1.00082   0.00008
  u233-sol-therm-001-004.i                     0.9998    0.0033    1.00089   0.00009
  u233-sol-therm-001-005.i                     0.9999    0.0033    0.99994   0.00008
  u233-sol-therm-005-001.i                     1.0000    0.0040    1.00181   0.00013
  u233-sol-therm-005-002.i                     1.0000    0.0049    1.00474   0.00012
  u233-sol-therm-008-001.i                     1.0006    0.0029    1.00136   0.00006
  u233-sol-therm-009-001.i                     0.9966    0.0044    0.99612   0.00006
  u233-sol-therm-009-002.i                     0.9981    0.0040    0.99929   0.00006
  u233-sol-therm-009-003.i                     0.9989    0.0038    1.00041   0.00005
  u233-sol-therm-009-004.i                     0.9998    0.0038    0.99935   0.00005
  u233-sol-therm-012-001.i                     1.0000    0.0028    1.00080   0.00015
  u233-sol-therm-012-002.i                     1.0000    0.0025    1.00010   0.00014
  u233-sol-therm-012-003.i                     1.0000    0.0023    1.00947   0.00015
  u233-sol-therm-012-004.i                     1.0000    0.0015    1.00254   0.00014
  u233-sol-therm-012-005.i                     1.0000    0.0071    1.00515   0.00014
  u233-sol-therm-012-006.i                     1.0000    0.0010    1.00579   0.00014
  u233-sol-therm-012-007.i                     1.0000    0.0038    1.00173   0.00012
  u233-sol-therm-012-008.i                     1.0000    0.0048    0.99916   0.00012
  u233-sol-therm-013-001.i                     0.9992    0.0073    1.00528   0.00016
  u233-sol-therm-013-002.i                     0.9992    0.0070    1.00604   0.00016
  u233-sol-therm-013-003.i                     0.9992    0.0069    1.00588   0.00016
  u233-sol-therm-013-004.i                     0.9992    0.0073    1.00657   0.00017
  u233-sol-therm-013-005.i                     0.9992    0.0067    1.00724   0.00015
```

| | | | | |
|---|---|---|---|---|
| u233-sol-therm-013-006.i | 0.9992 | 0.0050 | 1.00622 | 0.00016 |
| u233-sol-therm-013-007.i | 0.9992 | 0.0054 | 1.00610 | 0.00015 |
| u233-sol-therm-013-008.i | 0.9992 | 0.0050 | 1.00730 | 0.00016 |
| u233-sol-therm-013-009.i | 0.9992 | 0.0045 | 1.00740 | 0.00016 |
| u233-sol-therm-013-010.i | 0.9992 | 0.0046 | 1.00825 | 0.00017 |
| u233-sol-therm-013-011.i | 0.9992 | 0.0054 | 1.00510 | 0.00017 |
| u233-sol-therm-013-012.i | 0.9992 | 0.0050 | 1.00588 | 0.00016 |
| u233-sol-therm-013-013.i | 0.9992 | 0.0062 | 1.00354 | 0.00016 |
| u233-sol-therm-013-014.i | 0.9992 | 0.0051 | 1.00666 | 0.00015 |
| u233-sol-therm-013-015.i | 0.9996 | 0.0077 | 1.02128 | 0.00016 |
| u233-sol-therm-013-016.i | 0.9996 | 0.0069 | 0.99376 | 0.00015 |
| u233-sol-therm-013-017.i | 0.9996 | 0.0052 | 0.99644 | 0.00015 |
| u233-sol-therm-013-018.i | 0.9996 | 0.0020 | 1.00029 | 0.00016 |
| u233-sol-therm-013-019.i | 0.9996 | 0.0089 | 0.99625 | 0.00016 |
| u233-sol-therm-013-020.i | 0.9996 | 0.0056 | 0.99973 | 0.00014 |
| u233-sol-therm-013-021.i | 0.9996 | 0.0034 | 1.00279 | 0.00013 |
| u233-sol-therm-015-001.i | 1.0000 | 0.0075 | 0.99033 | 0.00015 |
| u233-sol-therm-015-002.i | 1.0000 | 0.0070 | 0.98597 | 0.00015 |
| u233-sol-therm-015-003.i | 1.0000 | 0.0068 | 0.98710 | 0.00015 |
| u233-sol-therm-015-004.i | 1.0000 | 0.0041 | 0.99033 | 0.00015 |
| u233-sol-therm-015-005.i | 1.0000 | 0.0055 | 0.98667 | 0.00016 |
| u233-sol-therm-015-006.i | 1.0000 | 0.0099 | 0.97710 | 0.00016 |
| u233-sol-therm-015-007.i | 1.0000 | 0.0070 | 0.98796 | 0.00015 |
| u233-sol-therm-015-008.i | 1.0000 | 0.0067 | 0.97363 | 0.00015 |
| u233-sol-therm-015-009.i | 1.0000 | 0.0050 | 0.96945 | 0.00017 |
| u233-sol-therm-015-010.i | 1.0000 | 0.0051 | 0.98977 | 0.00016 |
| u233-sol-therm-015-011.i | 1.0000 | 0.0075 | 0.99361 | 0.00016 |
| u233-sol-therm-015-012.i | 1.0000 | 0.0069 | 0.99409 | 0.00016 |
| u233-sol-therm-015-013.i | 1.0000 | 0.0069 | 0.99214 | 0.00017 |
| u233-sol-therm-015-014.i | 1.0000 | 0.0036 | 0.99852 | 0.00015 |
| u233-sol-therm-015-015.i | 1.0000 | 0.0060 | 0.98968 | 0.00016 |
| u233-sol-therm-015-016.i | 1.0000 | 0.0043 | 0.98879 | 0.00016 |
| u233-sol-therm-015-017.i | 1.0000 | 0.0029 | 0.99807 | 0.00016 |
| u233-sol-therm-015-018.i | 1.0000 | 0.0056 | 0.97480 | 0.00016 |
| u233-sol-therm-015-019.i | 1.0000 | 0.0052 | 0.97504 | 0.00017 |
| u233-sol-therm-015-020.i | 1.0000 | 0.0079 | 0.99528 | 0.00015 |
| u233-sol-therm-015-021.i | 1.0000 | 0.0070 | 0.99805 | 0.00015 |
| u233-sol-therm-015-022.i | 1.0000 | 0.0062 | 0.99645 | 0.00016 |
| u233-sol-therm-015-023.i | 1.0000 | 0.0055 | 0.99478 | 0.00015 |
| u233-sol-therm-015-024.i | 1.0000 | 0.0051 | 0.99088 | 0.00016 |
| u233-sol-therm-015-025.i | 1.0000 | 0.0023 | 0.99854 | 0.00015 |
| u233-sol-therm-015-026.i | 1.0000 | 0.0066 | 0.99418 | 0.00015 |
| u233-sol-therm-015-027.i | 1.0000 | 0.0063 | 0.99908 | 0.00015 |
| u233-sol-therm-015-028.i | 1.0000 | 0.0058 | 0.99716 | 0.00014 |
| u233-sol-therm-015-029.i | 1.0000 | 0.0051 | 0.99553 | 0.00015 |
| u233-sol-therm-015-030.i | 1.0000 | 0.0048 | 0.99477 | 0.00015 |
| u233-sol-therm-015-031.i | 1.0000 | 0.0055 | 0.99419 | 0.00015 |
| u233-sol-therm-016-001.i | 0.9987 | 0.0037 | 1.00416 | 0.00016 |
| u233-sol-therm-016-002.i | 0.9983 | 0.0044 | 1.00487 | 0.00016 |
| u233-sol-therm-016-003.i | 0.9992 | 0.0036 | 1.00443 | 0.00016 |
| u233-sol-therm-016-006.i | 0.9993 | 0.0034 | 0.99640 | 0.00017 |
| u233-sol-therm-016-007.i | 1.0008 | 0.0034 | 0.99710 | 0.00017 |
| u233-sol-therm-016-008.i | 1.0011 | 0.0028 | 0.99684 | 0.00016 |
| u233-sol-therm-016-010.i | 1.0000 | 0.0030 | 1.00490 | 0.00017 |
| u233-sol-therm-016-011.i | 0.9992 | 0.0041 | 1.00488 | 0.00017 |
| u233-sol-therm-016-012.i | 0.9992 | 0.0047 | 1.00475 | 0.00018 |
| u233-sol-therm-016-013.i | 0.9993 | 0.0036 | 1.00505 | 0.00016 |
| u233-sol-therm-016-014.i | 1.0000 | 0.0026 | 1.00578 | 0.00016 |
| u233-sol-therm-016-015.i | 1.0000 | 0.0027 | 1.00622 | 0.00016 |
| u233-sol-therm-016-016.i | 0.9994 | 0.0031 | 1.00978 | 0.00016 |
| u233-sol-therm-016-017.i | 1.0000 | 0.0028 | 0.99551 | 0.00015 |
| u233-sol-therm-016-018.i | 0.9988 | 0.0036 | 0.99566 | 0.00016 |
| u233-sol-therm-016-021.i | 1.0000 | 0.0028 | 1.00969 | 0.00016 |
| u233-sol-therm-016-022.i | 1.0000 | 0.0034 | 1.00945 | 0.00016 |
| u233-sol-therm-016-023.i | 1.0000 | 0.0031 | 1.01001 | 0.00017 |
| u233-sol-therm-016-025.i | 0.9981 | 0.0040 | 1.00042 | 0.00014 |
| u233-sol-therm-016-026.i | 0.9980 | 0.0034 | 1.00535 | 0.00015 |
| u233-sol-therm-016-027.i | 0.9988 | 0.0037 | 1.00372 | 0.00015 |
| u233-sol-therm-016-028.i | 0.9986 | 0.0037 | 0.99915 | 0.00014 |
| u233-sol-therm-016-029.i | 0.9985 | 0.0031 | 0.99979 | 0.00015 |
| u233-sol-therm-016-030.i | 0.9993 | 0.0032 | 0.99955 | 0.00016 |
| u233-sol-therm-016-031.i | 0.9990 | 0.0034 | 1.01041 | 0.00014 |
| u233-sol-therm-016-032.i | 0.9985 | 0.0032 | 1.01255 | 0.00013 |
| u233-sol-therm-016-033.i | 0.9986 | 0.0039 | 1.01253 | 0.00013 |
| u233-sol-therm-017-001.i | 0.9997 | 0.0032 | 1.00427 | 0.00015 |
| u233-sol-therm-017-002.i | 1.0000 | 0.0025 | 1.00007 | 0.00014 |
| u233-sol-therm-017-003.i | 1.0001 | 0.0035 | 1.00552 | 0.00015 |
| u233-sol-therm-017-004.i | 0.9994 | 0.0040 | 1.00549 | 0.00014 |
| u233-sol-therm-017-005.i | 1.0000 | 0.0029 | 1.00165 | 0.00015 |
| u233-sol-therm-017-006.i | 1.0000 | 0.0029 | 1.00055 | 0.00013 |
| u233-sol-therm-017-007.i | 1.0000 | 0.0037 | 1.00063 | 0.00012 |

```
#-----------------------------------------------------------------------------------------
##########################################################################################
# =====> NEW BENCHMARKS -- ADDED ON 2016-02-23
##########################################################################################
pu-met-fast-042-001.i                         1.0004    0.0077    1.01849    0.00012
pu-met-fast-042-002.i                         1.0007    0.0074    1.01271    0.00011
pu-met-fast-042-003.i                         1.0013    0.0080    1.01214    0.00011
pu-met-fast-042-004.i                         1.0026    0.0080    1.01021    0.00010
pu-met-fast-042-005.i                         1.0013    0.0080    1.01021    0.00010
pu-met-fast-042-006.i                         1.0015    0.0079    1.00915    0.00010
pu-met-fast-042-007.i                         1.0006    0.0075    1.00850    0.00010
pu-met-fast-042-008.i                         1.0019    0.0080    1.01140    0.00011
pu-met-fast-042-009.i                         1.0019    0.0073    1.01067    0.00010
pu-met-fast-042-010.i                         1.0015    0.0079    1.01295    0.00011
pu-met-fast-042-011.i                         1.0010    0.0078    1.01214    0.00010
pu-met-fast-042-012.i                         1.0016    0.0076    1.01212    0.00010
pu-met-fast-042-013.i                         1.0016    0.0074    1.01203    0.00011
pu-met-fast-042-014.i                         1.0016    0.0078    1.01273    0.00010
pu-met-fast-042-015.i                         1.0014    0.0076    1.01243    0.00010
##########################################################################################
```

# Appendix C - Whisper-1.1 Covariance Data

The covariance data for the nuclear cross-sections that are included with Whisper-1.1 are based on the BLO "low-fidelity" data [7,8]. The covariance data currently included with Whisper-1.1 are ACE format covariance files [8]. Extensive checking of the data was performed to verify that the numbers (not format) exactly matched those in the covariance files used with Whisper-1.0. The data contained in the ACE covariance files are consistent with the Scale6.0 low-fidelity covariance data from Scale file *scale.rev04.44groupcov*. See [8] for the correspondence between the ACE file ZA's and SCALE material numbers for comparable data.

The BLO-44g "low fidelity" covariance data files included with Whisper-1.1 are listed below. A few notes on the available ZA's are listed after that.

| | | | | | |
|---|---|---|---|---|---|
| 1001.01v | 1002.01v | 1003.01v | 2003.01v | 2004.01v | 3006.01v |
| 3007.01v | 4007.01v | 4009.01v | 5010.01v | 5011.01v | 6000.01v |
| 7014.01v | 7015.01v | 8016.01v | 8017.01v | 9019.01v | 11023.01v |
| 12000.01v | 12024.01v | 12025.01v | 12026.01v | 13027.01v | 14000.01v |
| 14028.01v | 14029.01v | 14030.01v | 15031.01v | 16000.01v | 16032.01v |
| 16033.01v | 16034.01v | 16036.01v | 17000.01v | 17035.01v | 17037.01v |
| 18036.01v | 18038.01v | 18040.01v | 19000.01v | 19039.01v | 19040.01v |
| 19041.01v | 20000.01v | 20040.01v | 20042.01v | 20043.01v | 20044.01v |
| 20046.01v | 20048.01v | 21045.01v | 22000.01v | 22046.01v | 22047.01v |
| 22048.01v | 22049.01v | 22050.01v | 23000.01v | 24050.01v | 24052.01v |
| 24053.01v | 24054.01v | 25055.01v | 26054.01v | 26056.01v | 26057.01v |
| 26058.01v | 27059.01v | 27059.01v | 27458.01v | 28058.01v | 28059.01v |
| 28060.01v | 28061.01v | 28062.01v | 28064.01v | 29063.01v | 29065.01v |
| 31000.01v | 31069.01v | 31071.01v | 32070.01v | 32072.01v | 32073.01v |
| 32074.01v | 32076.01v | 33074.01v | 33075.01v | 34074.01v | 34076.01v |
| 34077.01v | 34078.01v | 34079.01v | 34080.01v | 34082.01v | 35079.01v |
| 35081.01v | 36078.01v | 36080.01v | 36082.01v | 36083.01v | 36084.01v |
| 36085.01v | 36086.01v | 37085.01v | 37086.01v | 37087.01v | 38084.01v |
| 38086.01v | 38087.01v | 38088.01v | 38090.01v | 38090.01v | 39089.01v |
| 39090.01v | 39091.01v | 40000.01v | 40090.01v | 40091.01v | 40092.01v |
| 40093.01v | 40094.01v | 40095.01v | 40096.01v | 41093.01v | 41094.01v |
| 41095.01v | 42000.01v | 42092.01v | 42094.01v | 42095.01v | 42096.01v |
| 42097.01v | 42098.01v | 42099.01v | 42100.01v | 43099.01v | 44096.01v |
| 44098.01v | 44099.01v | 44100.01v | 44101.01v | 44102.01v | 44103.01v |
| 44104.01v | 44105.01v | 44106.01v | 45103.01v | 45105.01v | 46102.01v |
| 46104.01v | 46105.01v | 46106.01v | 46107.01v | 46108.01v | 46110.01v |
| 47107.01v | 47109.01v | 47111.01v | 47510.01v | 48000.01v | 48106.01v |
| 48108.01v | 48110.01v | 48111.01v | 48112.01v | 48113.01v | 48114.01v |
| 48116.01v | 48515.01v | 49000.01v | 49113.01v | 49115.01v | 50112.01v |
| 50113.01v | 50114.01v | 50115.01v | 50116.01v | 50117.01v | 50118.01v |
| 50119.01v | 50120.01v | 50122.01v | 50123.01v | 50124.01v | 50125.01v |
| 50126.01v | 51121.01v | 51123.01v | 51124.01v | 51125.01v | 51126.01v |
| 52120.01v | 52122.01v | 52123.01v | 52124.01v | 52125.01v | 52126.01v |
| 52128.01v | 52130.01v | 52132.01v | 52527.01v | 52529.01v | 53127.01v |
| 53129.01v | 53130.01v | 53131.01v | 53135.01v | 54123.01v | 54124.01v |
| 54126.01v | 54128.01v | 54129.01v | 54130.01v | 54131.01v | 54132.01v |
| 54133.01v | 54134.01v | 54135.01v | 54136.01v | 55133.01v | 55134.01v |
| 55135.01v | 55136.01v | 55137.01v | 56130.01v | 56132.01v | 56133.01v |
| 56134.01v | 56135.01v | 56136.01v | 56137.01v | 56138.01v | 56140.01v |
| 57138.01v | 57139.01v | 57140.01v | 58136.01v | 58138.01v | 58139.01v |
| 58140.01v | 58141.01v | 58142.01v | 58143.01v | 58144.01v | 59141.01v |
| 59142.01v | 59143.01v | 60142.01v | 60143.01v | 60144.01v | 60145.01v |
| 60146.01v | 60147.01v | 60148.01v | 60150.01v | 61147.01v | 61148.01v |
| 61149.01v | 61151.01v | 61548.01v | 62144.01v | 62147.01v | 62148.01v |
| 62149.01v | 62150.01v | 62151.01v | 62152.01v | 62153.01v | 62154.01v |
| 63151.01v | 63152.01v | 63153.01v | 63154.01v | 63155.01v | 63156.01v |
| 63157.01v | 64152.01v | 64153.01v | 64154.01v | 64155.01v | 64156.01v |
| 64157.01v | 64158.01v | 64160.01v | 65159.01v | 65160.01v | 66156.01v |
| 66158.01v | 66160.01v | 66161.01v | 66162.01v | 66163.01v | 66164.01v |
| 67165.01v | 67566.01v | 68162.01v | 68164.01v | 68166.01v | 68167.01v |
| 68168.01v | 68170.01v | 71175.01v | 71176.01v | 72000.01v | 72174.01v |

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72176.01v   72177.01v   72178.01v   72179.01v   72180.01v   73181.01v
73182.01v   74000.01v   74182.01v   74183.01v   74184.01v   74186.01v
75185.01v   75187.01v   77191.01v   77193.01v   79197.01v   80196.01v
80198.01v   80199.01v   80200.01v   80201.01v   80202.01v   80204.01v
82204.01v   82206.01v   82207.01v   82208.01v   83209.01v   89225.01v
89226.01v   89227.01v   90227.01v   90228.01v   90229.01v   90230.01v
90232.01v   90233.01v   90234.01v   91231.01v   91232.01v   91233.01v
92232.01v   92233.01v   92234.01v   92235.01v   92236.01v   92237.01v
92238.01v   92239.01v   92240.01v   92241.01v   93235.01v   93236.01v
93237.01v   93238.01v   93239.01v   94236.01v   94237.01v   94238.01v
94239.01v   94240.01v   94241.01v   94242.01v   94243.01v   94244.01v
94246.01v   95241.01v   95242.01v   95243.01v   95244.01v   95642.01v
95644.01v   96241.01v   96242.01v   96243.01v   96244.01v   96245.01v
96246.01v   96247.01v   96248.01v   96249.01v   96250.01v   97249.01v
97250.01v   98249.01v   98250.01v   98251.01v   98252.01v   98253.01v
98254.01v   99253.01v   99254.01v   99255.01v   100255.01v

grph.01v    h-zr.01v    hwtr.01v    lwtr.01v    poly.01v
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Notes:

For metastable nuclides, the old, traditional NJOY-MCNP scheme is used. Specific cases are:

| | | | |
|---|---|---|---|
| 27458 | - Co-58m | 67566 | - Ho-166m |
| 47510 | - Ag-110m | 95242 | - Am-242m - lanl oddity |
| 48515 | - Cd-115m | 95642 | - Am-242    - lanl oddity |
| 52527 | - Te-127m | 95644 | - Am-244m |
| 52529 | - Te-129m | 99654 | - Es-254m |
| 61548 | - Pm-148m | | |