RADCALC 4.1 VERIFICATION AND VALIDATION TEST REPORT

May 2009

Prepared by:

EnergySolutions Federal Services, Inc.
Richland, Washington

Prepared for:

Project Enhancement Corporation

On behalf of:

U.S. Department of Energy, Office of Packaging and Transportation

This page intentionally left blank.

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

ASME	American Society of Mechanical Engineers
CD	compact disk
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EM-63	U.S. Department of Energy, Office of Packaging and Transportation
Energy*Solutions*	Energy*Solutions* Federal Services, Inc., Northwest Operations
EPA	U.S. Environmental Protection Agency
FAQ	frequently asked question
ICRP	International Conference of Radiological Protection
NRC	U.S. Nuclear Regulatory Commission
PEC	Project Enhancement Corporation
PR/CR	problem report/change request

RADCALC 4.1 VERIFICATION AND VALIDATION TEST REPORT

1.0 INTRODUCTION, SCOPE, AND PURPOSE

1.1 INTRODUCTION

Radcalc is existing Microsoft Windows[1]-based software with applications in the packaging and transportation of radioactive materials.

Radcalc provides an automated means for users to evaluate input data to categorize radioactive material packages by performing selected regulatory determinations, radioactive decay and decay heat calculations, and hydrogen gas calculations. The software provides a cost-effective means to enhance accuracy, consistency, and reproducibility of packaging and transportation determinations. Radcalc capabilities include the following:

- Performs transportation classifications based on selected U.S. Department of Transportation (DOT) definitions and methodologies identified in Title 49, *Code of Federal Regulations* (49 CFR), "Transportation."

- Performs calculations and classification functions using selected methodologies prescribed by the U.S. Department of Energy (DOE), U.S. Nuclear Regulatory Commission (NRC), U.S. Environmental Protection Agency (EPA), and International Commission on Radiation Protection (ICRP).

- Calculates the decay heat and activity of radionuclides and their daughter products at the end of a specified time interval.

- Calculates the radiolytic hydrogen gas generated in a radioactive waste matrix.

- Calculates the helium gas production from radioactive decay.

- Imports and exports data with the ability of the user to enter, evaluate, and report information within minutes.

It is important to note that the verification and validation process does not relieve the user of responsibility to independently interpret regulations and perform regulatory determinations. Radcalc does not consider all regulatory criteria – the user must do so.

[1] Microsoft and Windows are registered trademarks of the Microsoft Corporation, Redmond, Washington.

This document is intended primarily for members of the software testing and project management team, and is also intended to allow outside users a means to evaluate quality assurance testing performed on the software.

1.2 SCOPE

*Energy*Solutions Federal Services, Inc., Northwest Operations (Energy*Solutions*), under contract to Project Enhancement Corporation (PEC), has developed and maintains Radcalc on behalf of the DOE Office of Packaging and Transportation (EM-63). Energy*Solutions* work is performed in accordance with its quality assurance (QA) program documented in FS-WO-QAPP-001, *Federal Services Hanford Quality Assurance Program Plan*, which is based on the following:

- 18 Basic and Supplement Requirements of American Society of Mechanical Engineers (ASME) NQA-1-1994 and -2000, *Quality Assurance Requirements for Nuclear Facility Applications*; the 18 Basic Requirements of NQA-1 match the [illegible]escribed in 10 CFR 71, "Packaging and Transportation of Radioactive Ma[illegible]erials," Subpart H, "Quality Assurance."

- 10 Criterion prescribed in 10 CFR 830, "Nuclear S[illegible]afety [illegible]anagement," 830.122, "Quality assurance criteria."

- DOE Order 414.1B, *Quality Assurance*; E[illegible]rgy*Solutions*' quality assurance program meets DOE Order 414.1C, *Quality Assurance*, for purposes of software management.

- DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Documents*.

1.3 PURPOSE

The purpose of this verification and validation test report is to document the information identified below.

- General Information

    - System Manager and System Engineer

    - Computer program, including version and version date

    - Computer hardware and serial number, and allowable configurations

    - Operating system and allowable systems

    - Documents relevant to software verification and validation testing, including version numbers and dates

- Dates of testing
- Tester and witness initials on each confirmation step in the test procedure
- Test operator and test witness name and signature.

- Summary of Test Results
  - Test cases and acceptance criteria as well as test results.
- Summary of Anomalies and Resolutions
  - Deviations from expected results and actions take to resolve deviations.
- Assessment of Software Test Performance

  Test results shall be documented and evaluated by a responsible authority to assure the test requirements have been satisfied. Criteria for assessing performance shall ensure:

  - Compliance with the requirements established in the FSWO-SQA-022, *Radcalc Software Requirements Specification (Current – Radcalc 4.1)*
  - Successful performance of test cases in Appendix C of FSWO-VV-028, *Radcalc 4.1 Verification and Validation Plan and Test Procedure*, such that the software:
    - Adequately and completely performs all intended functions
    - Produces correct results for each parameter employed, within the number of significant digits tested
    - Is valid throughout the permissible range of operation for the controlled function
    - Properly handles abnormal conditions and events as well as credible failures
    - Does not perform adverse unintended functions
    - Does not degrade the system either by itself, or in combination with other functions.

- Recommendations

  If appropriate, the test report shall document recommendations of the System Engineer, Independent Technical Reviewer(s), and System Manager.

2.0 GENERAL INFORMATION

2.1 SYSTEM MANAGER AND SYSTEM ENGINEER

System Manager:	D. J. Linstrum
System Engineer (design):	A. V. Savino
System Engineer (testing):	A. B. Carlson

2.2 COMPUTER PROGRAM, VERSION AND VERSION DATE

The obfuscation software used during testing activities as well as the filename information is identified below:

Software:	Dotfuscator Professional[2], Version 4.1.2743.26871	
Obfuscated Files:	Radcalc.exe	03/26/2009
	Unitconverter.exe	03/26/2009
	CalcDLL.dll	03/26/2009
	PackageDLL.dll	03/26/2009

As-Tested Computer Program:	Radcalc
As-Tested Version:	4.1
As-Tested Version Date:	03/26/2009

2.3 COMPUTER HARDWARE, SERIAL NUMBER, AND ALLOWABLE CONFIGURATION

The following information applies to the as-tested personal computer hardware, serial number, and configuration.

Computer System:	Dell, OptiPlex[3] GX620
Energy*Solutions* No.:	27745-D
Total Physical Memory:	1.06 GB
Processor:	x86 Family 15 Model 4 Stepping 7

[2] Dotfuscator Professional is a registered trademark of PreEmptive Solutions, LLC, Mayfield Village, Ohio.
[3] Dell and OptiPlex are registered trademarks of the Dell Corporation, Round Rock, Texas.

Clock Speed:	2793 MHz
BIOS Version	DELL – 7

The personal computer was connected at all times to the Energy*Solutions* Network. A default network printer was assigned and used for printing purposes during the testing activity.

2.4 OPERATING SYSTEM AND ALLOWABLE SYSTEMS

The obfuscated Radcalc 4.1 software was first installed onto a "test station" computer and was validated to successfully complete the install routine on the following operating systems:

- Windows 2000[4]
- Windows XP[4]
- Windows Vista Professional[4]

An individual personal computer was used to complete the test cases as identified in FSWO-VV-028, Appendix C. The following information applies to the as-tested computer hardware, serial number, and configuration for the personal computer described in Section 2.3 above.

Operating System:	Microsoft Windows XP Professional
Version:	5.1.2600
Service Pack:	2.0
Build:	2600
Available Physical Memory:	469.6 MB
Total Virtual Memory:	2.1 MB
Available Virtual Memory:	2.05 MB

2.5 RELEVANT DOCUMENTATION

The following documents are relevant to software verification and validation testing.

- FSWO-SQA-022, Rev. 1, *Radcalc Software Requirements Specification (Current to Radcalc 4.1)*, Energy*Solutions* Federal Services, Inc., Northwest Operations, Richland, Washington, released April 6, 2009.

- FSWO-SQA-023, Rev. 0, *Radcalc Software Design Description (Current to Radcalc 4.1)*, Energy*Solutions* Federal Services, Inc., Northwest Operations, Richland, Washington, released March 27, 2009.

[4] Windows 2000, XP, and Vista Professional are registered trademarks of the Microsoft Corporation, Redmond, Washington.

- FSWO-VV-028, Rev. 0, *Radcalc 4.1 Verification and Validation Plan and Test Procedure*, Energy*Solutions* Federal Services, Inc., Northwest Operations, Richland, Washington, Released March 27, 2009, released March 27, 2009.

2.6 DATES OF TESTING

All testing occurred from the period of March 30, 2009 through April 1, 2009.

2.7 TESTER AND WITNESS INITIALS ON TEST PROCEDURE

Tester and witness initials were documented for each confirmation step in the completed test procedure, FSWO-VV-028, Appendix C. A copy of the test procedure results, showing the steps verified by identification of the tester and w[illegible]s initials, is provided as Appendix A to this verification and validation repo[illegible].

2.8 TESTER AND WITNESS NAME AND SIGNATU[illegible]RE O[illegible] T[illegible]ST PROCEDURE

The name and signature for the tester and wi[illegible] are [illegible]umented in the completed test procedure, FSWO-VV-028, Appendix C. [illegible] copy [illegible] the [illegible]est procedure results that provides this information is provided as Appe[illegible]dix A to this verification and validation report.

[illegible].0 TEST RESULTS

The procedural steps, te[illegible]ases, ac[illegible]eptance criteria, and test results for Radcalc 4.1 are documented in FSWO-VV-[illegible]028. The test results include the initialed test procedure steps, and outputs generated as a part of the test procedure. The test witness provided minor comments and notes in the column identified as, "observations and/or actions taken for deviations (attach as necessary)," where further clarification of the output received was documented for review by the System Engineer (for testing) and the Independent Reviewer. Test outputs were printed and included with the test documentation, where noted. The printed documentation enabled the System Engineer (for testing) and the Independent Reviewer to further evaluate the performance of the software.

Ultimately, there were no test steps that failed to meet the identified acceptance criteria. The completed, initialed, and signed testing verification and validation documentation is provided as Appendix A to this report.

4.0 SUMMARY OF ANOMALIES AND RESOLUTIONS

As identified on FSWO-VV-028, Appendix C, Page C-265 (refer to Appendix A, "Test Procedure Results," of this report), the acceptance criteria for Steps 4.6.2 and 4.6.3 (on Page C-172) were reversed. As such, the acceptance criteria for Step 4.6.2 should have been identified as, "Comments section located as described." In addition, the acceptance criteria for Step 4.6.3 should have been identified as, "Warning is shown." The output that was generated for this test case has been included. The System Engineer (for testing) and the Independent Reviewer determined that this was a typographical error and not an error with the performance of the software program.

In summary, the appropriate results with regard to the software were performed in an acceptable manner. There were no deviations from expected results.

5.0 ASSESSMENT OF SOFTWARE TEST PERFORMANCE

5.1 COMPLIANCE WITH THE REQUIREMENTS

The requirements applicable to the Radcalc 4.1 software upgrade are established in FSWO-SQA-022, *Radcalc Software Requirements Specification (Current to Radcalc 4.1)*. The methods to be used to meet the requirements are found in FSWO-SQA-023, *Radcalc Software Design Description*.

Alpha and beta testing were conducted on Radcalc 4.1. Beta testing consisted of members from the Radcalc Steering Committee performing their own informal testing of Radcalc and reporting any issues or concerns to Energy*Solutions*. Formal testing on the obfuscated Radcalc 4.1 code was conducted by use of an installation compact disk (CD) with files identified with the date: March 26, 2009 (3-26-09).

Documentation of the source code and the executable programs is discussed in FSWO-SQA-025, *Radcalc 4.1 Implementation Document*. The coding for Radcalc 4.1 is extremely extensive; therefore, the actual source code and executable programs have been placed onto a CD and have not been printed out as hard copy. A copy of the implementation document and the CD (i.e., source code and executable files) will be transmitted to PEC for records retention and as a contract deliverable item. In addition, this information will also be held in the software quality assurance files at Energy*Solutions*.

5.2 PERFORMANCE OF TEST CASES

The test procedure identified in FSWO-VV-028, Appendix C, established a step-by-step method for testing Radcalc functions. Independent results (acceptance criteria) for unit conventions and regulatory classification modifications performed in response to problem report/change requests (PR/CRs) are provided in Appendix B and are duplicated in the Appendix C test procedure for ease of comparison with test case results.

The documented results from verification and validation testing are provided as Appendix A to this report.

The identified test cases were successfully performed and completed, and demonstrate that Radcalc 4.1:

- Adequately and completely performs all intended functions
- Produces correct results for each parameter employed within the number of significant digits tested
- Is valid through the permissible range of operation for the controlled functions
- Properly handles abnormal conditions and events as well as credible failures
- Does not perform adverse unintended functions
- Does not degrade the system either by itself, or in combination with other functions.

6.0 RECOMMENDATIONS

Radcalc 4.1 was fully tested to demonstrate compliance with the established requirements. The following recommendations are made for future work on Radcalc:

- The Radcalc Help Files (User Manual) are built into the Radcalc software and should be updated as needed to provide further clarifications to users if the need arises.
- A "Frequently Asked Questions" (FAQs) menu item should be identified on the Radcalc website as a user reference point for common questions and issue resolution.

7.0 REFERENCES

10 CFR 71, 2008, "Packaging and Transportation of Radioactive Materials," Subpart H, "Quality Assurance," *Code of Federal Regulations*, U.S. Nuclear Regulatory Commission, Washington, D.C.

10 CFR 830, 2008, "Nuclear Safety Management," 830.122, "Quality assurance criteria," *Code of Federal Regulations*, U.S. Department of Energy, Washington, D.C.

49 CFR, 2008, "Transportation," *Code of Federal Regulations*, U.S. Department of Transportation, Washington, D.C.

ASME NQA-1-1994 and -2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Part II, "Basic and Supplementary Requirements," Subpart 2.7, "Quality Assurance Requirements for Computer Software for Nuclear Facility Applications," American Society of Mechanical Engineers, New York, New York.

DOE Order 414.1B, 2004, *Quality Assurance*, U.S. Department of Energy, Washington, D.C.

DOE Order 414.1C, 2005, *Quality Assurance*, U.S. Department of Energy, Washington, D.C.

DOE/RL-96-68, 1998, *Hanford Analytical Services Quality Assurance Requirements Documents*, U.S. Department of Energy, Richland, Washington.

FS-WO-QAPP-001, 2008, *Federal Services Hanford Quality Assurance Program Plan*, Rev. 4, Energy*Solutions* Federal Services, Inc., Northwest Operations, Richland, Washington.

FSWO-SQA-022, Rev. 1, *Radcalc Software Requirements Specification (Current to Radcalc 4.1)*, Energy*Solutions* Federal Services, Inc., Northwest Operations, Richland, Washington.

FSWO-SQA-023, Rev. 0, *Radcalc Software Design Description (Current to Radcalc 4.1)*, Energy*Solutions* Federal Services, Inc., Northwest Operations, Richland, Washington.

FSWO-SQA-025, Rev. 0, *Radcalc 4.1 Implementation Document*, Energy*Solutions* Federal Services, Inc., Northwest Operations, Richland, Washington.

FSWO-SQA-028, Rev. 0, *Radcalc 4.1 Verification and Validation Plan and Test Procedure*, Energy*Solutions* Federal Services, Inc., Northwest Operations, Richland, Washington.

This page intentionally left blank.