

The Future of RADCALC- The Radioactive Material and Waste Transportation Software Program-15154

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ABSTRACT

This paper provides a thorough review of RADCALC, the U.S. Department of Energy (DOE)-developed software tool to assist DOE sites in making radioactive material and waste packaging and transportation determinations in compliance with applicable Federal regulations and DOE Orders and Standards. There are more than 400 registered users of the RADCALC tool across the DOE complex. DOE has also authorized a limited number of users from certain universities and foreign countries.

DOE periodically upgrades the software consistent with changing domestic and international requirements, as well as needs unique to DOE. Due to recent changes in regulatory requirements by the Department of Transportation (DOT), it is necessary that the current version of RADCALC should be updated in a timely manner. Prior to investing funds in software upgrades, DOE decided to evaluate the nature of changes required and level of operational support and looked for alternatives for meeting sites' operational needs.

DOE formed a joint review team consisting of experts from Energy Facility Contractors Group (EFCOG) sites, commercial waste treatment facilities and the National Laboratories. This team evaluated the RADCALC software, commercially available software packages, and internal DOE site-developed programs against an established set of criteria. The team also reviewed and prioritized regulatory changes and user-recommended enhancements.

Based on extensive review, the team recommended that DOE continue to support RADCALC noting that RADCALC is a cost-effective, technically robust tool that can perform complicated radioactive material shipping determinations. The tool promotes accuracy, consistency, and completeness between shipments by a single shipper, between shippers at a given site, and between sites. The isotopic coverage, decay algorithm and the range of calculations are without compare either within DOE or in industry in a tool of this kind. The team also recommended that DOE should actively promote RADCALC use throughout the DOE complex and consider cooperative arrangements with the Department of Defense or other government entities that may have similar needs.

INTRODUCTION

The U.S. Department of Energy (DOE) is the largest shipper of radioactive materials and radioactive wastes worldwide. The DOE ships radioactive materials in support of its research and development, environmental restoration and cleanup, and National defense activities. Like other shippers, DOE follows applicable International, Federal, Tribal, State, and local

government requirements. In addition, DOE administers its shipments according to a series of Departmental Orders (written policy requirements) and other internal guidance.

DOE's objectives include minimizing risk involved in movement of radioactive shipments, assuring the safety of workers and the public, and meeting applicable regulatory requirements. DOT regulates selection of packaging and the preparation of packages including hazard communication requirements. DOT also establishes transportation safety and security requirements for carriers (highway, rail, air, and sea) for transportation of hazardous materials including radioactive material and waste. DOT and NRC, as well as DOE, set radioactive material packaging standards. DOE recognizes the need to promote quality, consistency and completeness in complicated radioactive material shipping calculations as well as transportation safety analyses required throughout the DOE Complex.

The DOE Office of Packaging and Transportation (OPT) is responsible for developing, managing, and coordinating policies and procedures for transportation and packaging activities for DOE-owned materials, including hazardous (particularly radioactive) materials. OPT and its predecessor offices developed the RADCALC beginning in 1995 as software tool accessible to operational-level staff at DOE sites. Since then, the following versions of RADCALC were made available to DOE users and in some cases non-DOE users:

- RADCALC 1.0 issued in 1995 as a spreadsheet to calculate the production of hydrogen gas in the waste packages.
- RADCALC 2.0 incorporated DOT requirements and improved the user interface
- RADCALC 3.0 incorporated regulatory changes, expanded isotopic database, and other improvements and used NQA-1-1994 QA requirements
- RADCALC 4.0 issued 2004, incorporated regulatory changes and other items
- RADCALC 4.1 issued in 2008 resolved previously identified issues and implemented new security requirements, and was distributed through a web based application site.

The current RADCALC 4.1 software code incorporates:

- A rigorous decay algorithm utilizing an up-to-date decay data library of over 1,700 isotopes, suitable to diverse DOE operations,
- Decay heat calculations at user-specified times,
- Hydrogen gas generation calculations, consistent with U.S. Nuclear Regulatory Commission (NRC) Information Notice 84-72, based a G-value database or user inputs,
- U.S. Department of Transportation (DOT) determinations (radioactive, A_1/A_2 classification, limited quantity, low-specific activity, highway route controlled quantity, fissile and fissile excepted, reportable quantity, shipping paper entries),
- NRC Regulatory Guide 7.11 container category calculations,

- DOE calculations (DOE-STD-1027 Category 2 and 3, FGR-11 dose equivalents for workers, transuranic, fissile-gram equivalents, plutonium-equivalent curies),
- International Commission on Radiological Protection dose equivalent to public calculations, and
- Simple user interface that facilitates import and export of data.

The software, developed under an NQA-1 quality program, has been funded by OPT and provided free to DOE users. Currently, there are over 400 registered RADCALC 4.1 users at 23 DOE sites. The RADCALC users are responsible for understanding, interpreting, and implementing regulations. RADCALC does not evaluate all criteria, especially those that are qualitative in nature.

PRESENT SITUATION

DOE has periodically upgraded the software consistent with changing domestic and international requirements, as well as needs unique to DOE. On July 11, 2014, the Pipeline and Hazardous Materials Safety Administration (PHMSA) published a final rule (PHMSA-2009-0063-HM-250) in the Federal Register to harmonize the Hazardous Materials Regulations (HMR) governing the transportation of Class 7 (radioactive) materials in part to harmonize with requirements in the International Atomic Energy Agency (IAEA) publication "Regulations for the Safe Transport of Radioactive Material, 2009 Edition, IAEA Safety Standards Series No. TS-R-1."

Consistent with these changes, the RADCALC software must be revised to produce correct determinations. One of the new requirements mandates reporting the maximum activity during the course of shipment on shipping papers and labels. Current regulations are silent regarding at what point in the shipment the activity must be reported. It is likely that most shippers would assume the activity to be reported should be that present when a shipment is offered to the carrier. However, for many isotopes, the in-growth of daughters may result in a temporary or long-term increase in activity and, in some cases, the regulatory classification (e.g., radioactive, limited quantity, Type A, Type B).

Although RADCALC in its current form reports the total activity at the start of shipping, it could be used in an iterative manner to determine the maximum activity during the course of shipment. However, the process would be time consuming and would require attention to detail such that relying on individual implementation across the DOE Complex presents a systematic risk – specifically with regards to determining the peak activity during shipment considering in-growth of daughter radioisotopes.

In early FY2013, OPT solicited input from the RADCALC user community to better evaluate potential impacts to and a path forward for RADCALC. The OPT was concerned about the impact of proposed regulatory changes and other needed improvements on the RADCALC investment. Therefore, OPT decided to ask the Energy Facility Contractors Group (EFCOG) to assist the office in evaluation of continued investment in the software and to review the possibility of using commercially available software code to meet sites' transportation requirements.

REVIEW TEAMS

This review effort was performed by members of the two review teams selected from EFCOG member organizations based on their technical and/or managerial experience and direct involvement with the program. Representatives from DOE, the affected DOE waste generating sites, transportation expert organizations, and waste disposal facilities participated in this effort and provided input. Team-1 evaluated the impacts of HM-250 and considered other enhancements to software capabilities. The Team- 2 evaluated whether there are cost-effective commercial alternatives to the RADCALC software that represent better investments of DOE resources. Summaries from both teams are presented below.

Team-1: Evaluates Impacts of HM-250 to RADCALC 4.1

The objectives of Team-1 were (1) to identify/prioritize software changes based on HM-250 and user recommendations, and (2) estimate cost and schedule for changes. Team-1 reviewed HM-250 and RADCALC problem reports and solicited input on changes or enhancements through a user survey. Based on an initial priority list, the team developed recommendations regarding infrastructure, code and database modernization, and some reorganization for process efficiencies, and asked for some clarifications. The estimated cost for an update incorporating all proposed changes is approximately \$420,000. The following is a priority list of proposed changes within the total estimated cost.

Table-1

Priority	Modification
	Establish programmatic and testing infrastructure Modernize code and database Correct known errors documented in software problem reports
A	Report maximum activity during the course of shipping
	Report activity at the start of shipping
	Modify A1/A2 values for Cf-252 and Kr-79
	Add 173.435 footnotes (h) and (i)
	Add 173.436 values for Kr-79 and Te-121m
	Change software to match 173.436 footnote (b)
	Test to Windows 7
	Make RADCALC non-functional until the installation is verified
B	Revise fissile exception calculations
	Update RADCALC nuclear database
	Update physical constants
C	Add IAEA Code of Conduct/NRC RAMQC calculations
	Add DOE-STD-1027 mass thresholds
	Add LSA/SCO calculations
	Add NRC Class A/B/C calculations
D	Add A1/A2 values and dpm to unit converter
	Change "waste" to "material" in the user interface
	Complete documentation, testing (quality assurance to NQA-1)
	Prepare distribution package
	Procure hardware/software infrastructure

The recommendation is that DOE fund as many of the changes as possible. This is an excellent investment on a per user basis, especially considering the alternative cost of hand calculations by higher cost staff, the potential penalties and operational costs that could result from even a single radioactive material shipping error, and an inefficient piecemeal approach to revisions will be substantially less cost effective. Team-1 strongly encourages DOE to promote RADCALC use throughout the DOE Complex and to consider cooperative arrangements with the U.S. Department of Defense and other government entities that may have similar needs to help offset costs.

Team-2: Evaluates Software Alternatives

The objectives of team-2 were (1) to identify minimum criteria as a basis for comparison of alternatives, and (2) solicit input from potential sources of software. A preliminary set of evaluation criteria was identified; however, software applications offering functionality beyond those criteria would be viewed favorably. A range of commercial and DOE software (including site-specific spreadsheet applications) was identified and input was solicited from the software source.

1. DOE RADCALC 4.1
2. WMG RADMAN
3. Tetra Tech RAMPAC spreadsheet
4. Sandia National Laboratories SandRadWaste spreadsheet
5. Savannah River Site HM-230 spreadsheet
6. RRI RADCALC spreadsheet
7. Paducah RADCALC spreadsheet
8. MAXOM Services HazTrack
9. LowTrack Technology & Services LowTrack

Team-2 developed the following criteria for comparative analysis:

Table-2

DOT Classification	
Radioactive	ACEM and ALEC, exclude daughters per 436 footnotes
Exempt material classification	
Types of Packaging (IP, Type A or Type B)	A1/A2 – normal form, special form
Effective A1 or A2 for mixture	
Limited Quantity	
Low Specific Activity	Solid, liquid, gas, tritium, tritiated water; qualitative criteria?

DOT Classification	
SCO Classification	
Highway route controlled quantity	Correct use of criteria
Fissile	Is there a need for other fissionable?
Fissile Excepted	All six 173.453 criteria? How resolve 453(f) issue?
SCO determination	
Print shipping papers (UHWM)	Focus on waste only? 95% of A-value determination
Reportable Quantity	Does it evaluate isotopes not listed?
NRC Classification	
Container Category I, II, and III	
NRC uniform low level waste manifests(540 and 541)	
Waste Classification- Package Class A, B, or C	
DOE Determinations	
Transuranic waste	Consistent with WIPP?
Pu-239 fissile gram equivalent	Basis of calculation – reference for method, date.
Pu-239-equivalent activity	
Pu-239 Dose equivalent curie	Basis of calculation – reference for method, date. PE-Ci
Onsite shipment Hazard Category 2 & 3	
Other Functionality	
DE-Ci	How is fast-medium-slow absorption decided? Source/date
Radioactive Decay Heat Calculations	Decay from past dates? To start/finish of shipment?
Extent of Decay data Isotope Library	Number, date, source?
Hydrogen and Helium Gas Calculations	
Pressure Calculations	
Import and Export Data	
Web-based application	
Training Modules	
Multiple Packages (conveyance) Calculation	
NQA-1 Validated (subpart 2.7)	
Cost	
Purchase price	
operating cost	
Maintenance cost	
IT Factors	
IT support	How are software errors communicated to users
System Requirements	
USE	
Users DOE/Non DOE	
DOE Sites/Non DOE Entities	

The team also sought responses to the following other questions related to the performance of software:

1. Does it evaluate isotopes/daughters not in 173.435 and 173.436 tables? Does it perform decay?
2. What is the source/date and extent of isotopic data – decay mechanism and energy, daughters?
3. How does it account for isotopes that decay by multiple mechanisms at different branching ratios?
4. Has software been thoroughly tested including at boundary conditions?
5. Significant digits in calculations?
6. Source, date of fundamental physical constants.
7. Does the software have other limits (e.g. maximum number of isotopes, no decay,,...)?

While each of the software applications provides useful functionality in specific applications, only two (RADCALC and WMG's RADMAN) included the decay capability critical to regulatory determinations and DOE's diverse needs. A presentation by WMG impressed participants; however, RADMAN was tailored to the needs of commercial utilities. RADMAN also lacked existing built-in DOE-specific capabilities; the decay data library was too restricted for DOE's diverse needs; and the anticipated capital, maintenance and training costs associated with RADMAN would result in increased cost.

CONCLUSIONS

The conclusions of the two review teams are as follows:

- Although one other shipping software includes decay capabilities, RADCALC is the more cost-effective option, incorporates DOE-specific calculations, and offers an extensive decay data library uniquely suited to DOE's diverse research, environmental, and national security operations.
- Prioritized changes related to HM-250, as well as other user needs, should be incorporated in the software within the resource limits established by DOE.

RECOMMENDATION

RADCALC is a cost-effective, technically robust tool that can perform complicated radioactive material shipping determinations. The tool promotes accuracy, consistency, and completeness between shipments by a single shipper, between shippers at a given site, and between sites. The isotopic coverage and the range of calculations are without compare either within DOE or in industry. Both teams unanimously endorse DOE's continued support of this excellent tool.

The EFCOG review teams encourage OPT to fund as many of the proposed changes as possible within resource limits. The teams recommend that DOE actively promote RADCALC use throughout the DOE Complex and consider cooperative arrangements with DOD or other government entities that may have similar needs.

ACKNOWLEDGMENTS

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REFERENCE

1. U.S. Department of Transportation, Final Rule, Docket No. PHMSA–2009–0063 (HM–250), Hazardous Materials: Compatibility, With the Regulations of the International Atomic Energy Agency, July 11, 2014
2. Title 49 Code of Federal Regulations, Subchapter A- Hazardous Materials and Oil Transportation
3. Title 10 Code of Federal Regulations, Part 71 Packaging and Transportation of Radioactive Material