

ENVIRONMENTAL PROTECTION AGENCY

[EPA-HQ-OAR-2002-0050; FRL-9922-75-OAR]

National Emission Standards for Hazardous Air Pollutants (Radionuclides); Availability of Updated Compliance Model

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of Availability.

SUMMARY: The Environmental Protection Agency (EPA) is announcing the availability of Version 4 of the CAP88-PC model. This version may be used to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) applicable to radionuclides. CAP88-PC is approved for this use by EPA. Version 4 has many changes and improvements from previous versions. The most significant of these changes from a user perspective are the incorporation of age-dependent radionuclide dose and risk factors for ingestion and inhalation, the increase in the number of included radionuclides, and a change in the file management system used by the program. Other changes less visible to the user include new code architecture, incorporation of numerical solvers for the calculation of radioactive decay chains, including the ingrowth of decay products during air transport and ground surface deposition, enhanced error messages, updated on-line help, and a utility for migrating Version 3 datasets, wind files and population files to Version 4. The modifications have produced a significant improvement in speed and stability for Version 4 relative to Version 3, and eliminated the solution approximations used in Version 3.

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SUPPLEMENTARY INFORMATION:

I. General Information

A. Does this Action Apply to Me?

You may be potentially affected by this action if you are subject to the requirements for radionuclide NESHAP found in 40 CFR part 61, subpart H. This subpart applies to Department of Energy (DOE) facilities.

B. How Can I Get Copies Of the Model and Other Related Information?

1. *Docket.* EPA has established a docket for this action under Docket ID No. **EPA-HQ-OAR-2002-0050; FRL-9922-75-OAR**. Publicly available docket materials are available either electronically through www.regulations.gov or in hard copy at the Air and Radiation Docket in the EPA Docket Center (EPA/DC), EPA West, Room B 102, 1301 Constitution Avenue, NW, Washington, DC. The EPA Docket Center Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566-1744, and the telephone number for the Air and Radiation Docket is (202) 566-1742.

2. *Electronic Access.* You may access this **Federal Register** document electronically through the EPA website under the “**Federal Register**” listings at <http://www.epa.gov/fedrgstr/>.

3. *EPA Web Site.* You may download the CAP88-PC model and documentation from EPA’s web site at <http://www.epa.gov/radiation/assessment/CAP88/index.html>.

II. Background

On December 15, 1989, EPA promulgated the National Emission Standards for Hazardous Air Pollutants (NESHAPs) under section 112 of the Clean Air Act to control radionuclide emissions to the ambient air from a number of different source categories (54 FR 51654, December 15, 1989 (Docket EPA-HQ-OAR-2002-0050-0028)). Subpart H of 40 CFR part 61 is one of the source categories covered in the 1989 final rule. Facilities owned and operated by the Department of Energy (DOE) are regulated under subpart H. DOE administers many facilities across the country, including government-owned, contractor-operated facilities. Some of these facilities handle significant amounts of radioactive material that could potentially be emitted into the air in various chemical and physical states. The purpose of subpart H is to limit radionuclide emissions (not including radon) from the stacks and vents at DOE facilities so that no member of the public receives an effective dose equivalent of more than 10 millirems per year (mrem/yr) or in SI units 0.1 millisievert per year (mSv/yr). See 40 CFR 61.92.

III. CAP88-PC Model for Demonstrating Compliance

A. CAP88-PC History

EPA is today announcing the availability of Version 4 of the CAP88-PC model for use in subpart H. Section 63.93(a) states: “To determine compliance with the standard, radionuclide emissions shall be determined and effective dose equivalent values to members of the public calculated using EPA approved sampling procedures, computer models CAP-88 or AIRDOS-PC, or other procedures for which EPA has granted prior approval.”

CAP88 (Clean Air Act Assessment Package-1988) is a set of computer programs, databases and associated utility programs for estimation of dose and risk from radionuclide emissions to the air. CAP88-PC implements, on the personal computer platform, modified versions of the

AIRDOS-EPA and DARTAB codes that were written in FORTRAN 77 and executed in a mainframe computing environment. CAP88-PC provides for dose and risk assessments of collective populations, maximally-exposed individuals and selected individuals. The original CAP88-PC software package, Version 1.0 allowed users to perform full-featured dose and risk assessments in a DOS environment for the purpose of demonstrating compliance with the standard in 40 CFR 61.92; it was approved for compliance demonstration in February 1992.

CAP88-PC Version 2.0 provided a framework for developing inputs to perform full-featured dose and risk assessments in a Windows environment for the purpose of demonstrating compliance with the standard in 40 CFR 61.92. Version 2.0 was approved for compliance demonstration in 1999. Version 2.1 included some additional changes compared to the DOS version and the previous Windows version 2.0. The changes included the addition of more decay chains, improvements in the Windows code error handling and a modified nuclide data input form. Section 1.6 of the CAP88-PC Version 3 User's Guide provides a summary of the changes incorporated into Version 2.1 relative to Version 2.0.

CAP88-PC Version 3.0, released in 2007, was a significant update to Version 2.1. Version 3 incorporated dose and risk factors from Federal Guidance Report 13, "Cancer Risk Coefficients for Environmental Exposure to Radionuclides" (FGR 13) in place of the RADRISK data that was used in previous versions. In addition, the CAP88-PC database, the user interface, input files and output files were modified to accommodate the FGR 13 data formats and nomenclature. Section 1.7 of the CAP88-PC Version 3 User's Guide describes the modifications incorporated into Version 3 relative to Version 2.1.

CAP88-PC Version 4 is a significant update to Version 3. While keeping the main computer code used to conduct the calculations unmodified, modifications have been made to add

flexibility, enhance stability of the code, and make it easier for the user to use while also improving the quality assurance of the modeling. The most significant of these changes from a user perspective are the incorporation of age-dependent radionuclide dose and risk factors for ingestion and inhalation (the use of which is specified by the user), the increase in the number of included radionuclides, and a change in the file management system used by the program. Other changes less visible to the user include new code architecture, incorporation of numerical solvers for the calculation of radioactive decay chains, including the ingrowth of decay products during air transport and ground surface deposition, enhanced error messages, updated on-line help, and a utility for migrating Version 3 datasets, wind files and population files to Version 4. The modifications have produced a significant improvement in speed and stability for Version 4 relative to Version 3, and eliminated the solution approximations used in Version 3. EPA has implemented an extensive testing and documentation program for CAP88-PC Version 4 to address user concerns with past versions. This enhanced documentation has allowed for greater compatibility with user software quality assurance programs. The total number of radionuclides available has been increased from 825 in Version 3 to 1,252 in Version 4. The maximum number of radionuclides that can be included in any single case is increased from 256 in Version 3 to 500 in Version 4.

B. CAP88-PC Model Summary

All versions of CAP88-PC use a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six types of sources. The sources may be either elevated stacks, such as a smokestack, or uniform sources, such as a pile of uranium mill tailings. “Plume rise” can be calculated assuming either a momentum or buoyant-driven plume. Assessments are made for a circular grid of distances and directions for a radius of up to 80

kilometers (50 miles) around the source. The Gaussian plume model produces results that agree with experimental data as well as any model, is fairly easy to work with and is consistent with the random nature of turbulence. Site-specific information on population location and meteorological conditions is provided to CAP88-PC as input files developed by the user. The formats for these input files have not changed from the original mainframe version of the CAP88 code package.

CAP88-PC Version 4 is a significant modification intended to improve usability, increase stability by complying with the write restrictions on system folders, enhance the modeling methodology, update the dataset formats, and provide a more maintainable code base and documentation set for the future. Version 4 now provides age-dependent dose and risk factors and introduces a new code architecture that conforms to updated coding standards and data formats. The data updates include adoption of the ingestion and inhalation age and particle size dependent dose and risk factor data supplied by Oak Ridge National Laboratory in the DCFPAK Version 2.2 model¹, and age-dependent ingestion and inhalation rates from the EPA². The DCFPAK Version 2.2 external dose rate coefficients used in CAP88-PC Version 4 are not explicitly age-dependent. The external coefficients are calculated for adults but are applicable to all age groups.

CAP88-PC Version 4 not only adds significant features, but also redesigns the user interface (UI) experience to make it more similar to that of other programs developed for Microsoft Windows. The application uses the Microsoft .Net Framework Version 4, and the Microsoft Visual Studio 2010 development environment, to support security and connectivity models in Windows 7. The window structure presented to the user is in general unchanged from earlier

¹ <http://www.epa.gov/radiation/federal/techdocs.html>

² <http://www.epa.gov/ncea/efh/pdfs/efh-complete.pdf>

versions but has been updated to provide more flexible data entry, to include the new data fields mentioned earlier, and to eliminate the use of an intermediate database to relate filenames to datasets. The layout of the UI forms has been modified to include sub-windows that provide a running record of dataset modifications since the dataset was last saved, and provide real-time errors and warnings generated by the entry validation tests. The database of uptake and radionuclide-specific information is now in eXtensible Markup Language (XML) format, making it more accessible to the user and to other applications. One consequence of the move to an updated development and data environment is the fact that CAP88-PC Version 4 can only be installed on Windows XP Service Pack 3 and later operating systems.

The CAP88-PC Version 4 software was developed using a structured software engineering methodology that included adoption of a defined software architecture, rigorous source control, independent verification of source code as it was being implemented, multiple phases of testing, and configuration control of the documentation and the code as development progressed.

To conform to Windows 7 security requirements, and to improve usability, CAP88-PC Version 4 includes many significant changes to input and output file handling. Case-specific input and output data files are now stored by default in the user's Windows profile folders, rather than in the application's Program Files folder. For example, the default primary CAP88-PC Version 4 folder location in Windows 7 would be `c:\Users\xxxx\Documents\CAP88` for a username of `xxxx`. This was required because Windows Vista and 7 security improvements restrict writing files to the Program Files folder.

CAP88-PC Version 4 input datasets can be stored in their own folders, as subfolders of the Datasets folder. As an example, for the Modtest dataset included with the Version 4 distribution set, the folder holding the dataset and all associated data files and reports would be located at

c:\Users\xxxx\Documents\CAP88\Datasets\Modtest. Datasets are recommended to be put into their own folders, because using this data storage structure will make use of the code easier and management of case data simpler. Reports (formerly called "Output") are always stored in the same folder as the dataset. Population and wind files can be stored with the dataset or in the default Population/Wind folders. However, CAP88-PC Version 4 will preferentially use the population and wind files located in the dataset. This improves sharing dataset information between organizations, and simplifies configuration management of cases because all pertinent case records (input and report files) are stored together. A user can send a dataset, its population and wind files, and its reports to another user, who can open them, using CAP88-PC Version 4 or any text editor, confident that the proper files are being used.

As was the case with Version 3, Version 4 is not backward compatible, and datasets generated using Version 3 cannot be used directly by Version 4. This is the result of many factors, including the addition of age-specific data and the inclusion of many more nuclides than in previous versions. However, Version 4 includes a dataset migration utility that upgrades many Version 3 datasets to the Version 4 format. The migration utility runs on first use and is also available on demand from the Tools>Options drop-down menu. The migration utility will move Version 3 database files, input dataset files, population files, and wind files from the format used with the 9 December 2007 release of Version 3 to their respective Version 4 formats. The folder locations of the Version 3 files being migrated and the locations for the Version 4 files being generated are selectable by the user or the utility will select the default locations for those files.

The overall principle of the new architecture was to optimize the code by performing data manipulation in the UI and computational functions in FORTRAN. CAP88-PC Version 4 has accomplished this by having the UI collect the user input data, read the associated databases,

generate the dose and risk factors from the DCFPAK data, then build and write the case dataset. The UI also handles all program interactions with the file system. The FORTRAN computational sub-system now performs all decay and ground surface buildup calculations along with all the air dispersion, deposition, intake, dose and risk calculations. The only file manipulation performed by the FORTRAN sub-system is reading the dataset files and writing report files. The data system used in CAP88-PC Version 4 has access to information for all 1,252 radionuclides contained in DCFPAK Version 2.2, 737 of which have internal dose and risk factors. A significant change in Version 4 is the fact that radionuclides in the database having external but no internal dose factors is flagged to the user during radionuclide selection. This is an improvement over Version 3, where the code would produce a database read error when encountering a radionuclide having an external but no internal dose conversion factors. Flagging these radionuclides permits analysis to be performed in situations where only the external dose is of concern, but also creates the potential for under-reporting dose when a radionuclide with no internal dose factors is included in the case. Users must now be aware that when a radionuclide has no internal dose factors, an independent method, such as surrogates, must be used to account for internal dose resulting from intake of these radionuclides in a CAP88-PC Version 4 case.

C. Validation of the CAP88-PC Version 4 Model

The CAP88-PC Version 4 program represents one of the best available validated codes for the purpose of making comprehensive dose and risk assessments. The Gaussian plume model used in CAP88-PC to estimate dispersion in air is one of the most commonly used models for dispersion modeling. It produces results that agree with experimental data as well as any model, is fairly easy to work with, and is consistent with the random nature of turbulence. Version 4 has not modified the basic Gaussian plume algorithm used by the AIRDOS module of CAP88-PC,

and comparison cases between Versions 4 and 3 have been run.

EPA's Office of Radiation and Indoor Air (ORIA) has reviewed and verified through testing the contractor's initial testing and quality assurance results. The report³ can be found at <http://www.epa.gov/radiation/assessment/CAP88/index.html>.

The testing report includes a description of the testing of the user interface; a description of the six test cases used to test the incorporation of age-specific dose factors; a description of the seventh test case verifying the calculation of air concentrations and working levels for radon-only test cases; a description of the 31 issues identified by ORIA and the corrective actions that resolved those issues; a brief biographical sketch describing the independence and qualifications of the independent tester; and conclusions drawn from the testing.

As part of the software testing, the user interface was extensively tested. The testing verified that the interface only accepted:

- 1) Positive distances less than or equal to 80 kilometers (km) for receptor distances;
- 2) Non-negative release rates;
- 3) Annual precipitation amounts between 0.01 and 500 centimeters per year (cm/yr);
- 4) Annual ambient temperatures between -100 and 100 degrees Celsius (°C);
- 5) Lid heights between 25 and 10,000 meters (m);
- 6) Non-negative source heights, and positive source diameters or areas;
- 7) Non-negative heat release rates, exit velocities and fixed plume rises; and,
- 8) Agricultural fractions that summed to unity.

All issues identified with the interface have been resolved and closed.

Seven test cases were developed to test the capabilities of CAP88-PC Version 4. Six of these cases involve the calculation of dose and risk to an individual or population at the location

³ EPA-HQ-OAR-2002-0050-0004

identified by the model as that of the maximally exposed individual (MEI) or specified by the user. The testing objectives for these six cases include the following verifications:

- 1) Dose factors agree with those calculated using the Dose Coefficient Data File Package from Oak Ridge National Laboratory, Version 2.2 (DCFPAK2.2) to 1% or less;
- 2) Values of Chi-over-Q (χ/Q) agree within 1% with those calculated using CAP88-PC version 3.1, including but not limited to the direction of the MEI (the calculated values for χ/Q showed good agreement between Versions 3.1 and 4 in all directions);
- 3) Air concentrations and deposition rates (where applicable) agree within 1% with those calculated using CAP88-PC Version 3.1; and,
- 4) Results for dose rates and risks agree within 5% with independent calculations; the 5% criteria was used here to allow for differences caused by different modeling methods.

The objective of Test Case 7 was to verify the CAP88-PC Version 4 calculations of the air concentrations and working levels for radon-only are consistent with Version 3.1.

D. Limitations of the CAP88-PC Model

Like all models, there are some limitations in the CAP88-PC system. While up to six stacks or sources can be modeled, all the sources are modeled as if located at the same point; that is, stacks cannot be located in different areas of a facility. The same plume rise mechanism (buoyant or momentum) is used for each source. Also, multiple sources are treated as uniform. Variation in radionuclide concentrations due to complex terrain cannot be modeled. Errors arising from these assumptions will have a negligible effect for assessments where the distance of exposed individuals is large compared to the stack height, area or facility emissions.

E. Use of CAP88-PC Version 4 for Compliance Purposes

One of the primary requirements driving the production of CAP88-PC Version 4 was the

desire to incorporate the age-specific dose conversion factors and intake rates contained in DCFPAK Version 2.2. The code now allows the user to select the ingestion and inhalation dose conversion and intake rates from the age groups modeled in DCFPAK Version 2.2, infant (100 days old), one-year old, five-year old, ten-year old, fifteen-year old, and adult. To accommodate this, many variables across the entire code have increased dimensionality and the dataset structure required significant modification. The need to examine the entire code base in order to include age-dependency drove the decision to look for a new architecture that would enhance the performance and maintenance of CAP88-PC both in Version 4 and future versions.

Additionally, our in-house analysis of calculated doses between Versions 3 and 4 has shown that the dose in Version 4 is usually less than the dose in Version 3. This is primarily because we have updated the intake factors in Version 4 to be consistent with the latest version of the EPA Exposure Factors Handbook. Therefore, the user will likely see lower calculated doses in Version 4 for the source term and receptor.

F. Summary of Changes for CAP88-PC Version 3 to Version 4.

Version 4 of CAP88-PC is a significant update from Version 3. CAP88-PC Version 4 not only added significant features, but also redesigned the interface to give the user a more standard experience. The entire user interface module was re-written for Version 4 using VB.Net, the Microsoft.Net Framework Version 4, and the Visual Studio 2010 development environment, in order to better comply with updated code standards in Windows 7 and Windows 8. To conform to recent Windows security requirements, and to improve usability, the following additional significant changes were made:

Modeling and Architecture

1) All DCFPAK Version 2.2 nuclides are included. Nuclides in the database having external but

not internal dose factors are flagged to the user rather than crashing the run. *NOTE: the user must account for internal dose resulting from intake of these radionuclides using other methods, such as surrogates.*

- 2) Age-specific data is now returned for dose, risk, and inhalation/ingestion rate values.
- 3) Nuclide Release Rates less than $1.000\text{e-}25$ Ci/yr (e.g., "0") or greater than $7.92\text{e+}28$ are no longer allowed. A FORTRAN numerical solver is now used to calculate decay-in-flight and ground build up concentrations for each sector. The time for decay in flight is calculated using the annual Pasquill category-averaged wind speed for each direction.
- 4) Up to 500 radionuclides can be included in any case. The 500 limit includes both the nuclides released by the stacks and their progeny.
- 5) Whole body and organ dose and risk factors are from DCFPAK Version 2.2. The data include six age groups; infant (100 days old), 1 year old, 5 years old, ten years old, fifteen years old, and adult.
- 6) Age-specific inhalation and ingestion data developed by the U.S. Environmental Protection Agency have been included for the above age groups.
- 7) The FORTRAN computational code has been consolidated into one module and variable names made consistent throughout the module. Data transfer between the routines was streamlined by the use of Include statements for COMMON block variables.
- 8) All nuclide-specific data are now stored in eXtensible Markup Language (XML) format.
- 9) All significant floating-point calculations have been moved to the FORTRAN routines, greatly speeding up the code.
- 10) The code uses the Intel FORTRAN Composer XE 11 compiler that permits many of the calculations to be vectorized and multi-threaded to take advantage of these capabilities in

modern desktop processors.

- 11) The bit-length of variables has been doubled, allowing much greater computational ranges for cases with large or small release rates.

User Interface

- 1) A traditional document-style interface has been designed, similar to major applications with which users are already familiar. Users can more easily open, edit and save datasets, population and wind files using Windows menus and familiar icons on the application bar.
- 2) Dataset reports are now displayed in, and generated from a Reports tab when the dataset is opened. The code is now executed using the Report generation button rather than a “Save and Close” button. The reports to be generated and viewed are selectable from the Reports tab. The “Save and Close” button from Version 3 has been removed.
- 3) Multiple files (datasets, population files, wind files) can be open at once.
- 4) When editing files, changes and errors are displayed in real time.
- 5) Editing of nuclides is clearer and easier. In-grid editing is allowed, but note that fields are not recorded until the user clicks away from the field being edited. A Save performed without first clicking away from a field being edited will result in that field’s data not being saved.
- 6) The application recognizes when a user is opening a Version 3 file, and launches the migration utility, offering to create a Version 4 copy of the file.
- 7) The general layout, look, and feel of the user interface are similar to that in earlier versions of CAP88-PC in order to ease transition to CAP88-PC Version 4.

File Formats

The dataset file format has changed in Version 4 from Version 3 to accommodate the new requirements. The new dataset file format is documented both in the Version 4 User’s Manual

and the on-line help files.

- 1) Population and Wind files previously had extended values such as State and Census stored in a Microsoft Access database. When migrating from Version 3, this data--if available--is stored in the file itself. Doing so removed the need for an external database, and allowed users to send their custom population/wind files with the extended values intact. These changes have been documented in the file format description in the Version 4 User's Manual and the on-line help files.
- 2) Version 3 population and wind files can still be used in Version 4 datasets. Extended values are only added to the pop/wind files if they are edited to add them.
- 3) The use of additional applications, such as Microsoft Access, to manage data has been eliminated in CAP88-PC Version 4. Radionuclide, agricultural, and other data previously held in the Microsoft Access database are now in a more portable and more easily accessible XML database.

Error Handling

CAP88-PC Version 4 contains an enhanced internal error logging and tracking system. In the case of internal code errors, the code will write errors to a file in the Message Log folder located in the same folder set as the folder containing the datasets. Sending this file to the EPA representative will facilitate troubleshooting.

On-Line Help System

CAP88-PC Version 4 includes a context-sensitive help system that is accessible during operation. The on-line help system is a hypertext version of the traditional user manual; the traditional user manual is included as part of the release distribution package in pdf format.

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